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Characterization and Classification of some Flood Plain Soils in the Southern Guinea Savannah of Nigeria

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ABSTRACT

Soils of GidanTindi and Jangwa flood plains, Awe Local Government Area of Nassarawa State were studied using the reconnaissance method of soil survey with a view to characterized, classify and evaluate their potentials for sustainable crop production. The flood plain is a low-lying area found East of Awe Local Government Area, Guinea Savannah Zone of Nigeria. Six soil units were identified on the field based on soil colour, texture, surface characteristics, topography and depth to water table. Two pits were sunk in each soil unit, described and sampled for laboratory analysis. The soils were deep (120cm – 130cm) and well drained, poorly to very poorly drained. The soils were fine textured and strongly to moderately acidic and slightly alkaline in reaction (PH 4.01 – 7.15). The percentage sand fraction ranged from 30.9% to 86%; silt 5.4% to 18.4% and clay 8.6% to 58.1%. The hydraulic conductivity values ranged from 0.145ms to 2.145ms; bulk density values ranged 1.008mgm^{-3} and 1.575mgm, moisture content ranged between 30% and 39%; total porosity ranged from 10.06% to 16.4%. They had low to moderate organic carbon (0.01% to 2.88%); total N (0.02% to 0.25%); available P (1.64mglkg^{-1} to 4.89mg/kg^{-1}), exchangeable bases (2.85cmol/kg^{-1} to 8.26cmol/kg^{-1}), CEC (4.10cmol/kg^{-1} to 8.34cmol/kg^{-1}), base saturation (53% to 97%) and Fe^{2+} (1.25-2.45). The soils were classified according to USDA soil taxonomy and FAO/WRB as VerticEpiaqualfs/StagnicLixisols (profiles 1,2,7,8) of GidanTindi and Jangwa, VerticEndoaqualfs/Stagniclixisols (profile 3,4,9,10) of GidanTindi andJangwa. (5,6) of GidanTindi and 11-12 of Jangwa;AericEndoaqualfs/Aericlixisols.

1.0 Introduction

Soils are important natural resource and foundational materials for crops, houses, roads and buildings. Properties of soils including the physical, chemical and biological are the soil qualities/characteristics which play an important part in the behaviour of soils and what they can be used for (Lal *et al*., 2004). Several physical properties such as soil structure, texture, colour, depth, consistence, density, porosity, permeability, soil inclusion and soil temperature can and do change with management (Idoga and Ogbu 2012, Pimental 2005). The general soil chemical properties often required in most basic soil survey include organic carbon, total N, available P, exchangeable bases, pH, CEC and base saturation (Ufot, 2012). Good knowledge about the soil resources and proper use and management will guarantee sustainable crop production.

For sustainable crop production, there is need to have good knowledge of soils of the different agro-ecological zones for effective management and sustainable yield.For optimum production and enhanced productivity, adequate information on soil properties will give the desired approach to averting or ameliorating soil physical and chemical limitations.A good knowledge of soil properties helps in the effective and efficient management as they determine the amount of water, air and nutrient availability for plant growth and development. This research is designed to characterize, classify and evaluate their potentials for sustainable crop production.

2.0 Materials and Methods

2.1 Study Area

The study area is south- eastern block of Nasarawa State stretching from Jangwa in the North East to GidanTindiin the South. The land area is geomorphologically referred to as Jangwa flood Plains. It lies between latitude 7^o 45^1 and 9^o 25^1 N and longitude $7^o32^1$and 9^o 37E and covers a total area of over 22,000 hectares of Fadama along Rivers Shankodi, Wuse and Ankwe (ASU river group).Two principal air masses influence the climate of the area.

The south west maritime wind which originates from the Atlantic Ocean blows across Lafia between April and October and is associated with the wet season while the dry season which starts from November to March is brought about by the north eastern wind locally called harmattan. Nassarawa State experiences two rainfall peaks, July andSeptember, separated by moderate decrease in August known as August break (Hill,1979). Annual rainfall in the area is between

