LAND CHARACTERISTICS AND FERTILITY CAPABILITY CLASSIFICATION FOR SELECTED SOILS OF NORTHERN CROSS RIVER STATE, NIGERIA

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ABSTRACT
Some selected soils of Northern Cross River State within the guinea savanna zone of Nigeria, were surveyed, characterized, classified and evaluated for fertility capability. The free soil survey method delineated the entire study area into three mapping units based on soil homogeneity. The potentials as well as the limitations of the three mapping units were highlighted. The fertility capability evaluation placed the soils of unit 1 under class LCgg^{+}v, unit 2 as SLdi and unit 3 as SLnmedhip. The study recommend that installation of surface and sub surface drainage facilities will enhance sustained agricultural cultivation on soils of unit 1 with loamy top soils and clayey sub soils. The soils of unit 2 having few limitations of low available phosphorus and dry udic environment, can support agricultural utilization through moderate fertilization with NPK, high in phosphorus and irrigation. Soils of unit 3 with limitation of high gravel content, low CEC, low organic matter, available P and dry udic environment is so severe to permit sustained economic agricultural utilization.
Key words: Soil Characteristics, Fertility, Capability, Classification.

INTRODUCTION
Land evaluation is an important requirement for sustainable land use planning. Elaalem *et al*. (2010) posited that if self-sufficiency in agricultural production is to be achieved in developing and transitional countries, land evaluation techniques will be required to develop models for predicting the land's capabilities for different kinds of Agriculture Minh *et al*. (2006) noted that land characterization and evaluation precedes land use of planning, which may facilitate predicting the behavior and sustainability of different parcels of land for agricultural and non-agricultural uses.
Fertility capability classification is an important tool for evaluating the potentials, constraints and management requirements of taxonomically varied soils. Sanchez *et al*. (2003) described fertility capability classification as a technical soil classification system that focuses quantitatively on the physical and chemical properties of the soil that are important towards soil management Nsor (2017) showed that the basic difference between soils of different physiographic terrain were texture and condition modifiers (constraints).
Productive agriculture is the product of soil or land characterization and good management practices. Soil characteristics such as pH, salt content, nutrient status, texture and structure have direct bearing on the growth and yield of cultivated crops. Aroh & Isirinah (2003) stated that soil fertility capability is the major criterion for assessing the potentials of agricultural land.
The soils of Northern Cross River State, Nigeria had not been adequately characterized in terms of evaluating its fertility capability. This probably might be the reason for the declining productivity of these soils. Hence, the present study aimed at generation of data on specific constraints and potentials of these soils that can be used for future ecologically sound land use options. The specific objective of this study is to characterize, classify and evaluate their fertility capability. This will improve the productivity of soils in the study area through good soil management practices.

MATERIALS AND METHODS
Study Area
The northern part of Cross River State lies between latitude 5º20´ and 6º20´ N and longitude 8º00´ and 9º20´ E. Northern Cross River State has a total land area of about 7556.69sq km, consisting of five (5) Local Government Areas: Obudu, Obanliku, Bekwara, Ogoja, and Yala (NPC, 2006).
This study was carried out in representative soils derived from diverse lithological formation in Northen Cross River State within the guinea savanna zone of Nigeria. The sampling locations were selected based on information contained in the map of Cross River State (2005) and on previous works of Ekwueme *et al.,* (1995) on the geology of Eastern Nigeria and geomorphology of Cross River State.

Field Work/Sampling Technique

A reconnaissance visit was made to the study area to familiarize with the environment and the various community leaders. An advocacy visit to stake holders to obtain permission to work in the area was made as an aid to proper planning and design of the field work. The free soil survey method was adopted in mapping the entire area using a scale of 1:500,000. Auger points were made across the field to delineate the study area into mapping units. Profile pits were dug based on the sampling units, two (2) to (3) profile pits per mapping unit were dug and described according to the procedure specified in the field book for describing and sampling soils (Schoenberger *et al.*, 2012). Soil samples were collected for laboratory analysis from each genetic horizon.

Sample Preparation and analysis

Soil samples for routine analysis were air dried, crushed gently with a wooden roller and sieved through a 2mm diameter mesh sized sieves and laboratory analysis. Particle size distribution was done by the Bouyoucos, 1951 hydrometer method (Gee & Or, 2002). Bulk density was measured by the cylindrical core method (Anderson & Ingram 1996). Porosity was evaluated using the relationship.

Porosity = (1-Bd/Pd) 100 % …. Equation 1 Where Bd=bulk density, Pd = particle density ($2.65cm^{-3}$). Soil erodibility index was determined using the relationship. Soil Erodibility index =%sand +% silt/% clay...Equation 2

Electrical Conductivity was determined in 1:2.5 soil: water extract using conductivity bridge and expressed as dSm^{-1} (Jackson, 1962). The percentage gravel content which were the materials collected on the sieve (>2mm in diameter), regarded as gravels were weighed and its percentage to whole soil sample weight calculated. Soil pH values in H_2O was determined by using a pH meter in 1:2.5, soil/water ratios respectively, according to the method of (Thomas, 1996). Available phosphorus was determined by Bray-2 and Kurtz as modified by Olsen & Sommers (1982). Organic Carbon was determined by using Walkley & Black (1934) wet oxidation method as outlined by Nelson & Sommer (1996). Total nitrogen was determined by the Kjeldahl method as modified by Bremner (1996). Exchangeable acidity was determined by KCl extraction using Mclean's (1965) method. Exchangeable bases were extracted with neutral NH_4OAc solution; Ca and Mg were determined by Atomic Absorption Spectrometer (ASS) while K and Na were determined by flame photometry (Grant, 1982). Cation exchange capacity (CEC) was measured using ammonium acetate leaching at pH 7.0 (Rhodes,1982). Base saturation percentage was calculated as follow:% BS = Total Exchangeable Bases x 100 Cation Exchange Capacity 1 …. Equation 3

Available Micro nutrients (Fe,Zn,Mn and Cu) were extracted with 1N HCl and determined by atomic Absorption Spectrophotometry (AAS) using Association of Analytical Chemist (AOAC) 1990 methodology.

