

SOIL-LANDSCAPE CHARACTERISTICS IN RELATION TO ITS SUITABILITY FOR MAIZE (*ZEA MAYS*) CULTIVATION IN IKOT-ESIDEM, SOUTHERN NIGERIA

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ABSTRACT

The soil-landscape characteristics in relation to its suitability for maize cultivation were evaluated for soils on diverse landforms in Ikot-Esidem, Southern Nigeria. The study area was stratified into four landform types, namely the flood plains, inland valleys, gentle slopes and crests. Eight (8) profile pits, two (2) per landform type were dug and characterized. The results indicate that the soils of flood plains and inland valleys under moist condition had brownish black (5YR 3/1) to brownish grey (5YR 5/1) epipedons over greyish brown (5YR 4/2) to reddish grey (2.5YR 6/1) hydromorphically mottled endopedons. The gentle slopes and crest units had dark reddish brown (5YR 3/2) surface soils over reddish brown (5YR 4/8) sub soils. Silt (25-55 %) and clay (19-51 %) dominated the pedons of flood plains and inland valleys while sand (30-78%) dominated pedons of gentle slopes and crests. The soils of flood plains and inland valleys were moderately acid (pH 5.0-5.7), medium to high in organic carbon (6.3-20.5 g/kg) and had medium to high base saturation (46-90 %). The gentle slopes and crest units were strongly acid (pH 4.5-5.1), low in organic carbon (4.0-11.1 g/kg) and base saturation (20.5-34.7 %). The soils of flood plains, inland valleys and gentle slopes were evaluated marginally suitable (S3) while the soils on crest were rated currently not suitable (NI) for maize cultivation. The fertility capability classification of the soils in the study area evaluated the soils of flood plains as LCgg⁺v, the inland valleys as LCgg⁺vi⁺ and the gentle slopes and crest as SCidh. The study recommended efficient drainage for flood plains and inland valleys as well as manuring, erosion control, liming and leguminous intercropping for soils on gentle slopes and crest as measures to enhance the suitability of soils in the study area for maize cultivation.

Key words: Soil-Landscape, Characteristics, Suitability, Maize, Cultivation

INTRODUCTION

The configuration of the land surface has a dominant influence controlling both the hydrological and pedogenic process of soil formation. Soil-landscape relationship has been widely used in soil characterization and land evaluations. Nsor and Ibanga (2008) observed that variations in soils characteristics are usually a reflection of differences in materials from which the soil was formed and its local relief. Norton and Smith (2007) identified slope steepness and length as two most important factors of relief that influences soil formation. This causes variation in drainage, degree of erosion and deposition of sediments which invariably results in variation of soil properties derived from similar parent materials, environmental condition and age in the different landscape positions (Lawal *et al.*, 2013).

Soil-landscape relations play an important role in crop growth and yield. In complex terrains of varying slopes, soil forming factors and erosion do not act uniformly, but

vary with landscape type and position. Marques da Silva and Alexandre (2005) presumed that what eroded at higher landscape positions must move downhill and alter what existed at the lower lying positions. Soil-landscape relationships had been used to study soil variability in large geomorphic regions (Olatunji *et al.*, 2007 and Esu *et al.*, 2008). Osujieke *et al.*, (2016) observed that intensive cultivation of slope land has caused soil deterioration due to erosion, fertility depletion and poor management. Topography should be an important consideration in the overall landuse and management of soils (Nsor and Akamigbo, 2014). Pilesjo *et al.*, (2005) featured that different topographical parameters can be used to delineate agricultural management zones.

Land suitability evaluation enables more accurate and useful prediction to be made for specific purposes and eliminates costly and avoidable mistakes, hence the incidence of soil degradation emanating from land misuse can be reduced (Nsor and Akamigbo, 2015).

Suitability is a concept that is becoming more and more accepted among planners, soil scientist and other environmentalists. Sustainable use of soil resources require an extensive knowledge about genesis, terrain features and properties.