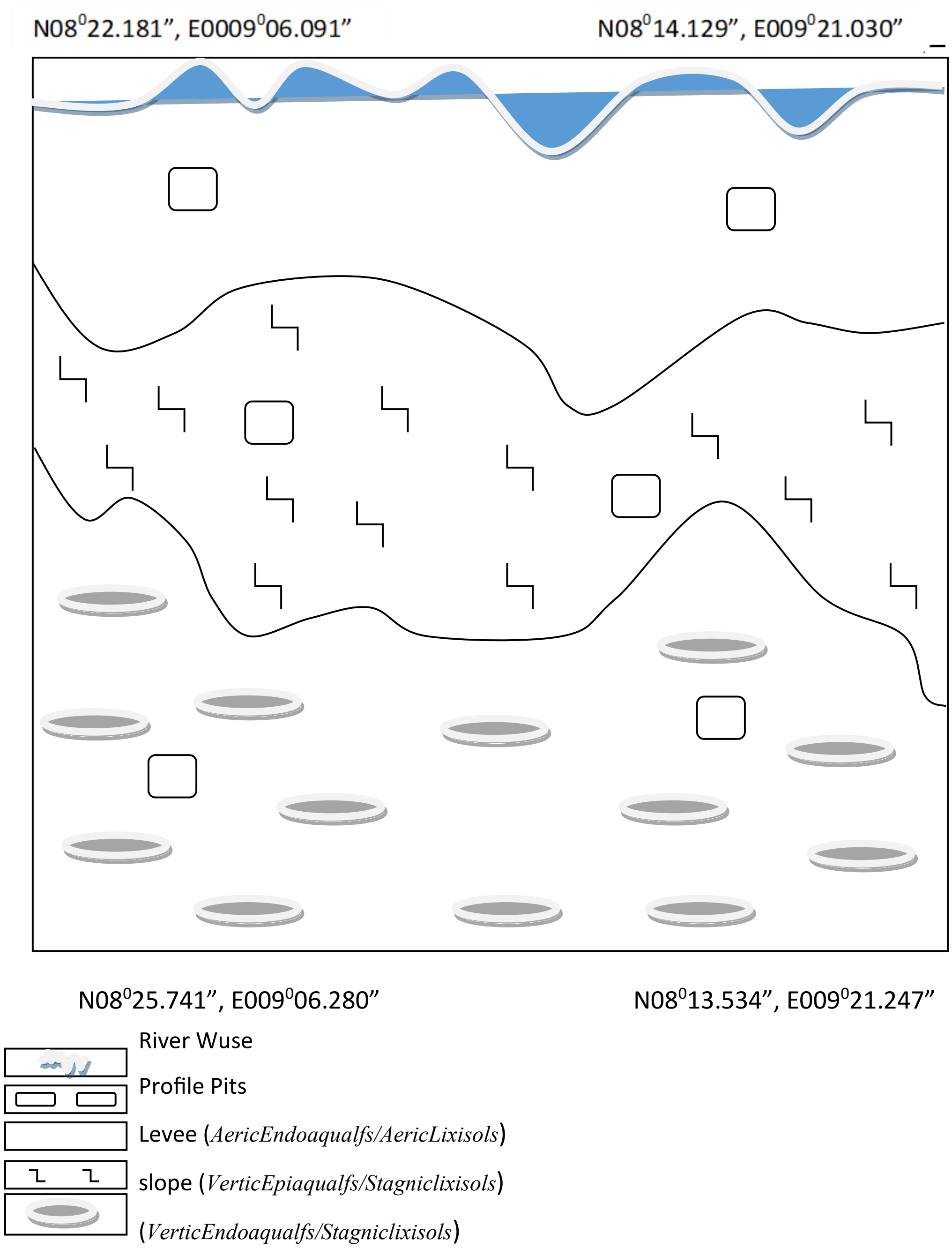

Figure 1: Soil map of the study areas

1143mm and 1270mm. The monthly maximum mean air temperature was highest (36.4°C) in the period prior to the onset of rains in March/April and lowest (22.9°C) during the period of heaviest rainfall in August

The flood plains studied are drained by Asu group of rivers and its tributaries. The river which runs north–south forms a dendritic drainage system with its tributaries. The slope of the area is about 0 to 2% and the elevation above mean sea level is about 93m (Hill, 1979). From River BakinKogi, the land is a flat gently low-lying wide flood plains eastwards to the river bank. Within the study sites, the area bordering the river channel is slightly more elevated than areas farther away from the bank(Levee), such that the lowest elevation occurs between the break of slope (Toeslope) and the river bank. The lowest spots are characterized by gilgai micro-relief, a feature of hydromorphism,referred to as the deep swamp.The plain continues south wards to River Benue, westwards to the rolling plains of Lafia and eastward to River Maiburugu. There are few isolated lateritic mesas in the area. The Jangwa flood plain has an abrupt boundary with the Namu formation and Benue piedmont which is predominantly made of cretaceous shales(Fagbemi and Akamigbo, 1986).

2.2 Field and Laboratory Studies

A reconnaissance survey was carried out in the area. Based on the local relief/drainage, six soil units were mapped out as soils on Levee, soils of the lower slope from the surrounding upland and the soils over toeslope between the lowerslope and the levee correspondingto shallow swamp (>0cm),medium swamp (lower slope) (0-50cm), and deep swamp(>50cm).Auger point investigation were carried out across the slope according to the topographic positions mentioned above. Two profile pits were sunk in eachof the unit; giving a total of 12 profile pits. Each profile pit was described according to the guideline for soil profile description (soil survey staff, 2014) and samples collected from identified soil horizons into polythene bags carefully labelled and taken to the laboratory for physical and chemical analysis.The samples were air dried, crushed and sieved (d<2mm). The samples were analyzed for particle size distribution, pH, organic carbon, CEC, exchangeable bases (Ca, Mg, K and Na), total nitrogen and available P. PSD was determined by Bouyoucos hydrometer method (Day, 1965). Soil pH was determined by electrometric methods as described by IITA (2015). Walkley- black method as described by Nelson and Sommers (1982) was employed for organic matter content. Total nitrogen was determined using the modified macro-kjeldahl method as described by IITA (2015). Bray No.1 method as described by IITA 2015 was used for extractable P. For exchangeable

3.0 Result and Discussion

3.1 Soil Morphology

From the auger point investigation, three soil mapping units were identified in each of the two locations based on their morphological characteristics namely colour, texture, structure, depth, drainage, surface characteristics, flooding, vegetation and the relief of the area. The spatial distribution of the three soil mapping units is shown in figure 5.

The soils in unit 1 (toeslope flood level) are generally nearly flat with gentle slopes of about 0-2% gradients. This unit covers about 45% of the study area. The major surface characteristics are gilgai micro-relief and poor drainage as indicated by the presence of mottles at the surface. Soil structure is well developed and soil texture is generally sandy clay loam to clay loam at surface and clay at subsurface. The surface soil is moderate- fine subangular blocky to strong subangular blocky at the subsurface. Soils in unit 2 (lower slope flood level) were generally low-lying and nearly flat and co-

Table 1: Morphological Description of the study area in in GidanTindi, Awe Local Government Area (2015 and 2016)

Horizon	Depth	Munsell colour (moist)	Mottling	Texture	Structure	Boundary	Inclusions	Consistency	Remarks
Profile 1 Toeslope – VerticEpiaqualfs/StagnicLixisols									
A	0 – 7	10YR 3/3		SCL	2mcsbk	CW		SSW	
B	07 – 32	10YR ¾		C	3csbk	GS	Many fine roots	VSW	
Bt1	32 – 51	2.5Y 4/2	5YR 3/2clf	C	3csbk	GS	few medium roots	VSW	
Bt2	51 – 72	2.5Y 4/6	7.5YR 3/2	C	3csbk	GS	Few fine roots	VSW	Concretions
Bt3	72 – 130	7.5YR 5/6		C	3csbk	GS	Few fine roots	VSW	
Profile 2: Toeslope – VerticEpiaqualfs/StagnicLixsol									
Ap	0 – 14	10YR 3/2	7.5YR 4/4flf	SCL	2mbsk	GS	Many coarse roots	SSW	Pores
Ab	14 – 33	10YR 4/4	7.5YR 4/6clf	C	2csbk	GS	Medium fine roots	VSW	Pores
B	33 – 52	2.5Y 4/3	7.5YR 4/6clf	C	3msbk	DS	Few fine roots	VSW	Stones
Bt1	52 – 74	2.5Y 4/4	7.5YR 4/4	C	3csbk	DS	Few fine roots	SW	Concretion
Bt2	74 – 110	2.5Y 4/2		C	3csbk	DS	Few fine roots	SW	
Profile 3 lower slope: – VerticEndoaqualfs/StagnicLixisols									
Ap	0 – 11	10YR7/2	7.5YR 4/4flf	CL	2msbk	GS	Medium roots	SW	
Ab	11 – 32	10YR 3/2	10YR 4/6clf	C	2msbk	GS	Medium roots	VSW	
Bt1	32 – 54	10YR 6/2	7.5YR 4/2clf	C	3csbk	GS	Common fine roots	VSW	
Bt2	54 – 70	10YR 6/3		C	2csbk	GS	Few fine roots	SW	