Land Suitability Evaluation Procedure

Fertility Capability Procedure

Fertility Capability Classification (FCC) of the study area was done to assess its potential for agronomic management as outlined by Sanchez *et al.,* (2003). The system consists of three categorical levels, 'Type' (texture of plough layer or top 20 cm), 'Substrata Type' (texture of subsoils), and 'modifiers' (soil properties or conditions which act as constraints to crop performance). FCC units were determined by combining class designations from the three categorical levels. The soils were, therefore, classified according to the characteristics as detailed in the fertility capability soil classification system: version 4 (Sanchez *et al.,* 2003).

Statistical Analysis

The data obtained were analysed using ranges and simple arithmetic means and presented in Tables and maps

Results and Discussion

The data on morphology, physical and chemical properties of selected soils of Guinean Savana Zone of Nigeria is presented, discussed and evaluated for the cultivation of cotton (*Gossypum spp*). The section also presents a classification of the soils using the USDA soil taxonomy with approximate correlation with the World Reference Base (WRB) system.

Morphological Characteristics

The morphological characteristics of selected soils of Guinea Savanna zone of Nigeria are presented in Table 1. The results are presented for the various mapping units identified and delineated in the field. The soils of mapping unit 1 consists of flood plain and inland valley soils occurring on flat or nearly flat terrains of 0-2 % slopes. The soils are shallow to moderately deep and seasonally water logged with hydromorphic features. The extent of wetland soils is vast and occupies an approximate area of about 264.6 ha. This mapping unit dominates Bansara axis of Ogoja and some parts of Yala Local Government Area. The parent material of this unit is an ad-mixture of colluvio-alluvial deposits however with a much higher percentage of alluvial materials. Under moist conditions the soils of mapping unit 1 were characterized by very dark greyish brown (10YR 3/2) to dark grey (5YR 4/1) to grey (7.5YR 5/1) epipedons over reddish grey (5YR 5/1) to grey (7.5YR 5/1) endopedons (Table 1). The grey sub soil colouration of this mapping unit might be due to gleization arising from poor drainage condition of the soils. This observation corroborates Akpan-Idiok and Ogbaji (2013) who attributed gleying of fadama or inland valleys (flood plains) of River Onwu to gleization. The soils of this unit were redoximorphically mottled with few fine faint to common medium distinct to prominent strong brown (7.5YR 5/6) and reddish yellow (7.5YR 6/6) mottles. The mottling was attributed to episaturation of flood water, seasonal water table fluctuation and reduction- oxidation cycles taking place in these soils. Mottling of wetland soils had been reported by many scholars including Nsor and Akamigbo (2009); Fasina *et al*., (2015) and Sahu *et al*, (2001). Structurally, the soils of this unit consist of weak to moderate medium crumb and granular top soils over moderate to strong, medium prismatic sub soils structure (Table 1). The consistence of this unit indicate soft surface soils over slightly hard to hard sub surface soils (dry), loose to friable top soils over firm to very firm sub soils (moist), and slightly sticky, slightly plastic top soils over sticky plastic to sticky very plastic sub soils (wet). The soils had common medium top soil pores over common fine to many fine sub soil pore geometry. The occurrence of meso pores over fine pores in the profile of this unit might be the reason for the poor drainage condition of the soils.

Table 1: Morphological Characteristics of Selected Soils of Guinea Savanna zone of Nigeria.

Location	Horizon Designation	Horizon Thickness (cm)	Major Colour	Mottle Colour	Texture	Structure	Consistence Dry	Moist	Wet	Roots	Pores	Horizon Boundary
						Mapping Unit 1						
Bansara I	Ap	0-18	10YR 3/2; Vdgb		L	1 M Cr	S	l	ss-sp	cm	cm	cs
	Bgh_1	18-38	7.5YR 4/1; Dg	7.5YR 5/6; fff, Sb	SiL	2 M Gr	Sh	fr	s-p	cf	cm	gw
	Bgh_2	38-74	5YR 5/1; Rg	7.5YR 5/6; Cmd, Sb	SiC	2 M Pr	Sh	f	s-vp	ff	mf	gw
	Bg	74-118	5YR 5/1 Rg	7.5YR 5/6; Cmd, Sb	CL	3 C Pr	H	vf	s-vp	ff	mf	
Bansara II	Ap	0-9	10YR 4/2; Vdgb		L	1 F Gr	S	l	ns-sp	mm	cm	cs
	Bh	9-32	7.5YR 3/1; Vdg		SiL	2 M Gr	S	fr	ss-sp	mm	cm	gw
	Bgh	32-49	7.5YR 4/1; Dg	7.5YR 6/6; Cmd, Ry	SiCL	2 M Gr	Sh	f	ss-sp	cf	mf	gw
	Bg	49-90	7.5YR 5/1; G	7.5YR 6/6; Cmp, Ry	SiC	2 M Pr	Sh	f	s-p	ff	mf	
						Mapping Unit 2						
Imajie	Ap	0-11	5YR 3/3; Drb		SL	1 F Gr	S	l	ns-np	mm	cm	cs
	AB	11-36	5YR 4/4; Rb		SL	1 M Gr	S	vfr	ns-np	ff	fm	gw
	Bt_1	36-74	5YR 4/8; Yr		SCL	2 M Sbk	Sh	fr	s-p	fm	mm	gw
	Bt_2	74-115	10YR 5/6; Yb		CL	2 C Sbk	Sh	f	s-p	fvf	fmm	
Adagom	Ap	0-15	7.5YR 3/4; Db		LS	1 F Gr	S	l	ns-ns	cf	cm	cs
	AB	15-36	7.5YR 4/3; B		SiL	1 F Sbk	S	vfr	ss-p	fm	mm	gw
	Bt_1	36-67	7.5YR 6/4; Lb		SiC	2 M Sbk	Sh	fr	ss-p	fvf	mm	gw
	Bt_2	67-118	10YR 5/6; Yb		SCL	2 C Sbk	Sh	f	s-p	fvf	mc	
Idum Mbube	Ap	0-8	10YR 3/3; Db		LS	1 F Gr	S	l	ns-np	mf	cm	cs
	AB	8-27	10YR 4/4; Dyb		SL	2 M Sbk	Sh	fr	ss-sp	ff	mf	gw
	Bt_1	27-55	7.5YR 6/4; Lb		SC	2 M Sbk	H	f	s-vp	mf	mc	gw
	Bt_2	55-108	10YR 5/6; Yb		SC	2 M Sbk	H	vf	s-vp	fvf	mc	
						Mapping Unit 3						
Bebi	Ap	0-9	7.5YR 3/2; Drb		SL	2 M Cr	L	fr	ns-ns	cf	mm	gw
	Btv_1	9-27	5YR 7/6; O		LS	2 M Sbk	Sh	f	ss-sp	fm	fm	gw
	Btv_2	27-61	5YR 4/8; Rb		SCL	3 C Sbk	Vh	vf	s-vp	mf	ff	
Utugwang	Ap	0-15	7.5YR 2/3; Vdb		SL	1 M Gr	S	fr	ns-np	mm	mm	cw
	Bt_1	15-4 3	7.5YR 4/6; B		SL	2 M Sbk	Sh	f	ss-sp	fm	fm	gw
	Bt_2	43-77	5YR 4/8; Rb		CL	3 C Sbk	H	vf	s-sp	ff	mm	
Utukpuru	Ap	0-18	7.5YR ¾; Db		LS	1 F Sbk	S	fr	ns-np	mf	mc	gw
	Bt_1	18-32	7.5YR 4/3; B		SL	1 M Sbk	Sh	f	ss-np	fm	fm	gw
	Bt_2	32-63	5YR 4/8; Rb		CL	2 M Sbk	Sh	vf	s-p	ff	fvf	gw
	BC	63-98	5YR 4/8; Rb		SC	3 M Sbk	H	vf	s-p	fm	fm	