Maize (*Zea mays* L.) is one of the most important cereal grains grown worldwide in a wider range of environments because of its greater adaptability (Kogbe and Adediran, 2003). It is a main source of food, forage and processed industrial products (Troyer, 2006). Rosegrant *et al.*, (2009) predicts that global demand for maize will increase from 526 million tons to 784 million tons from 1993 to 2020, with most of the increased demand coming from developing countries.

There is a dearth of soil information in the study area likely to assist farmers in extensive maize production. Most previous soil studies did not cover most of the cluster villages and besides evaluation of the suitability of those soils in relation to landscape for maize, a major staple food in the world had not been considered. The conspicuous absence of soil information and land suitability map for Ikot Esidem a major farming community in Akwa Ibom State, Southern Nigeria, specifically on maize production has prompted the choice of the area for study to maximize its potentials and ameliorate constraints. This will also permit the

emergence of the most appropriate soil management systems for increased maize production in the different landscape positions existing in the study area. The objectives of the study were to determine soil-landscape relationships, evaluate the suitability of soils on the different landscapes for maize cultivation and perform a fertility capability classification (FCC) of the soils in the study area.

MATERIALS AND METHODS

Study Area

This study was carried out in Ikot Esidem, Ibiono Local Government Area of Akwa Ibom State, located in the humid tropics of south-southern region of Nigeria. The study area lies between latitude 05°13'10", 05°17'50" N, and longitude 07°50'0", 07°53'30" E (Figure 1).

The climate of the study area is humid tropic, with annual rainfall of about 2500 to 3000mm with 1 to 3 dry months in a year. The soil moisture regime is udic in the elevated areas and aquic in the low-lying areas. Mean annual temperature varies between 27 and 28 °C with relative humidity of 75 to 80 % (Usono and Akpan, 2010).