vers about 35% of the study area. The texture is generally to clay loam to loamy sand to sandy loam at the surface and clay loam to clay at subsurface. In the case of unit 3 (Levee flood level), it is located by the river bank and relatively more elevated and nearly flat. The soils in both locations are somewhat poorly drained. Soil texture is sandy clay loam at surface and clay at subsurface. Soil structure influenced the fertility of soil root development, penetration, seedling emergence, plant growth, adsorption of water and nutrients at surface and subsurface of soil, percolation, infiltration,

Table 1 cont.

Horizon	Depth	Munsell colour (moist)	Mottling	Texture	Structure	Boundary	Inclusions	Consistency	Remarks
Profile 4: lower slope – VerticEpiaqualfs/stagniclixisols									
Ap	0 – 12	10YR 3/3	7.5YR 4/3flf	CL	3csbk	CW	Many fine and medium	SW	
Ab	12 – 29	10YR 4/4	10YR 4/6cld	C	3csbk	GS	Few medium roots	VSW	
B	29 – 48	10YR 5/4	10YR 6/8clf	C	3csbk	GS	Few fine roots	VSW	
Bt1	48 – 67	10YR 3/3	2.5Y 4/3	C	2mbk	GS	Few fine roots	SW	
Bt2	67 – 118	10YR 5/6	7.5YR 5/6	C	2mbk	GS	Few fine roots	SW	
Profile 5: Levee – AericEndoaqualfs/Aericlixisols									
Ap	0 – 35	10YR 4/2		SCL	2msbk	GS	Many coarse roots	SSW	
Ab	35 – 41	10YR 5/2	5YR 3/2flf	C	3csbk	GS	Many fine roots	SSW	
Bt1	41 – 63	10YR 3/2	5YR 5/4clf	C	3csbk	DS	Few fine roots	VSW	
Bt2	63 – 80	10YR 6/8	2.5Y 5/2cld	C	2msbk	DS	Few fine roots	VSW	
Bc	80 – 155	10YR 8/6	7.5YR 5/8cld	C	2msbk	GS	Fine roots	SW	
Profile 6: Levee – AericEndoaqualfs/Aericlixisols									
Ap	0 – 25	10YR 2/2		SCL	2msbk	GS	Many coarse roots	SSW	
Ab	25 – 44	10YR 4/4	7.5YR 4/4flf	C	3msbk	DS	Many fine roots	VSW	
B	44 – 60	2.5Y 4/3		C	3mbsk	GS	Few fine roots	VSW	
Bt1	60 – 89	2.5Y 4/4	10YR 4/6cld	C	3mbsk	DS	Few fine roots	SW	Water

c

Depth	Munsell colour (moist)	Mottling	Texture	Structure	Boundary	Inclusions	Consistency	Remarks
Profile 7 Toeslope – VerticEpiaqualfs/stagniclixisols								
0 – 32	10YR 2/2		SCL	2msbk	CS	Common fine roots	SSW	
32 – 57	10YR 3/2	10YR 3/1fif	C	2msbk	GS	Common fine roots	VSW	
57 – 96	2.5Y5/2	10YR 5/8cif	C	2msbk	GS	Common fine roots	VSW	
96 – 120	2.5Y 5/3	10YR 6/4cif	C	2msbk	GS	Fine roots	VSW	
120 – 170	10YR 4/4	7.5YR 4/6cid	C	2msbk	GS	Fine roots	SW	
Profile 8 Toeslope – VerticEpiaqualfs/stagniclixisols								
0 – 35	10YR 2/2		CL	2msbk	CS	Many fine and medium roots	SSW	
35 – 61	10YR 3/3	7.5YR 4/4fif	C	2msbk	GS	Common fine and medium fine roots	VSW	
61 – 94	2.5Y 5/6	7.5YR 6/4cif	C	2msbk	GS	Fine roots	VSW	
94 – 122	2.5Y 5/2	10YR 5/8cid	C	2msbk	GS	Few fine roots	VSW	
122 – 170	2.5Y 5/6	10YR 5/8cid	C	2msbk	GS	Few fine roots	VSW	
Profile 9 lower slope – Verticendoqualfs/stagniclixisols								
0 – 10	10YR 5/4		LS	2msbk	CS	Common fine root	SSW	
10 – 22	7.5YR 4/4		LS	2msbk	GS	Few fine roots	VSW	
22 – 89	7.5YR 5/6		SL	2msbk	DS	Few fine roots	VSW	
89 – 101	7.5YR 4/6		SCL	2msbk			SW	

aeration and water holding capacity. The Ahorizon of all the pedons had predominantly strong coarse subangular blocky structure. This could be attributed to the relatively high level of organic matter in the surface horizons as well as the high clay content of the soils. The pedons were characterized by medium to strong coarse subangular blocky structure indicating moderate to high degree of soil development.