Keys:

1. **Colour:**Vdgh = Very dark greyish brown, Dg = dark grey, Rg = Reddish grey, Vdg = Very dark grey, G = grey, Drb = Dark reddish brown, Rb = Reddish brown, Yr = Yellowish red, Yb = Yellowish brown, Db = Dark brown, B = Brown, Lb = Light brown, Dyb = Dark yellowish brown, O = Orange, Vdb = Verb dark brown, Sb = Strong brown, Ry = Reddish yellow.
2. **Mottles:**fff = Few fine faint, Cmd = Common medium distinct, Cmp = Common medium prominent
3. **Texture:** L = Loam, SiL = Silty loam, SiC = Silty clay, CL = Clay loam, SiCL = Silky clay loam, Sl = Sandy loam, SCL = Sandy clay loam, LS = Loamy sand, SC = Sandy clay
4. **Structure:** 1 = weak, 2 = moderate, 3 = strong, F = fine, M = Medium, C = Coarse, Sbk = Sub angular blocky, Cr = Crumb, Gr = Granular, Pr = Prismatic
5. **Consistence:** S = soft, Sh = slightly hard, h = hard, f = firm, vh = very hard, l = loose, fr = friable, f = firm, vf = very firm, Vfr = very friable, ss-sp = slightly sticky-slightly plastic, s-p = sticky-plastics, s-vp=sticky-very plastic, ns-sp=non sticky-slightly plastic, ss-sp = slightly sticky-slightly plastic, ns-np = non sticky-non plastic, ss-np = slightly sticky-non plastic, ns-ns = non sticky-non sticky, s-sp=sticky-slightly plastic
6. **Horizon Boundary:** Cs= clear smooth, gw = gradual wavy, cw = clear wavy

Soil mapping unit 2 consists of soils that are moderately deep to deep found on nearly flat to undulating plains of 3-5% slopes, developed on sedimentary siltstone parent materials. The soils are fine to medium textured and gravel free. This mapping unit is vast and occupies an approximate land area of about 296.3 ha. This mapping unit dominates farm lands around Imajie, Mbube and Adagom communities in Ogoja, Yala and Bekwara Local Government Area in Guinea Savanna zone of Nigeria. Under moist conditions the soils of mapping unit 2 were characterized by dark reddish brown (5YR 3/3) to dark brown (10YR 3/3) epipedons over dark yellowish brown (10YR4/4) to yellowish brown (10YR5/6) endopedons (Table 1). Structurally, the soils of this unit had weak fine to medium granular top soils over moderate medium to coarse sub angular blocky sub soil structural aggregates. Investigations on the consistence of mapping unit 2 revealed a soft surface soil over slightly hard to hard sub surface soils (dry); loose to very friable top soils over friable to firm sub soils (moist) and non-sticky, non-plastic top soil over slightly sticky-plastic to sticky-plastic sub soils (wet), Table 1.

The sticky-plastic sub soils of this unit present strong evidence of clay migration for the existence of sub soil argillic (Bt) horizon. The profile pore geometry revealed the existence of common medium pores over many medium to coarse pores. This profile pore size distribution might be the reason for the improved drainage condition of soils of this unit. This observation corroborates Mbagwu (1997) who reported that water infiltration into soil depend on texture and profile pore geometry in his study on Quasi-steady infiltration rates of highly permeable tropical savannah soils in relation to land use and poor size distribution. Soils of mapping unit 3 consists of soils that are well drained, medium to coarse textured, shallow and gravelly with plinthites. The soils of this unit are found on moderate to strongly undulating plains of slopes of 7-12% surrounded by large hills with a few minor pockets of imperfectly drained soils. The soils are developed on basement complex rock parent materials dominated by granites. This unit consist of about 145 ha of land, and occur extensively around Bebi, Utugwang and Utukpuru axis of Obudu LGA of Cross River State, Nigeria. Under moist condition the soils of this mapping unit consist of dark reddish brown (7.5YR3/2) to dark brown (7.5YR3/4) epipedons over reddish brown (5YR4/5) to orange (5YR7/6) endopedons (Table 1). Structurally, soils of this unit had weak to moderate medium crumb or granular top soil structures over moderate to strong medium to coarse sub angular blocky sub soil structural aggregates. The consistence revealed a loose to soft top soil over slightly hard to hard sub soils (dry) , friable top soil over firm to very firm sub soils (moist), and non-sticky, non-plastic top soils over sticky-plastic sub soils (wet). The sticky-plastic sub soils might be due to clay illuviation suggestive of argillic Bt sub soil diagnostic horizon. This observation corroborates Nsor (2017). The soil's pore geometry indicated that the soils had many medium pores over few fine to few very fine sub soil pore (Table 1).