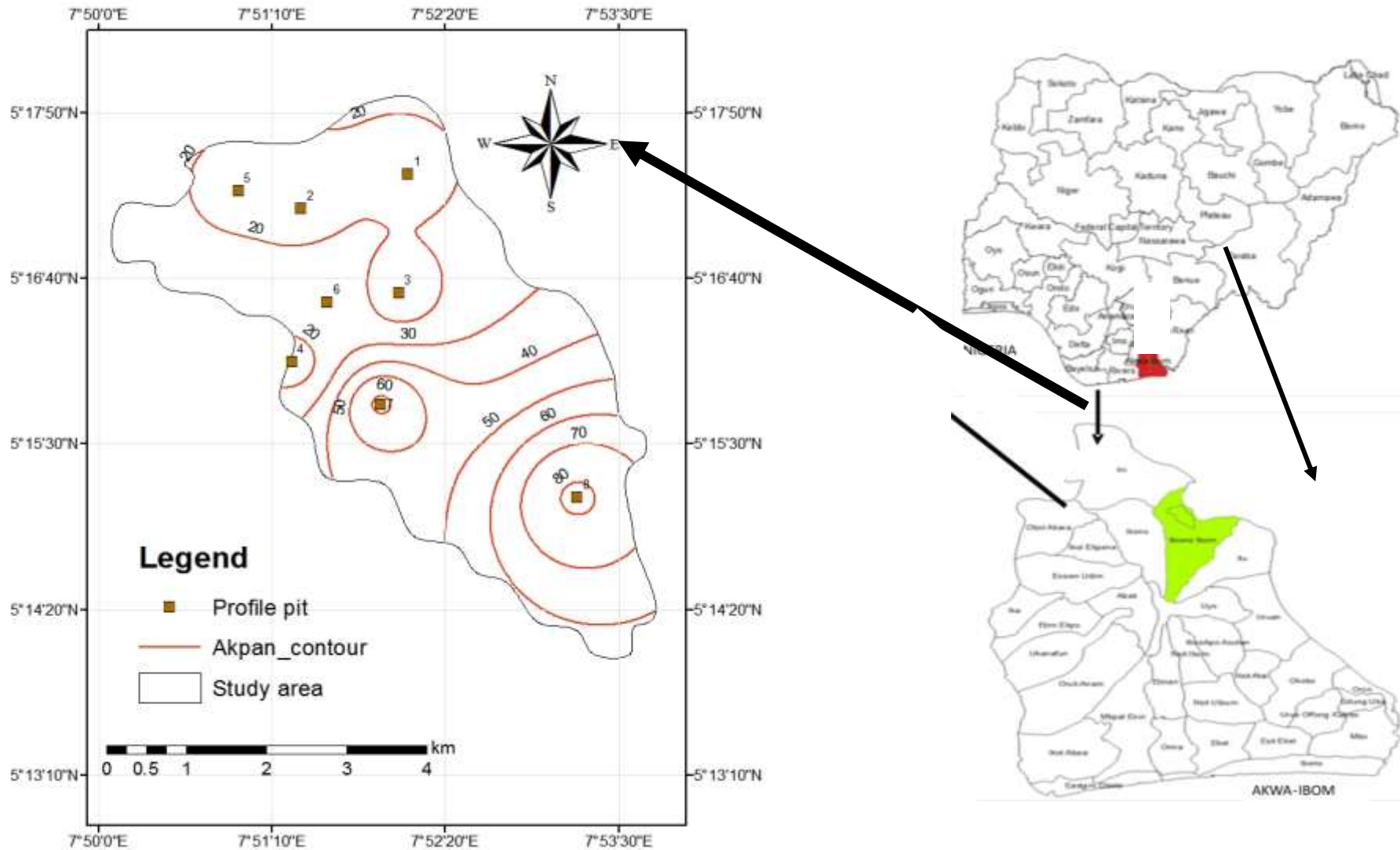


Figure 1: Topographic Map of Ikot Esidem, Ibiono Ibom L.G.A., Akwa Ibom State, Nigeria showing location of profile pits

Sampling Technique

The stratified simple random sampling technique based on topographic attributes of slope was adopted in this study. A reconnaissance survey of the study area was carried out to compliment information contained in the GIS acquired topographic map of the area. The study area was stratified on the basis of existing terrain features into flood plains, inland valleys, gentle slopes, and crests landscapes respectively. Two (2) profile pits per each landscape were dug. A hand held ground positioning system (GPS) receiver was used to determine the geographical positioning altitude and coordinates of profile pits in the various sampling locations. The different landscapes constituted the various mapping units.

Field Investigation of Soil Properties

Soil morphology was described in the field according to the guidelines for soil profile description (FAO, 2006). Core soil samples for bulk and particle density determination were collected at depth 0-25cm and 50-75cm respectively. Soil samples were also collected from each genetic horizon in all the profile pits for routine physical and chemical laboratory analysis.

Laboratory Analysis

Soil samples for laboratory analysis were air-dried, crushed and sieved through a 2mm mesh sized sieve. Particle size analysis was determined by the Boyoucos hydrometer method (Gee and Or, 2002). The bulk density was determined by the cylindrical core method. Total porosity was calculated from the values of bulk density using the relationship,

$$P = \left(1 - \frac{bd}{pd}\right) \times 100,$$

where, P= porosity, bd= Bulk Density, pd= particles density, with an assumed particle density of 2.65g/cm³,

Soil pH was determined using pH meter in a 1:2.5 soil: water suspension. Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black as described by Nelson and Sommers (1996). Available phosphorus was determined using Bray II method and estimated by the molybdenum blue colour technique (Kuo, 1996). Total nitrogen was determined using micro Kjeldahl method (Bremner, 1996). Exchangeable Acidity (H⁺ and Al³⁺) was determined by titration method from an extract

obtained using IN HCl solution. Cation exchange capacity was determined by the ammonium acetate (NH₄OAc) method. Exchangeable K and Na in the extract were determined by flame photometry while exchangeable Ca and Mg were determined by the EDTA methodology. Available micro nutrients (Fe, Zn, Mn and Cu) were extracted with IN HCl and determined by Atomic Absorption Spectrophotometry (AAS) using Association of Analytical Chemist (AOAC) 1990 methodology.