Jangwa (2016)								
profile 10 lower slope – Verticendoqualfs/stagnicLixisols								
Depth	Munsell colour (moist)	Mottling	Texture	Structure	Boundary	Inclusions	Consistency	Remarks
0 – 14	10YR 4/2		SL	3csbk	GS	Common fine roots	SSW	
14 – 25	10YR 5/6		SL	3csbk	GS	Common fine roots	VSW	
25 – 78	7.5YR 4/6		SL	3csbk	GS	Common fine roots	VSW	
78 – 110	10YR 5/8		SL	2msbk	GS	Few fine roots	VSW	
110 – 150	7.5YR 6/4		SCL	2msbk	GS	Few fine roots	VSW	
Profile 11 Levee – AericEndoaqualfs/AericLixisols								
0 – 22	10YR 4/2		SCL	3csbk	CS	Many fine and medium roots	VSW	
22 – 57	10YR 5/6		SCL	2msbk	DS	Common fine roots	VSW	
57 – 89	10YR 4/3		SCL	2msbk	DS	Common fine roots	VSW	
89 – 101	2.5Y 5/1	10YR 6/3	SCL	2msbk	DS	Few fine roots	VSW	
101 – 150	5YR 3/2		LS	2msbk	DS	Nodules	VSW	
Profile 12 Levee – AericEndoaqusalfs/AericLixisols								
0 – 22	10YR 2/2		CL	3csbk	CS	Many fine and medium roots	SW	
22 – 53	10YR 5/6	7.5YR4/6	CL	2msbk	CS	Common fine roots	VSW	
53 – 92	10YR 5/6	2.5Y5/6	CL	2msbk	DS	Fine roots	VSW	
92 – 115	10YR 5/2		CL	2msbk	DS	Fine roots	VSW	

Mottling Details:
FIF = Few fine faint, C2D = Few Common medium distinct, M3P = Many coarse prominent, C3P = Common coarse prominent
Texture
S = Sandy, C = Clay, SL = Sandy Loam, SCL = Sandy Clay Loam, SC = Sandy Clay
Structure
3CCR = Strong Coarse Crumb, 2CCOr = Moderate Coarse Crumb, 2MCR = Moderate Medium Crumb, 2MSBK = Moderate Medium Subangular blocky, 2MFBK = Moderate Fine Subangular Blocky, 3 CSBK = Strong Coarse Subangular Blocky, 3MSBK = Strong Medium Subangular Blocky
Consistence
SSW = Slightly Sticky Wet, VSW = Very Sticky Wet, VPW = Very Sticky Wet, SW = Stick Wet, NSW = Non-Sticky Wet, NPW = Non-plastic Wet
Inclusion
C2F = Common Medium Faint, M2D = Many Medium Distinct, F1F= Few Fine Faint, C3D = Common Coarse Distinct
Boundary
DS = Diffuse smooth, GS = Gradual Smooth, CS = Clear Smooth, AS = Abrupt Smooth
Colour
DB = Dark Brown, VDGB = Very Dark Grayisn Brown, LB = Light Brown, SB = Strong Brown, RY = Redishn Yellow, BRB = Dark Redish Brown, RG = Redish Green, DYB = Arkn Yellowish Brown, G = Gray, B = Brown

Soil Physical Properties

Soil physical properties such as particle soil analysis texture, soil structure, bulk density, porosity hydraulic conductivity, moisture content, colour and depth are responsible for the transport of water, air, heat and solutes through the soil and often change with management. Based on their qualities, they determine their behaviour and what they can be put to.

Table 5 shows the particle size distribution of soils of the area. Generally, the soils are relatively high in clay content in both locations except for Pedons 9, 10,11 and 12 of Jangwa. The values ranged from 11.0% to about 55%. The relatively high clay content could be due to nature of the underlying geological materials (shales). The Awgu shales are presumed to have constituted the underlying geology of the area (Idoga, 2005). Clay is the dominant mineral in shale and therefore tends to accumulate when shale weathers (Idoga and Azagaku, 2005). Alluvium is another geologic material in the area, being an inland depression. The fine materials are deposited here probably because of the reduction in the velocity of flow of rivers due to low slope gradient. The relative differences in clay content among the pedons could be due to slight difference in topography and cultivation. Clay content increases with depth in some Pedons of both locations due to some pedogenic processes such as lessivage, eluviation and illuviation as well as the contribution of the underlying geology of weathering (Ugwu*et al.,* 2001).

Sand fraction was most the dominant particle size at surface and subsurface horizons in all the mapping units of both locations ranging from 32.8% to 86% in the surface horizons and 30.9% to 73.4% in the subsurface horizons. The high sand fraction is a feature of most savannah soils due to eluviations and illuviation processes as well as the effect of erosion and lessivage. Soils with high sand fractions are vulnerable to erosion because they can easily be detached where heavy down pour and running water are frequent. The silt fraction was irregular with depth in most of the units due to the rate of materials brought by flood (flash and river flood). The silt fractions values ranged from 5.0% to 18.4% in both locations.

Table 5: Some Physical and chemical properties of the inland wetland soils of GidanTindi Awe Local Government Area (2015/2016)

		Particle Size dist						Total N	Avail. P	Exchangeable Bases				TEB	CEC	BS	Fe
Hori-zon	Depth (cm)	Sand	Silt (%)	Clay	Texture	pH H2O	Org. C	%	Mg/kg	Ca	Mg	K	Na	Coml kg		%	
Profile 1: Toeslope-VerticEpiaqualfs/stagniclixisols																	
A	0-7	74.4	5.4	20.2	SCL	6.5	1.64	0.06	3.99	1.97	1.66	0.98	0.64	5.25	5.36	87	1.65
AB	7-32	48.6	5.4	46.0	C	6.5	0.27	0.05	3.68	2..68	2.38	0.64	0.48	6.80	6.29	85	1.75
B	32-51	48.0	8.8	43.2	C	5.55	0.01	0.07	3.84	3.70	2.62	0.72	0.48	7.52	7.53	78	2.08
BC	51-72	49.4	7.6	45.2	C	5.52	1.04	0.05	2.57	3.73	1.08	0.54	0.37	5.72	5.72	74	2.40
C	72-130	48.1	5.4	43.5	C	5.01	1.02	0.06	2.26	1.99	0.84	0.58	0.48	4.17	4.37	53	2.45
Profile 2: Toeslope -VerticEpiaqualfs/ stagniclixisols																	
Ap	0-14	70.4	6.0	29.6	SCL	5.55	1.65	0.05	3.67	1.69	1.38	0.82	0.79	4.68	4.78	82	1.58
A	14-33	45.0	10.0	44.0	C	5.46	1.55	0.06	3.98	2.47	1.86	0.54	0.46	5.33	5.35	83	1.88
Bt_1	33-52	48.0	6.2	45.8	C	5.35	1.25	0.05	4.89	3.93	2.41	0.54	0.48	7.36	7.47	77	1.95
Bt_2	52-74	46.1	6.3	47.6	C	5.27	1.18	0.04	3.87	2.01	1.76	0.93	0.64	5.34	5.35	71	2.15
Bt_3	74-110	47.4	7.5	45.1	C	5.07	1.12	0.06	2.15	1.38	2.43	0.35	0.29	4.45	4.58	63	2.20
Profile 3 Lower slope -Verticendoaqualfs/ stagniclixisols																	
Ap	0-11	54.2	5.8	40.0	CL	5.55	1.60	0.07	3.52	2.05	2.03	0.84	0.44	5.35	5.38	64	1.55
Ap	11-32	46.4	5.4	43.2	C	5.46	1.05	0.08	3.46	1.93	1.75	0.72	0.54	4.94	4.98	58	1.80
Bt_1	32-54	45.4	6.6	48.0	C	5.35	1.15	0.06	2.65	2.07	2.04	0.75	0.54	5.60	5.73	88	2.00
Bt_2	54-70	45.8	5.0	48.2	C	5.27	1.20	0.97	2.61	2.13	1.84	0.69	0.43	5.09	5.12	88	2.35