Physical Properties

The data on physical properties of soils in the study area is presented in Table 2. The results indicate that soils of mapping unit 1 had loamy top soils over silty loam to silty clay sub soils. Similarly the soils of mapping unit 2 also had loam to silty loam top soils over silty clay loam sub soils. However soils of mapping unit 3 contrasted the other mapping units with medium to coarse textures of loamy sand to sandy loam textures over sandy clay loam to sandy clay sub soil texture. Silt fraction dorminated top soils of profiles of mapping units 1 and 2, while sand dorminated the profile of mapping unit 3. In all the pedons evaluated, clay separates were observed to increase with soil depth as a result of clay eluviations-illuviation in soils. This corroborated Ewulo *et al*. (2002) in their studies on soils with Kandic horizons in Southwestern Nigeria. The dorminance of sand fraction in pedons of mapping unit 3 might be due to their granitic parent materials. This observation agrees with the findings of Nsor & Adesemuyi (2018) who reported that granitic parent materials yields medium to coarse textured soils.

Bulk density values in the study area showed that the soils were non-compacted as they were generally moderate (1.35-1.60 gcm^{-3}) and thus possess no serious limitation to agricultural productivity. Plants perform best in bulk densities below 1.4gcm^{-3} and 1.6 gcm^{-3} for fine and coarse textured soils respectively, because of soil resistance to root penetration, poor aeration, slow movement of nutrients or water and buildup of toxic gases and roots exudates (Brady & Weil, 2005;and Odunze, 2006). The bulk density increased gradually downward (Table 2) from the top soils. This increase in bulk density with depth may be due to decreased organic matter content, less aggregation and compaction caused by overlying weights of soil layers (Ayolagha & Opene, 2012).

Table 2: Physical Properties of Soils in the Study Area

Location	Horizon Designation	Horizon Thickness (cm)	Sand %	Silt %	Clay %	Textural Class	Silt: Clay Ratio	Bulk Density gcm^{-3}	Porosity %	Soil Erodibility Index	EC (dsm^{-1})	Gravel %	Illuvia: Eluvia Clay
						Mapping Unit 1							
Bansara I	Ap	0-18	32	48	20	L	2.4	1.38	47.9	4.0	0.11	4.4	1.2
	Bgh_1	18-38	24	52	24	SiL	2.2			3.2	0.10	4.8	1.5
	Bgh_2	38-74	24	40	36	SiL	1.1	1.55	41.5	1.8	0.21	3.1	1.6
	Bg	74-118	20	24	56	C	0.4			0.8	0.26	3.0	
Bansara II	Ap	0-9	40	35	25	L	1.4	1.42	46.4	3.0	0.30	2.5	1.0
	Bh	9-32	30	46	24	SiL	1.9			3.2	0.35	2.2	1.5
	Bgh	32-49	15	50	35	SiCL	1.4	1.53	42.3	1.9	0.42	2.0	1.2
	Bg	49-90	13	44	43	SiC	1.0			1.3	0.51	2.3	
	Mean		24.8	42.4	32.9		1.5	1.47	44.5				
						Mapping Unit 2							
Imajie	Ap	0-11	21	56	23	SiL	2.4	1.35	49.1	3.3	0.19	9.2	0.7
	AB	11-36	20	63	17	SiL	3.7			4.9	0.33	11.1	1.6
	Bt_1	36-74	27	45	28	SiCL	2.5	1.45	45.3	2.3	0.44	14.3	1.4
	Bt_2	74-115	06	54	40	SiC	1.4			1.5	0.50	16.5	
Adagom	Ap	0-15	32	44	24	L	1.8	1.41	46.8	3.2	0.24	6.6	0.8
	AB	15-36	32	48	20	L	2.4			4.0	0.36	7.1	0.7
	Bt_1	36-67	30	56	14	SiL	4.0	1.51	43.0	6.1	0.50	7.8	2.1
	Bt_2	67-118	40	30	30	CL	1.0			2.3	0.52	7.7	
Idum Mbube	Ap	0-8	30	44	26	L	1.7	1.40	47.2	2.8	0.26	4.4	1.2
	AB	8-27	24	44	32	CL	1.4			2.1	0.29	6.3	1.1
	Bt_1	27-55	16	50	34	SiCL	1.5	1.46	44.9	1.9	0.30	6.9	0.9
	Bt_2	55-108	17	51	32	SiCL	1.6			2.1	0.37	6.6	
	Mean		23.8	25.8	25.8		2.1	1.43	46.1				
						Mapping Unit 3							
Bebi	Ap	0-9	76	12	12	LS	1.0	1.44	45.7	7.3	0.16	36.9	1.5
	Btv_1	9-27	75	18	18	SL	0.4			4.6	0.19	58.1	1.6
	Btv_2	27-61	60	28	28	SCL	0.4	1.60	39.6	2.6	0.22	71.2	
Utugwang	Ap	0-15	68	10	10	SL	2.2	1.45	45.3	9.0	0.30	42.0	1.2
	Bt_1	15-43	68	12	12	SL	1.7			7.3	0.34	51.2	3.2
	Bt_2	43-77	28	38	38	CL	0.9	1.53	42.3	1.6	0.39	63.5	
Utukpuru	Ap	0-18	84	10	10	LS	0.6	1.40	47.2	9.0	0.41	32.6	1.8
	Bt_1	18-32	74	18	18	SL	0.4			4.6	0.46	54.4	1.9
	Bt_2	32-63	57	34	34	CL	0.3	1.55	41.5	1.9	0.50	62.1	1.3
	BC	63-98	50	45	45	SC	0.1			1.2	0.55	70.2	
	Mean		64.0	22.5	22.5		0.8	1.50	43.6				