The Parametric Square Root method (khaddir, 1986) was used to calculate the land productivity index using the equation below:

$$PI = R_{\min} \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times \frac{C}{100} \times \dots}$$

Where:

PI= Productivity index (%)

R_{min}= factor with minimum rating

A, B, C etc = Ratings of different remaining factors

All the factors of the land characteristic were inserted in the square root, except the factor with the least land characteristic limitation among them. The non parametric simple limitation method was also employed.

The following percentage ratings according to Riquier *et al*, (1970) were used for these degrees of limitations.

Percentage Ratings %: 100 95 85
60 <40

Degree of Limitation: None slight moderate
severe very severe

Based on the resulting productivity index (PI), the soils in the study area were assigned productivity classes as indicated below

Class 1 = (65-100%, excellent)

Class 2 = (35-64%, good)

Class 3 = (20-34%, Average)

Class 4 = (8-19%, poor)

Class 5 = (0-7%, extremely poor)

These productivity classes 1-5 are assumed to correspond to the FAO (2006) Land suitability classes of S1 (High), S2 (Moderate), S3 (Marginal), N1 (currently not suitable), N2 (Permanently not suitable). The potentials and limitations of land qualities/characteristics in determining the suitability of the area for maize (*Zea mays*) were evaluated using FAO frame work for Land suitability Evaluation (FAO, 2006). The parametric method consists of

numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum and the minimum value (Table 4).

RESULTS AND DISCUSSION

The data on morphology, physical and chemical characteristics of soils on diverse landforms in Ikot Esidem, Ibiono Ibom L.G.A. of Akwa Ibom State, Nigeria is presented and discussed below.

Morphological Characteristics

Table 1 presents the morphological characteristics of soils in the study area. The soils of flood plain landform occur on level or nearly level (0-2 %) physiography. This soil unit occupy an area of about 10.8 ha (14.1 %) of total study area. Under moist condition these soils had brownish black (5YR 3/1) to brownish gray (5YR 5/1) surface soils over reddish gray (2.5YR 6/1) subsurface soil colours (Table 4.1). The brownish black tinge in the 'A' horizon of pedons 1 and 2 representing this landscape type was due to the presence of accumulated organic matter which is the main colouring agent of top soils and especially in flood plains (Nsor and Akamigbo, 2009). The entire pedons of flood plains soil units were also characterized with few fine faint bright brown (5YR 5/6) to common medium reddish brown (5YR 4/6) mottles. This redoximorphic feature is evident of poor drainage arising from seasonal rise in water table. This observation corroborates Akamigbo *et al.* (2002). The soils of this landscape type were also characterized by weak fine to medium granular epipedon structural aggregates over moderate to strong, medium to coarse sub-angular blocky endopedon structures. The consistence of this unit indicated soft to slightly hard top soils over hard to very had subsoil (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 very sticky-very plastic sub soils(wet) Table 1.

The soils of inland valley landform occur on nearly level to gentle slopes (2-4 %) physiography and were represented by pedons 3 and 4. This soil mapping unit is about 38.5ha (50.3 %) of total study area. The soils of this landform type had moist soil colour of grayish brown (5YR 4/2) top soils over brownish grey (5YR 5/1) sub soil colours (Table 1). The pedons of this soil unit were also mottled