GidanTindi (2015/2016)

		Particle Size dist						Total N	Avail. P	Exchangeable Bases				TEB	CEC	BS	Fe
Hori-zon	**Depth (cm)**	**Sand**	**Silt (%)**	**Clay**	**Tex-ture**	**pH H2O**	**Org. C**	**%**	**Mg/kg**	**Ca**	**Mg**	**K**	**Na**	**Coml kg**		**%**	
Profile 4 Lower slope–*Verticendoaqualfs/ stagniclixisols*																	
Ap	0-12	53.9	5.9	40.2	CL	6.5	2.64	0.06	3.64	2.60	2.34	0.82	0.53	6.29	6.34	63	1.60
A	12-29	47.0	7.8	45.2	C	6.5	1.47	0.21	2.96	1.98	0.96	0.76	0.58	4.28	4.39	54	1.65
AB	29-48	46.2	6.0	47.8	C	5.55	2.11	0.08	3.84	3.36	2.73	0.52	0.64	7.25	7.34	90	1.75
B	48-67	47.1	7.7	45.2	C	5.52	1.01	0.07	2.57	2.69	2.48	0.73	0.64	6.54	6.72	91	1.85
Bt1	67-118	45.2	6.4	48.4	C	5.01	1.02	0.06	2.26	3.38	2.43	0.8	0.55	7.23	7.23	92	1.90
Profile 5 Levee-*Aericendoaqualfs/Aericlixisols*																	
AP	0-35	62.8	8.0	29.2	SCL	6.54	1.88	0.06	3.74	1.98	1.42	0.82	0.58	4.80	4.85	65	1.78
AB	35-41	34.4	18.4	49.2	C	6.25	1.42	0.25	1.96	1.98	2.64	1.03	0.94	7.59	7.68	91	1.65
B	41-63	31.4	6.6	55.0	C	6.12	1.45	0.03	3.85	2.99	2.32	0.94	0.82	7.07	7.07	76	2.00
Bt1	63-80	30.9	6.6	59.0	C	5.25	2.35	0.02	1.78	1.82	0.98	0.73	0.64	4.17	4.28	67	2.20
Bt2	80-155	30.4	6.2	54.4	C	4.01	1.3	0.01	2.25	3.38	2.41	0.84	0.58	7.21	7.22	90	2.25
Profile 6 Levee-*Aericendoaqualfs/Aericlixisols*																	
Ap	0-25	61.0	8.2	30.8	SCL	6.52	2.24	0.09	3.46	2.68	2.55	1.86	0.98	8.07	8.19	93	1.85
B	25-44	44.4	9.5	46.1	C	6.20	1.56	0.08	2.98	4.94	1.83	0.87	0.62	8.26	8.28	82	1.90
Bt1	44-60	48.0	6.8	45.2	C	6. 15	1.60	0.06	1.85	3.93	2.34	1.04	0.94	8.25	8.34	80	2.10
Bt2	60-89	41.2	5.4	53.2	C	5.20	1.35	0.05	2.78	3.24	2.38	0.82	0.62	7.06	7.16	78	1.90

GidanTindi (2015/2016)

Hori-zon	Depth (cm)	Particle Size dist Sand	Silt (%)	Clay	Tex-ture	pH H2O	Org. C	Total N %	Avail. P Mg/kg	Exchangeable Bases Ca	Mg	K	Na	TEB Coml kg	CEC	BS %	Fe
Profile 4 Lower slope–*Verticendoaqualfs/ stagniclixisols*																	
Ap	0-12	53.9	5.9	40.2	CL	6.5	2.64	0.06	3.64	2.60	2.34	0.82	0.53	6.29	6.34	63	1.60
A	12-29	47.0	7.8	45.2	C	6.5	1.47	0.21	2.96	1.98	0.96	0.76	0.58	4.28	4.39	54	1.65
AB	29-48	46.2	6.0	47.8	C	5.55	2.11	0.08	3.84	3.36	2.73	0.52	0.64	7.25	7.34	90	1.75
B	48-67	47.1	7.7	45.2	C	5.52	1.01	0.07	2.57	2.69	2.48	0.73	0.64	6.54	6.72	91	1.85
Bt1	67-118	45.2	6.4	48.4	C	5.01	1.02	0.06	2.26	3.38	2.43	0.8	0.55	7.23	7.23	92	1.90
Profile 5 Levee-*Aericendoaqualfs/Aericlixisols*																	
AP	0-35	62.8	8.0	29.2	SCL	6.54	1.88	0.06	3.74	1.98	1.42	0.82	0.58	4.80	4.85	65	1.78
AB	35-41	34.4	18.4	49.2	C	6.25	1.42	0.25	1.96	1.98	2.64	1.03	0.94	7.59	7.68	91	1.65
B	41-63	31.4	6.6	55.0	C	6.12	1.45	0.03	3.85	2.99	2.32	0.94	0.82	7.07	7.07	76	2.00
Bt1	63-80	30.9	6.6	59.0	C	5.25	2.35	0.02	1.78	1.82	0.98	0.73	0.64	4.17	4.28	67	2.20
Bt2	80-155	30.4	6.2	54.4	C	4.01	1.3	0.01	2.25	3.38	2.41	0.84	0.58	7.21	7.22	90	2.25
Profile 6 Levee-*Aericendoaqualfs/Aericlixisols*																	
Ap	0-25	61.0	8.2	30.8	SCL	6.52	2.24	0.09	3.46	2.68	2.55	1.86	0.98	8.07	8.19	93	1.85
B	25-44	44.4	9.5	46.1	C	6.20	1.56	0.08	2.98	4.94	1.83	0.87	0.62	8.26	8.28	82	1.90
Bt1	44-60	48.0	6.8	45.2	C	6. 15	1.60	0.06	1.85	3.93	2.34	1.04	0.94	8.25	8.34	80	2.10
Bt2	60-89	41.2	5.4	53.2	C	5.20	1.35	0.05	2.78	3.24	2.38	0.82	0.62	7.06	7.16	78	1.90