Key: L = Loam, Sil=Silty loam, C=clay,SiCl=silty clay loam, SiC=Silty clay, LS=loamy sand, SL=sandy loam, CL=Clay loam, SCL=sandy clay loam, SC=sandy clay

Soil porosity was adequate (39.6-49.1 %) for all the mapping units as the values were within the 40-50 % range, assumed optimal for any productive soil (Brady and Weil, 1999) The soils of mapping unit 1 and 2 with mean porosities of 44.5% - 46.1 % respectively were more porous than soils of mapping unit 3 with mean porosity of 43.6 % (Table 2). The implication here is that soils of mapping unit 1 and 2 will have higher water retention capacity and hence continuous nutrient supply and absorption into crop tissue and therefore will result in better crop performance than soils of mapping unit 3.

The erodibility index of soils in the study area was generally low to moderate for the fine to medium textured soils of mapping unit 1 and 2 (0.8-4.9), but moderate to high for the coarse textured soils of mapping unit 3 (1.2-9.0). This observation corroborates Hudson (1995) who reported that soil properties such as texture, structure, porosity directly affect erodibility of soils. The results also indicate that top soils with erodibility index in the range (3.0-9.0) were above the critical value of 1.0 and 3.0 suggested by Kinnell (1981) for coarse and fine textured soils respectively, are more vulnerable to sheet and gully erosion than the sub-soils with erodibilty index range of (1.2-2.6).

Electrical conductivity, a measure of soil salinity was generally low (0.10-0.52 dSm^{-1}) in all the pedons studied. This low EC values may be due to the low cations status of the soils in the study area (Plaster, 1992). The root of mapping unit 1 and 2 were relatively gravel free with percent gravel content >11.1 % while the soils of mapping unit 3 were generally gravelly, having the highest gravel content (32.6-71.2 %). The high gravel content in this unit may be due to their granite parent material which yields large fragments on weathering. The sub soils of all the pedons studied had illuvia-eluvial clay ratios < 1.4, confirming evidence of argillic sub soil horizons (Table 2).

Chemical Properties

The data on chemical properties of soils in the study area as presented in Table 3 showed that the soils were moderately acid in mapping unit 1 (pH 5.0-5.9) and mapping unit 2 (pH 5.3-5.8).However the soils of mapping unit 3 were strongly acid (pH 4.4-4.9). The strongly acid condition of soils of mapping unit 3 might be attributed to the medium to coarsed texture of these soils which permits extensive leaching of basic cations by high rainfall of the Nigeria southern savanna region (Abagyeh & Idoga, 2013). In all pedons studied epipedons had higher pH values than endopedons. This might be attributed to nutrient cycling through root absorption of bases from the subsoils to the top soils through litter fall.

Organic carbon in the study area ranged from medium in mapping unit 1 (4.8-12.4 gkg^{-1}) and mapping unit 2 (4.7-14.7 gkg^{-1}) to low in mapping unit 3 (1.2-5.2 gkg^{-1}).The low level of organic carbon content in soils of mapping unit 3 might be attributed to its slope condition which favour rapid removal of leaf litter as well as high rate of organic matter turnover due to rapid mineralization as a result of the well drained condition of this soil unit. This corroborates Ezenwa & Barrera (1985) who reported that differences in slope steepness contributed to variation in soil organic carbon in their soil survey of Ribako forest Reserve.

Total nitrogen was low to medium (0.1-1.4 gkg^{-1}) in mapping unit 1, low (0.2-1.0 gkg^{-1}) in mapping unit 2 and very low (0.01-0.07 kg^{-1}) in mapping unit 3 (Table 3). The low content of total nitrogen across the study area might be due to continuous cultivation of the soils which rapidly increases the rate of organic matter decomposition due to increased aeration and crop uptake. This observation corroborates Havlin *et al*. (2005).