throughout the entire soil depth indicating evidence of gleization. This mottling might be due to the oxidation and reduction of iron and or manganese coupled with their removal and translocation as evidence in the reddish oily water flowing on the soil surface. Similar observations were reported by Nsor *et al.* (2014) in their study on physico-chemical evaluation and site suitability of soils along River Cross. The inland valley soil unit had weak fine to medium granular top soil structural aggregates over moderate to strong, medium to coarse prismatic sub soil structures (Table 1). Essoka and Esu (2003) encountered prismatic structures in sub soils of some inland valleys in central Cross River State, Nigeria. The consistence of the inland valley soils in the study area indicated a soft to slightly hard top soil over hard to very hard sub soil (dry); very friable to friable top soil over firm to very firm sub soils (moist) and slightly sticky-slightly plastic top soil over sticky-plastic to very sticky-very plastic sub soil (wet), Table 1.

The soils of gentle slope landforms occur on gently undulating slope (4-7 %) physiography, and represented by pedons 5 and 6 occupying an area of about 21.6ha (28.2 %) of total study area. Under moist conditions the pedons of this landform type had dark reddish brown (5YR 3/2) to bright reddish brown (5YR 4/6) epipedons over reddish brown (5YR 4/8) to greyish brown (7.5YR 5/2) endopedons. The greyish brown subsoil in pedon 5 might be as a result of its shale parent material (Nsor and Ibanga, 2008). The soils had weak fine granular top soils over moderate to strong medium sub angular blocky sub soil structures. The sub soil of pedon 5 was characterized by strong medium platy structure which might be due to the influence of shale parent material (Table 1). The consistence of this soil unit revealed a loose to soft top soil over slightly hard to hard sub soil (dry); very friable to friable top soil over firm sub soils (moist) and non sticky, non plastic top soil over sticky, plastic sub soil (wet) (Table 1). The sticky-plastic sub soil is evident of argillic Bt sub soil diagnostic horizon.

The soils on crest land form in the study area had slope in the range 7-12 % referred to as being very strongly sloping. This soil unit occupy a land area of about 5.7ha (7.4 %) of total study area. The soils on this landform had moist soil colours of dark reddish brown (5YR 3/2) over bright brown (2.5YR 5/8) to orange (5YR 6/8).

These soils were also characterized by weak fine granular top soil epipedons over moderate to strong sub angular blocky structures (Table 1). The consistence indicated a soft to slightly hard top soil over hard sub soil (dry); very friable to friable top soil over firm sub soils (moist) and non-sticky-slightly plastic top soils over slightly sticky-slightly plastic to sticky-plastic sub soils (wet) (Table 1).

Table 1: Morphological Characteristics of Soils along a Toposequence at Ikot Esidem, Ibiono Ibom L.G.A, Akwa Ibom State, Nigeria