c

Hori-zon	Depth (cm)	Particle Size dist Sand	Silt (%)	Clay	Tex-ture	pH H2O	Org. C	Total N %	Avail. P Mg/kg	Exchangeable Bases Ca	Mg	K	Na	TEB Coml kg	CEC	BS %	Fe
Profile 7: Toeslope*VerticEpiaqualfs/ stagniclixisols*																	
Ap	0-32	62.0	7.4	30.6	SCL	7.10	3.62	0.06	3.35	1.82	1.34	0.86	0.77	4.79	4.89	72	1.25
B	32-57	48.0	7.6	44.4	C	6.99	1.6	0.07	3.26	2.94	1.86	0.93	0.56	6.29	6.29	78	1.10
Bt_1	57-96	47.0	6.4	46.6	C	6.98	2.54	0.08	2.21	3.67	2.48	0.89	0.03	7.97	7.98	91	1.46
Bt_2	96-120	49.0	7.4	43.6	C	5.86	0.72	0.06	2.42	2.47	1.65	0.42	0.84	5.38	5.49	72	1.45
Bt_3	120-170	47.0	5.4	47.6	C	5.53	2.10	0.04	1.67	1.64	1.34	0.64	0.53	4.15	4.26	65	1.50
Profile 8: Toeslope -*VerticEpiaqualfs/ stagniclixisols*																	
Ap	0-35	52.1	8.0	30.9	CL	7.15	2.65	0.05	3.56	2.34	1.86	0.95	0.82	5.97	5.98	73	1.60
B	35-61	50.0	7.1	42.7	C	6.58	2.88	0.08	2.25	2.78	2.02	0.41	0.36	5.55	5.67	65	1.76
Bt_1	61-94	44.8	8.4	46.8	C	6.24	1.54	0.06	3.51	3.37	2.62	0.82	0.72	7.53	7.33	91	1.72
Bt_2	94-122	48.0	7.3	44.7	C	5.25	2.72	0.05	2.62	3.43	2.14	1.58	0.42	7.57	7.69	77	1.98
Bt_3	122-170	48.0	6.6	43.4	C	5.14	1.25	0.04	2.42	2.34	2.31	0.32	0.64	4.45	4.74	81	2.01
Profile 9: Lower slope-*Verticendoqaualfs/stagniclixisols*																	
A	0-19	86.0	5.4	8.6	LS	6.89	1.65	0.04	3.29	3.68	1.42	0.46	0.55	5.06	7.26	69.9	1.43
AB	10-22	79.0	7.4	13.6	LS	6.85	0.61	0.08	3.61	3.66	2.41	0.35	0.37	6.33	6.98	91.0	1.39
B	22-89	75.0	6.5	18.5	SL	6.75	1.59	0.06	3.72	3.65	1.36	0.36	0.18	5.59	6.57	83.3	1.28
BC	89-101	61.0	8.2	30.8	SCL	6.13	2.52	0.05	2.55	3.15	1.20	0.30	0.24	4.91	6.38	77.2	1.56

Hori-zon	Depth (cm)	Particle Size dist Sand	Silt	Clay	Tex-ture	pH H2O	Org. C	Total N %	Avail. P Mg/kg	Exchangeable Bases Ca	Mg	K	Na	TEB Coml kg	CEC	BS %	Fe
			(%)														
Profile 10: Lower slope–*Verticendoaqualfs/StagnicLixisols*																	
Ap	0-14	83.1	7.2	9.7	SL	6.80	2.72	0.05	3.36	3.68	2.34	0.41	0.62	7.05	7.23	97.5	1.48
A	14-25	80.3	7.0	12.7	SL	6.72	2.61	0.08	2.28	3.67	0.95	0.39	0.37	5.38	6.94	77.5	1.52
AB	25-78	76.0	9.2	14.8	SL	6.70	1.59	0.07	3.21	3.05	1.68	0.38	0.16	5.27	6.67	79.0	1.76
	78-110	77.0	10.2	12.8	SL	6.30	0.72	0.11	2.75	3.15	1.25	0.32	0.11	4.83	6.36	75.9	1.98
Bt$_3$	110-130	70.4	8.2	21.4	SCL	5.26	1.42	0.06	2.68	1.35	1.32	0.28	0.17	3.21	4.10	78.2	2.11
Profile 11: Levee -*AericEndoaqualfs/ AericLixisols*																	
Ap	0-22	60	6.4	33.6	SCL	5.43	2.06	0.05	3.12	1.87	0.56	0.37	0.60	3.40	5.02	84.5	1.58
Bt$_1$	22-57	58	9.4	32.6	SCL	5.35	1.56	0.07	2.98	2.56	0.53	0.35	0.38	4.02	4.93	81.5	1.69
Bt$_2$	57-89	62	7.4	30.6	SCL	5.14	1.52	0.08	3.26	2.14	1.34	0.31	0.34	4.13	4.34	95.1	1.90
Bt$_3$	89-101	60	8.5	31.6	SCL	5.10	0.41	0.06	1.87	2.11	1.20	0.30	0.21	3.82	4.22	90.5	2.06
Bt$_3$	110-130	82.6	8.2	9.4	LS	5.25	1.42	0.05	2.36	2.15	1.12	0.28	0.22	3.77	4.10	91.9	2.11
Profile 12: Levee –*AericEndoaqualfs/ AericLixisols*																	
Ap	0-22	59.0	6.4	34.6	CL	5.40	1.53	0.07	3.27	2.67	1.40	0.37	0.25	4.69	5.62	93.4	1.36
Bt$_1$	22-53	54.0	9.2	36.8	CL	5.35	1.53	0.08	2.50	1.56	0.68	0.35	0.38	2.97	5.22	90.3	1.48
Bt$_2$	53-92	58.0	7.4	34.6	CL	5.14	1.44	0.05	2.15	2.14	1.06	0.30	0.31	3.81	4.33	87.9	1.64
Bt$_3$	92-115	53.2	8.6	38.2	CL	5.12	1.34	0.04	1.64	2.13	0.23	0.29	0.20	2.85	4.15	68.6	1.92