Table 3: Chemical Properties of Selected Soils in Guinea Savanna zone of Nigeria

Horizon Designation	Horizon thickness (cm)	pH (H_2O)	Org. C.	O.M. gkg^{-1}	T.N	Ca^{2+}	Mg^{2+}	K^+ cmol/kg^{-1}	Na^+	CEC	Esp (%)	BS (%)	Al^{3+} cmol/kg^{-1}	H^+ cmol/kg^{-1}	EA cmol/kg	ECEC	AV.P $mgkg^{-1}$	Fe	Zn gkg^{-1}	Cu	Mn
										Mapping Unit 1											
Ap	0-18	5.8	12.4	21.4	0.7	2.20	1.10	0.24	0.06	10.5	1.20	34.3	0.21	1.20	1.41	5.01	7.3	1.3	0.7	1.1	0.20
Bgh_1	18-38	5.3	10.5	18.8	1.2	2.70	1.36	1.12	0.06	16.9	0.87	31.0	0.40	1.28	1.68	6.92	10.1	1.2	0.6	1.4	0.10
Bgh_2	38-74	5.1	10.2	17.6	0.9	2.90	1.33	1.11	0.05	17.2	0.70	31.2	0.24	1.56	1.80	7.19	9.8	1.4	0.6	1.2	0.06
Bg	74-118	5.1	4.8	8.3	0.3	2.50	1.25	1.19	0.06	17.1	0.91	29.2	0.42	1.16	1.58	6.58	7.7	1.5	0.6	1.2	0.06
Ap	0-9	5.9	11.1	19.1	1.4	2.10	1.80	0.46	0.20	10.2	3.57	4.7	0.45	0.60	1.05	5.61	17.8	1.4	0.5	0.8	0.20
Bh	9-32	5.6	11.6	20.0	1.1	2.40	1.74	0.40	0.10	12.8	1.74	36.3	0.22	0.90	1.12	5.76	16.2	1.8	0.5	0.8	0.30
Bgh	32-49	5.4	6.6	11.4	0.3	2.60	1.95	0.47	0.15	15.2	2.51	34.1	0.10	0.70	0.80	5.97	8.0	1.9	0.6	1.0	0.10
Bg	49-90	5.0	5.1	3.6	0.1	1.10	1.21	0.30	0.10	15.0	2.93	18.1	0.10	0.60	0.70	3.41	6.1	1.2	0.7	1.1	0.10
X		5.4	10.1	15.0	0.8	2.31	1.47	0.66	0.10	14.4	1.80	32.4	0.27	1.00	1.27	5.81	10.4	1.5	0.6	1.1	0.14
										Mapping Unit 2											
Ap	0-11	5.8	6.3	11.0	0.8	2.80	0.60	0.23	0.05	11.1	0.79	33.2	2.10	0.57	2.67	6.35	12.1	1.6	0.4	1.2	0.1
AB	11-36	5.7	5.4	5.9	0.5	2.40	0.70	0.23	0.42	12.4	5.61	30.2	2.40	1.33	3.73	7.48	11.2	1.8	0.2	0.6	0.1
Bt_1	36-74	5.5	5.0	3.4	0.2	2.20	0.90	0.24	0.56	14.2	7.39	27.5	2.60	1.08	3.68	7.58	10.1	1.0	0.4	0.8	0.0
Bt_2	74-115	5.3	4.7	2.9	0.2	1.80	1.00	0.30	0.56	14.4	7.44	25.4	2.70	1.17	3.87	7.53	6.5	1.6	0.4	0.8	0.0
Ap	0-15	5.8	14.7	39.1	1.0	2.10	0.50	0.17	0.09	10.2	1.72	28.0	2.00	0.38	2.38	5.24	13.2	1.1	0.3	1.1	0.5
AB	15-36	5.5	11.2	19.3	0.6	2.50	0.40	0.15	0.08	12.0	1.37	26.1	1.90	0.83	2.73	5.86	13.1	1.1	0.3	1.2	0.6
Bt_1	36-67	5.5	8.4	14.5	0.6	3.00	0.60	0.15	0.08	14.5	1.36	26.4	1.70	0.34	2.04	5.87	12.4	1.3	0.3	1.0	0.2
Bt_2	67-118	5.6	6.8	11.7	0.5	2.60	0.60	0.17	0.13	15.3	2.20	22.9	1.90	0.51	2.41	5.91	8.3	1.4	0.3	1.0	0.2
Ap	0-8	5.7	13.2	22.8	0.5	2.50	0.30	0.20	0.07	11.7	1.44	26.2	1.20	0.60	1.80	4.87	14.1	1.0	0.5	1.3	0.7
AB	8-27	5.4	10.8	18.6	0.6	2.20	0.30	0.16	0.08	11.9	1.19	23.0	2.60	1.40	4.00	6.74	14.0	1.8	0.6	1.2	0.5
Bt_1	27-55	5.5	5.6	9.6	0.4	2.20	0.40	0.15	0.07	12.2	1.06	23.1	2.40	1.40	3.80	6.62	12.2	1.3	0.6	1.0	0.3
Bt_2	55-108	5.5	5.6	6.2	0.3	2.30	0.40	0.21	0.07	12.6	0.86	23.7	2.20	3.00	5.20	8.18	10.3	1.6	0.7	1.1	0.3
X		5.6	8.0	13.8	0.5	2.38	0.56	0.20	0.19	11.9	2.70	26.3	2.14	1.05	3.19	6.52	11.5	1.1	1.3	1.0	1.3
										Mapping Unit 3											
Ap	0-9	4.7	5.2	9.0	0.04	0.10	0.40	0.11	0.05	5.2	1.17	31.9	3.00	0.60	3.60	4.26	9.2	5.8	1.7	0.9	0.40
Btv_1	9-27	4.6	4.4	7.6	0.03	1.12	0.30	0.09	0.05	5.5	0.63	28.4	4.20	2.20	6.40	7.96	7.1	5.4	1.7	0.8	0.20
Btv_2	27-61	4.4	2.1	3.6	0.01	1.00	0.10	0.08	0.06	5.8	0.56	21.4	5.40	4.00	9.40	10.64	6.5	5.2	1.6	0.8	0.55
Ap	0-15	4.9	4.6	7.9	0.03	1.40	0.30	0.13	0.06	6.1	0.61	31.0	4.60	3.40	8.00	9.89	8.8	5.6	1.8	1.3	0.5
Bt_1	15-43	4.8	4.1	7.1	0.03	1.20	0.40	0.10	0.10	6.4	1.06	28.1	4.40	3.20	7.60	9.40	8.6	5.5	1.7	1.5	0.40
Bt_2	43-77	4.7	2.0	3.4	0.01	1.20	0.40	0.07	0.05	6.8	0.63	25.3	3.40	2.80	6.20	7.92	5.2	4.7	1.7	1.5	0.40
Ap	0-18	4.8	3.3	5.7	0.07	1.70	0.50	0.14	0.04	7.6	0.40	31.3	4.60	2.90	7.50	9.88	8.3	5.6	1.3	1.6	0.4
Bt_1	18-32	4.6	3.0	5.2	0.04	1.80	0.40	0.11	0.04	8.2	0.46	28.7	3.30	3.00	6.30	8.65	8.0	4.4	1.3	1.4	0.33

Bt_2	32-63	4.5	1.8	3.1	0.02	1.40	0.50	0.05	0.06	8.5	0.69	23.6	3.60	3.10	6.70	8.71	4.5	4.4	1.0	1.3	0.33
BC	63-98	4.5	1.2	2.1	0.02	1.00	0.50	0.05	0.06	8.7	0.72	18.6	3.50	3.20	6.70	8.31	4.1	4.7	1.3	1.3	0.4
X		4.7	3.2	5.5	0.03	1.19	0.38	0.09	0.06	6.9	0.69	26.8	4.00	2.84	6.84	8.56	7.0	5.5	1.6	1.2	0.4