Landscape Type	Horizon Designation	Horizon Thickness (cm)	Major colour	Mottles	Texture	Structure	Dry	CONSISTENCE			Roots	Pores
								Moist	Wet			
FP	Pedon 1 (Flood plain) 5°17'24.7"N; 7°52'4.62"E Ele. 13m											
	Ap	0-16	5YR 4/1; Bg	5YR 5/6 fff, Brb	SiCL	1F granular	S	L		ss-sp	cm	cm
	Bgh ₁	16-45	5YR 5/1; Bg	5YR 5/8 Cmd, Brb	SiCL	M granular	Sh	Fr		s-p	ff	cm
	Bgh ₂	45-78	5YR 6/1; Bg	5YR 4/6 Cmd, Rb	CL	2M sbk	H	F		vs-vp	fvf	mvf
	Bgh ₃	78-122	5YR 6/1; Bg	5YR 6/8 Mmp, O	C	3C sbk	vh	Vf		vs-vp	fvf	mvf
	Pedon 2 (Flood plain) 5°17'9.13"N; 7°51'20.89"E Elev. 17m											
	Ap	0-11	5YR 3/1; Bbl		SiCl	1M granular	S	Fr		ss-sp	cf	cc
	Bgh ₁	11-29	2.5YR 5/1; Rg	2.5YR 5/6; fff, Bb	SCL	2M sbk	Sh	Fr		s-sp	fvf	ff
IV	Bgh ₂	29-54	2.5YR 6/1; Rg	2.5YR 6/6; Cff, O	CL	2M sbk	Vh	F		vs-vp	fc	fvf
	Bgh ₃	54-105	2.5YR 5/1; Rg	2.5YR 5/6; Cmd, Bb	C	3M sbk	Eh	Vf		vs-vp	fc	cf
	Pedon 3 (Inland valley) 5°16'34.96"N; 7°52'0.56"E Elev. 14m											
	Ap	0-23	5YR 4/2; Gb	5YR 4/6 fff; Brb	SiCL	1F granular	S	Fr		ss-sp	ff	mm
	Bg ₁	23-41	5YR 5/1; Bg	5YR 7/3 fmd; Drb	SiCL	1F prismatic	Sh	F		s-p	fvf	cf
	Bg ₂	41-69	5YR 5/1; Bg	5YR 5/6 ffd; Brb	CL	2M prismatic	H	Vf		s-p	fvf	mvf
	Bg ₃	69-130	5YR 5/1; Bg	5YR 5/6 fmd; Brb	CL	3M prismatic	Vh	Vf		vs-vp	fvf	mvf
	Pedons 4 (Inland valley) 5°16'4.7"N; 7°51'18.14"E Elev. 21											
GS	Ap	0-22	5YR 4/2; Gb	5YR 5/6 fff; Brb	SiL	1M granular	S	Vfr		ss-sp	cc	cm
	Bg ₁	22-47	5YR 5/1; Bg	5YR 5/8 fff; Brb	SiL	2Mprismatic	Sh	Fr		s-p	fm	cm
	Bg ₂	47-69	5YR 5/1; Bg	5YR 6/8 fmd; O	C	2M prismatic	H	F		s-vp	ff	mf
	Bg ₃	69-110	5YR 5/1; Bg	5YR 5/8 Cmd; Brb	C	3C prismatic	Vf	Vh		vs-vp	ff	mvf
	Pedon 5 (Gentle slope) 5°17'17.77"N; 7°50'56.14"E Elev. 19m											
	Ap	0-13	5YR 4/6; Brb		SL	1F granular	L	vfr		ns-np	ff	cc
	Bt	13-36	5YR 5/8; Brb		CL	2M sbk	S	Fr		ss-sp	fm	cm
	Btv ₁	36-72	5YR 4/8; Rb		SC	2M sbk	H	F		s-p	fvf	cf
CR	Btv ₂	72-125	5YR 5/2; Gb		C	3M platy	H	F		s-p	fm	mvf
	Pedon 6 (Gentle slope) 5°16'30.63"N; 7°51'31.5"E Elev. 26m											
	Ap	0-10	5YR 3/2; Drb		LS	1F granular	S	Vfr		ns-np	fm	mm
	Bt ₁	10-29	5YR 4/8; Rb		SCL	1F sbk	Sh	Fr		s-p	ff	mm
	Bt ₂	29-43	5YR 4/8; Rb		SC	1M sbk	Sh	F		s-p	fvf	cm
	Bt ₃	43-94	5YR 5/8; Brb		C	2M sbk	H	F		s-p	fvf	cf
	Pedon 7 (Crest) 5°15'47.42"N; 7°51'52.31"E Elev. 67m											
	Ap	0-10	5YR 3/2; Drb		SL	1F granular	S	Vfr		ns-np	fm	cm
CR	AB	10-41	5YR 4/4; Drb		SCL	2M sbk	Sh	Fr		ns-np	fm	cf
	Bt	41-63	5YR 4/4; Drb		SCL	3M sbk	H	F		ss-sp	ff	cm
	BC	63-95	5YR 6/3; Db		SC	2M platy	H	F		s-p	fvf	mvf
	Pedon 8 (Crest) 5°15'8.15"N; 7°53'12.44"E Elev. 81m											
	A	0-19	5YR 5/6; Brb		SL	1F granular	S	Fr		ns-np	cm	mm
	AB	19-44	5YR 6/8; O		SL	2M sbk	H	F		ss-sp	fm	mm
	BC	44-84	2.5YR 5/8; Bb		SCL	3M sbk	H	F		s-p	fvf	cf