The soils of the area of study were predominantly dark brown (10 YR 3/3, 10 YR 4/3 Moist) in their A and AP horizons of all the profiles. This could be attributed to the presence of relatively high organic matter which is the main colouring agent on surface soils (Ufot, 2012, Ray, 2014). The dark grayish brown colour (10 YR 4/2, moist) on surface horizons of profile 3,4 10, 11, 12 may be associated with humified nature of soil organic matter coupled with the high water table (Abagyeh*et al*; 2017). In the subsurface horizons of profiles 4, 5, 6, 11, 12 the presence of reddish brown (2.5 Y 4/3) colour, is an indication of complete organic matter decomposition (oxygen rich soil) and seasonal fluctuation of ground water table resulting in the yellowish red mottles observed. Such mottles were mainly confined to root channels because of the oxidizing effect of oxygen, which enters the channels as soon as the water table recedes.

The hydraulic conductivity of the study area was moderate to high in the A and AP horizons which is ideal for cropping due to better soil aggregates resulting to high pore space for agricultural activities.Hydraulic conductivity is the flow of water through soil per unit of energy gradient. For practical purposes, it is a measure of the rate at which water moves into and through the soil. It is useful for predicting runoff from rainfall, soil drainage, irrigation rates, leakages from dams and deep drainage that contributes to salinity (Cass, 1999).The knowledge of water movement in field soil is essential with respect to plant nutrient transport. The measure of the soil's ability to transmit water called hydraulic conductivity does not remain constant due to the various chemical, physical and biological processes going on in the soil. Therefore, hydraulic conductivity may change as water permeates and flows through the soil (Abdulkadir, 2006). Hydraulic conductivity is influenced by total porosity of the soil, which in turn is affected by the bulk density and available water content and other factors (Mbagwu, 1995; Rawls *et al*., 1998; Abdulkadir, 2006).

Bulk density values ranged between 1.008mgm^{-3} and 1.575mgm^{-3}. The bulk density of the study area was moderate to high. The bulk density decreases with depth and midway high by forming a hard pan layer due to frequent use of tractors in yearly farm operations. After the hard layer it increases down the profiledue to the influence of clay as the dorminant mineral. The frequent deposit of harvested residues also reduces the bulk density of soils. Bulk density is influenced by vegetation and aggregation; the moderate bulk density in profile 9,10,11 and 12 was due to the dominance of sand. High bulk density is an indication of low soil porosity and high compaction which may cause restriction of root growth and poor movement of air and water through the soil. (Arshaal and Lowery, 1996). Also use of heavy equipment in soil could lead to increased bulk density and reduced pore space with associated consequences. Incorporation of organic matter into the soil would improve soil aggregation and moisture availability for sustainable crop production (FAO, 2006; Odunze, 2006).

The total porosity values ranged between 10.06% and 15.43%. The total porosity value decreased with depth in all the units. This may be due to high compaction and vegetation in the lower soil, leading to lower soil porosity values. Use of heavy equipment on soil reduces pore space by increasing bulk density.

3.3 Soil Chemical Properties

The pH values in table 5 indicate that the soils of both locations were strongly acidic to slightly Alkaline in reaction.

The pH of the soils varied from 4.89 to 7.15. These pH levels fall within the range (4.5 – 7.5) considered highly suitable for rice production (Maniyunda*et al.,* 2015). The pH values decreased with depth from surface to subsurface in both locations. This decrease with depth may probably be due to the effect of nutrient biocycling (Ogunwale*et al.,* 2002; Idoga and Azagaku 2005). This could be accounted for by the direct deposition of crop and vegetation residues on the soil Surface and their subsequent decomposition to release basic cations to the soil. Idoga and Ogbu (2012) attributed the reduction in soil pH with depth to frequent crop harvesting and leaching of bases.

The organic carbon content of the soils was low to moderately high ranging from 0.01% to 2.88% in the subsurface and surface horizon. The values decreased with depth in all the Pedons due to the concentration of plant roots and plant residues on the topsoil.The high values may be attributed to the "aquic moisture" conditions of the flood plains, which reduce soil temperature and consequently lower the rate of organic matter decomposition (Idoga and Azagaku, 2005; Dengiz, 2010). The percentage organic carbon content of the area is relatively high compared with most savannah soils because of the incorporation of the crop/vegetation residues to the soil and the droppings from the cattle that are reared in the field during the dry season.The low soil temperatures resulting from poor drainage could also encourage organic matter accumulation in both locations that are poorly drained. Earthworms, soil microflora and fauna increase organic carbon content of soil by breaking, burrowing and biochemically altering fresh organic matter through mixing with some inorganic materials and later excreting them to form moist middens that prevent rapid loss of humic compounds (ESU, 1982).