Amongst the exchangeable cations, sodium was generally low to medium (0.04-0.56 cmolkg^{-1}) across the study area. Potassium was medium to high (0.24-1.19 cmolkg^{-1}) in mapping unit 1, medium (0.15-0.30 cmolkg^{-1}) in mapping unit 2 and low (0.05-0.10 cmolkg^{-1}) in mapping unit 3. Calcium was medium (1.10-3.00 cmolkg^{-1}) in mapping unit 1 and 2, but low (0.10-1.80 cmolkg^{-1}) in mapping unit 3. Magnesium content was high in mapping unit 1 (1.10-1.95 cmolkg^{-1}) and medium in mapping unit 2 (0.30-1.00 cmolkg^{-1}) and mapping unit 3 (0.10-0.50 cmolkg^{-1}) (Table 3). The medium to high contents of exchangeable bases in mapping unit 1 might be due to flat terrain characteristics feature of the soils of this mapping unit which favour deposition of erosional sediments. However the low to medium content of exchangeable bases in mapping unit 2 and 3 may be attributed to intensive cropping of the soils, leaching, erosion losses and crop removal without replacement resulting in chemical deterioration as also reported by Eswaran *et al*. (2001) and Odunze (2006).

Cation exchange capacity (CEC) values were medium for soils of mapping unit 1 (10.2-17.2 cmolkg^{-1}) and mapping unit 2 (10.2-15.3 cmolkg^{-1}), but low (5.2-8.7 cmolkg^{-1}) in soils of mapping unit 3. This observation corroborates Afu *et al.* (2015) who attributed low CEC observed in some selected soils of Northern Cross River State to the dominance of 1:1 non-expanding clay minerals in these soils. The low to moderate cation exchange capacity of the soils in the study area implies that with continuous cultivation, the soils would undergo rapid degradation physically and chemically. The incorporation of organic matter and addition of fertilizers would raise and stabilize cation exchange capacity in these soils (Brandy and Weil, 2005).

The base saturation values in the study area were generally low and less than 35% by ammonium acetate method. This is suggestive of an ultisol soil order. The exchangeable acidity values in the study area was in the range 0.80- 1.80 cmolkg (mapping unit 1), 1.80-3.87 cmolkg^{-1} (mapping unit 2) and 3.60-9.40 cmolkg^{-1} (mapping unit 3).Indeed, the Ap horizons hard highest values across the profiles (Table 3).This result is similar to the low exchangeable bases and high exchangeable acidity reported by Afu *et al*. (2015) for selected soils under different land use in Northern Cross River State and Markus *et al*.(2008) for Oxisols developed from three different parent materials. Exchangeable Al^{3+} dominated H^+, indicating that the soils have a high potential for acidification.

Available phosphorus values were medium for soils of mapping unit 1 (6.1-17.8 mgkg^{-1}) but low (3.0-9.2 mgkg^{-1}) in soil of mapping unit 3. The low to medium level of available P might be due to fixation (Al-P) arising from the high Al^{3+} status of the soils and crop uptake. This observation corroborates Odunze (2006) who attributed low available phosphorus observed in Niger flood plains to P-fixation and retention in soils.

Amongst the cationic available micronutrients iron (Fe) was deficient in mapping unit 1 (1.2-1.9 gkg^{-1}) and in mapping unit 2 (1.0-1.8 gkg^{-1}) and adequate (4.4-5.8 gkg^{-1}) in mapping unit 3. Zinc was marginal (0.5-0.7 gkg^{-1}) in mapping unit 1 and 2, but adequate (1.0-1.7 gkg^{-1}) in mapping unit 3 (Table 3). Copper was generally adequate (0.6-1.6 gkg^{-1}) in soils of the study area. Manganese was deficient to marginal (0.06-0.7 gkg^{-1}) in all the mapping units studied. The variation of micro nutrient content between the mapping units might be attributed to the contributing effect of parent material and rainfall. The fine to medium textured soils of mapping units 1 and 2 favoured the low level of Iron in these soils due to its resistance to leaching of basic cations unlike the coarse textural soils derived from granites of mapping unit 3 which accelerated leaching, hence enhanced or dominance of micro nutrient contents. This observation corroborated Kparmwang *et al*. (2000) on extractable micronutrients in some soils developed on sand stone and shale.