Key:

- Colour:** Brb = Bright reddish brown, Gb = Greyish Brown, Drb = Dark reddish brown, Rb = Reddish brown, Drb = Dull reddish brown, Db = Dull brown, O = Orange,
- Bb = Bright brown, Bg = Brownish gray, Bbl = Brownish black, Rg = Reddish grey
- Mottles:** fff = few fine faint, cmd = common medium distinct, mmp = many medium prominent, cff = common fine faint, mmd = many medium distinct, mcp = many coarse prominent, ffd = few fine distinct, fmd = few medium distinct
- Structure:** 1 = weak, 2 = moderate, 3 = strong, sbk = sub angular blocky, f = fine, m = medium, c = coarse
- Texture:** SiCL = Silt clay loam, CL = Clay loam, C = Clay, SL = Sandy loam, LS = Loamy sand, SCL = Sandy clay loam, SC = Sandy clay, SiL = Silt loam
- Consistence:** s = Soft, sh = slightly hard, h = hard, vh = very hard, eh = extremely hard, fr = friable, f = firm, vf = very firm, vfr = very friable, l = loose, ss = slightly sticky, sp = slightly plastic, s = sticky, vs = very sticky, vp = very plastic, p = plastic, np = non plastic, ns = non-sticky.
- Pores/Roots:** ff = few fine, cc = common coarse, fm = few medium, cm = common medium, fvf = few very fine, cf = common fine, mvf = many very fine, mm = many medium, fc = few coarse, mf = many fine
- Landscape Type:** FP = Flood plain, IV = Inland valley, GS = Gentle slope, CR = Crest

Physical Characteristics

Table 2 presents the physical characteristics of soils in the study area. The particle size distribution data showed that sand (30-78 %) dominated pedons of gentle slopes and crest landforms and this decreased with depth (Table 2). Silt (25-55 %) and clay (19-51 %) separates dominated the pedons of flood plains and inland valley landforms. Clay content generally increased with soil depth indicating evidence of argillic (Bt) sub soil horizons especially in gentle slope and crest landscapes. There was no definite sequence in the distribution of silt within the pedons studied. The silt:clay ratios were generally low to moderate (0.18-2.89 %) for all the pedons studied. The silt:clay ratio was used by Van Wambeke (1962) to differentiate old from young parent materials, and when this ratio was applied here, it could be seen that the gentle slope and crest pedons with lower ratios are in an advanced stage of development while flood plain and inland valley pedons are in their juvenile or immature stages (Abate *et al.*, 2014). From the data on Table 2 regarding the irregular distribution of silt contents especially in flood plains and inland valleys, it could be concluded that the soils here are actively and continuously receiving substantial amounts of erosional sediments from adjoining high elevation landforms. The soils of flood plain landforms were generally characterized by silty loam top soils over clay loam to clay sub soils. The inland valley soils had silty loam top soils over clay loam to clay sub soils. The soils of gentle slopes had sandy loam to loamy sand top soils over sandy clay to clayey sub soils. The soils on crest landforms were characterized with sandy loam top soils over sandy clay loam sub soil pedons (Table 2). This confirms the existence of both clay migration and translocation in pedons.