Total Nitrogen values of the soil ranged from 0.05% to 0.35%. This is rated low at the surface and high in the subsurface (Lawal*et al.,* 2012). The nitrogen values decreased with depth generally savannah soils are low in total nitrogen which is attributed to low percentage of organic carbon content because the two occur together in relatively fixed ratios naturally. Low nitrogen is attributed to release from plant tissues, gaseous loss, loss in surface runoffs, leaching, climatic factors, vegetation, human activities and initial soil/ pH. Nitrogen loss through volatilization and denitrification may also contribute to the low level of nitrogen in the wetland soils (Brady and Ray, 2014). Activities of bush burning and continuous cropping over years reduce the organic matter content of soils and subsequently nitrogen content. The phosphorus content of the study area was extremely low with values ranging from 1.64mg/kg to 4.89mg/kg.The low values however agree with the views of (Brady and Ray 2014) that the total quantity of phosphorus in most native soil is low, with most of it present in the form quite unavailable to plants. The low availability of phosphorus in the wetlands soils of the study area especially in almost all they profiles may be attributed to the low pHlevel which fixed the Phosphorus and makes it unavailable. It may also be attributed to low amount of organic carbon of the flood plains.

The exchangeable bases (Ca, Mg, K and Na) are low in both locations of the research. The range of total exchangeable bases of these soils, ranged from 2.85cmol/kg to 8.26cmol/ kg. Total exchangeable bases (TEB) fluctuates with depth in both locations of identified soil units. Similar findings were reported by Idoga, 2005 and Fasina*et al*. 2007). The low exchangeable bases may be attributed to the nature of the underlying materials, intensity of weathering, scorching, low activity clay very low organic matter content, surface runoff and the lateral translocation of bases. The low content of organic matter and clay reduce the ability of the soil to hold/ attract cations in exchangeable forms (Krasilinikoff*et al.,* 2002). These results confirm the findings of Sanchez (1976) that soils in tropical savannah are rapidly impoverished under continuous cultivation. Calcium is the most dominant cation in the exchange complex.

The CEC values ranged between 4.10cmol/kg^{-} and 8.34cmol/ kg^{-1}. It has the ability to hold cations against leaching and determines acidity or basicity of soils. The CEC of the soils of the study area was low to medium according to ESU (1991) rating of <6 = low, 6-2 = medium and <12 = high. Soils having low potentials for retaining plant nutrient is an attribute of low CEC values and indication for low plant nutrient retention, hence the necessity for adequate soil management. The low CEC values of the soils could be attributed to the nature of the silicate clay minerals (Kaolinite) believed to be the dominant clay type in depressed soils (Hassan *et al*., 2011). The low organic carbon content of the inland valleys could also be attributed to the low CEC values of the soils (Yakubu*et al.,* 2011).

The percentage base saturation values of the soils (54% to 97.5%) were rated moderately high to very high. The distribution of base saturation is irregular in all the units. This could be attributed to the active plant litter decomposition process which incorporated cations from the litter into the soil surface and also the contribution by harmattan dust known to contain some high fraction of cations especially Ca (Idoga, 2002). High base saturation (96 – 98%) is probably associated with the presence of the weatherable minerals in soil profiles and inadequate leaching caused by the several dry months and seasonal high water table.The decreasing trend of base saturation with depth may be a consequence of nutrient bio cycling (Idoga and Azagaku, 2005).

Extractable FeO was determined for soils of the study area for reasons of establishing the possibility of Fe toxicity. The Ferrous oxide constitute the soluble forms of iron and therefore can be readily absorbed by plants in high amounts if highly concentrated in soils. The increasing amount of Fe^{2t} with depth may be due to the high mobility of Fe with percolating water. The Fe^{2t}get accumulated in the subsurface horizon as water dries out. Generally, the extractable Fe^{2t} content of the soils is low. The values are below 3.0mg/kg, and therefore cannot constitute any toxicity problems. Fe toxicity is primarily pH related and occurs where pH has dropped sufficiently to create excess available iron. Iron toxicity causes bronzing in leaves and reduce root oxidation power, occurs in wide range of soils but generally in low land rice soils with permanent flooding crop growth. To avoid Fe toxicity, you delay planting, carry out dry tillage after the rice harvest to enhance Fe oxidation during fallow. Draining of field and keep free of floodwater IRRI fair 2000.

3.4 Soil Classification

3.4.1 Soil Classification according to USDA Soil Taxonomy

The key to soil Taxonomy (Soil Survey Staff, 2014) was used in the classification of the soils of both locations. Except profiles 3 and 9 which showed regular increasing trend with depth, all other profiles showed irregular trend in the amount of clay with depth and also a high degree of soil aggregation. The clay distribution pattern shows that there are argillic horizons in all the profiles studied. The clay distribution pattern coupled with the high base status (<50%) of the soils qualify them as Alfisols.

The aquic conditions as evidenced by the dominant matrix hue of 10YR and the presence of mottles at or close to the soil surface, and a chrome of 2 in some horizons further qualify these soils as Aqualfs. Profile 1,2,3,4,5 and 6 of GidanTindi,profile 7,8,9 and 10 of Jangwashow evidence of episaturation due to ground water influence and therefore qualified as Epiaqualfs. The presence of cracks narrower than <2cm and shallower than 50cm of soil surface places these profiles in the subgroup verticepiaqualfs.Profile 5 and 6of GidanTindi and 11 and 12 of Jangwa showed signs of endosaturation and therefore qualified as endoaqualf at the great group level. The subsurface horizons are mottled with the dominant matrix colour of 10YR or yellower and chroma of 3 or more and therefore, qualified as AericEndoaqualfs.

3.4.2 Classification according to World Reference Base (WRB)

The soils have higher clay content in the sub soil than in the topsoil as result of pedogenetic processes (Elluviation and illuviayion) leading to an argillic horizon, profile 1,2,3,4,of GidanTindi and 7,8,9,10 of Jangwa classify as StagnicLixisols because of the presence of argillic horizons and a base saturation greater than 50% as well as the presence of stagnic properties within 50cm of soil surface.Profile 5, 6,11 and 12 of GidanTindi and Jangwawere classify as AericLixisols because of the sandy clay loam texture and coarse surface structures.

4.0 Conclusion

Both location have limitation that can easily be overcome by farmers to obtain substantial yield. All the three flood levels (toeslope, lower slope and Levee) were highly suitable for water loving crop such as rice, if followed logically based on past experience or knowledge of yearly cropping. All the Pedons in both locations experience flash flooding and river flooding between the months of August and September. However, incidences of deep flooding usually take place occasionally, especially when there is heavy down pour from the upper region.

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