Fertility Capability Evaluation of Soils in the Study Area

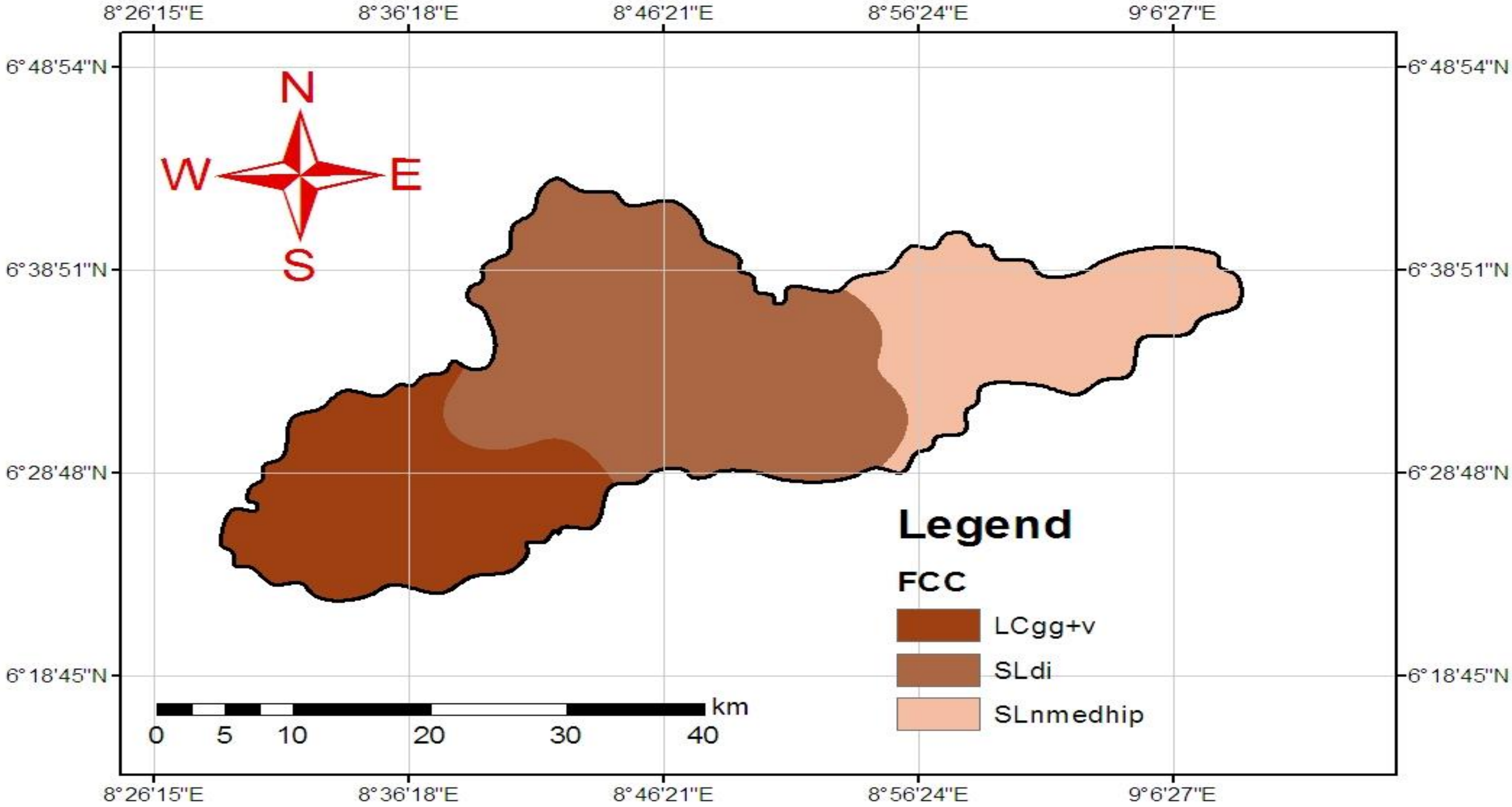
Fertility capability classification of soils in the study area was done to further interpret the soil taxonomy and give additional soil attributes directly relevant to the cultivation of cotton (*Gossypum Spp*). The FCC for selected soils of Northern Cross River State, within the Guinean Savanna Zone of Nigeria is presented in Table 4.

The soils of unit 1 had loamy (L) top soil type and clayey (C) sub strata type. The soils of this mapping unit were associated with anaerobic conditions, redoximorphic features (gleying) associated with aquic soil moisture regimes (Table 4). The soils possessed vertic properties, the properties of soils of this unit in its present state cannot support commercial cotton production. However, installation of both surface and sub-surface drainage facilities at an increased cost making it economically marginal for sustained cultivation of cotton. The soils of unit 2 had sandy (S) top soil type and clayey (C) substrata type. This soil unit had few limitations of low available phosphorus and a dry udic environment. This soil unit in its present state can marginally support the commercial cultivation of cotton. However, if its fertility limitations are removed through manuring, fertilization and irrigation to supplement rainfall, this soil unit can moderately sustain commercial cotton production in the study area. The soils of unit 3 belonged to sandy (S) type top soils and clayey (C) substrata type. It has limitations of high gravel content, low CEC, organic matter and available phosphorus. Soils of this mapping unit are also limited by acidic soil conditions with an Udic soil moisture regime. These properties in aggregate are so severe as to prevent any possibility of successful sustained cotton cultivation.

Table 4: Checklist Showing Type, Substrate Type and Modifiers

Soil Mapping units	**Type**	**Substrate**	**Modifiers**										
		Type	g	g^+	v	n	m	e	d	h	i	p	Aggregate
1	L	C	+	+	+	-	-	-	-	-	-	-	$LCgg^+v$
2	S	C	-	-	-	-	-	-	+	-	+	-	SCdi
3	S	C	-	-	-	+	+	+	+	+	+	+	SCnmedhip

Key:
S = Loamy sand and sands
L = Loamy having < 35% clay but not loamy sand or sandy loams
C = Soils having >35% Clay (Clayey top or sub soils)
g = gleying, mottles
d = dry udic environment
e = low CEC of plough layer
h = acidic, pH in H_2O between 4 and 5
i = low available p
v = vertic properties
g^+ = prolonged water logging
m = low organic carbon
n = high gravel content
p = plinthization


8°26'15"E
8°36'18"E
8°46'21"E
8°56'24"E
9°6'27"E
6°48'54"N
6°38'51"N
6°28'48"N
6°18'45"N
N
W
E
S
Legend
FCC
LCgg+v
SLdi
SLnmedhip
km
0
5
10
20
30
40

Fig

CONCLUSION

Land characterization and evaluation indicates potentials and limitations of soil and furnishes valuable information to farmers, developers, environment list, engineers and individual land owners for various utilization. The study under consideration highlighted the lands potentials and indicated its fertility limitations under agricultural land utilization. The fertility capability classification system of land evaluation simplified information about profile characteristics and analyzed the soils for the benefit of those who are not familiar with complex soil classification system. This system of land evaluation is suitable to both pedologist and agronomists.

The fertility capability classification (FCC) evaluated the land in terms of top and sub soils textural characteristics as well as climate, drainage and fertility condition modifiers (limitations). The fertility capability evaluation placed the soils of unit 1 under class LCgg^{+}v, unit 2 as SLdi and unit 3 as SLnmedhip.

RECOMMENDATIONS

The study recommended that:

- The installation of surface and sub-surface drainage facilities will enhance sustained agricultural utilization on soils of unit 1.
- The soils of unit 2 having few limitations of low available phosphorus and dry udic environment, can support agricultural utilization through moderate fertilization with NPK, high in phosphorus and irrigation.
- Soils of unit 3 with limitation of high gravel content, low (CEC, organic matter, available phosphorus) and dry udic environment is so severe to permit sustained economic agricultural utilization.

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