Mean bulk density values of 1.07g/cm^3 for top soils over 1.48g/cm^3 sub soils were obtained for soils of flood plains, 1.20g/cm^3 over 1.45g/cm^3 for soils of inland valleys, 1.52g/cm^3 over 1.56g/cm^3 for soils of crest landscapes. The bulk density values in the range ($1.01\text{-}1.60\text{g/cm}^3$) encountered in the study area are ideal for agronomic activities due to absence of excessively high bulk densities as soils with bulk densities less than 1.65g/cm^3 do not impede root penetration and development (Asadu *et al.*, 1990). The porosity values (34.0 - 61.9 %) in the study area were directly proportional to percentage sand content and inversely proportional to clay contents. Porosity in the soils of flood plains and inland valley decreased with soil depth with top soils being more porous than sub soils. This explains why soils of flood plains and inland valley landforms are water logged.

Soil erodibility index values were generally in the range 0.96 - 2.33 with top soils having higher values than the sub soils (Table 2). This reflects the vulnerability of top soils to erosive forces of rainfall and wind than the sub soils.

Table 2: Physical characteristics of Soils in the Study Area

Landscape Type	Horizon designation	Depth (cm)	Sand %	Silt %	Clay %	Silt: clay ratio	Textural class	Density bulk g/cm ³	Porosity	Soil erodibility index
FP	Ap	0-16	23	48	29	1.85	SiCL	1.01	61.9	2.45
	Bgh ₁	16-45	19	46	35	1.31	SiCL			1.86
	Bgh ₂	45-78	35	32	33	0.97	CL	1.50	43.4	2.03
	Bgh ₃	78-122	25	25	50	0.50	C			1.00
	Ap	0-11	25	42	33	1.27	SiCL	1.12	57.7	2.03
	Bgh ₁	11-29	22	42	36	1.17	CL			1.78
	Bgh ₂	29-54	35	25	40	0.63	CL	1.45	45.3	1.50
	Bgh ₃	54-105	25	30	45	0.67	C			1.22
	Ap	0-23	26	55	19	2.89	SiL	1.17	55.8	4.26
IV	Bg ₁	23-41	22	49	29	1.69	SiCL			2.45
	Bg ₂	41-69	29	36	35	1.03	CL	1.54	41.9	1.78
	Bg ₃	69-130	28	36	36	1.00	CL			1.78
	Ap	0-22	29	25	46	0.54	SiL	1.22	54.0	1.17
	Bg ₁	22-47	25	45	30	1.50	SiL			2.33
	Bg ₂	47-64	20	40	40	1.00	C	1.35	49.1	1.50
	Bg ₃	64-110	20	38	42	0.90	C			1.38
	Ap	0-13	70	16	14	1.14	SL	1.39	47.5	6.14
	Bt	13-36	49	21	30	0.70	CL			2.33
GS	Btv ₁	36-72	47	8	45	0.18	SC	1.45	45.3	1.22
	Btv ₂	72-125	30	19	51	0.37	C			0.96
	Ap	0-10	78	10	12	0.83	LS	1.64	38.1	7.33
	Bt ₁	10-29	62	11	27	0.41	SCL			2.70
	Bt ₂	29-43	49	15	36	0.42	SC	1.67	37.0	1.78
	Bt ₃	43-94	31	24	45	0.53	C			1.22
	Ap	0-10	65	16	19	0.84	SL	1.29	51.3	4.26
	AB	10-41	63	14	23	0.61	SCL			3.34
	Bt	41-63	49	17	34	0.50	SCL	1.50	43.4	1.94
CR	BC	63-95	48	15	37	0.41	SC			1.70
	A	0-19	75	9	16	0.56	SL	1.47	44.5	5.25
	AB	19-44	69	13	18	0.72	SL			4.56
	BC	44-84	65	13	22	0.59	SCL	1.75	34.0	3.55

Key: FP = Flood plain, IV = Inland valley, GS = Gentle slope, CR = Crest

Chemical Characteristics

The soils of flood plain landforms were moderately acid (pH 5.0-5.7) in reaction. This might be due to its alluvial origin which according to Brady and Weil (2008) results in soils high in organic matter which acts as a buffering agent in soils. The moderate acidity implies that essential nutrients are likely to be available for crop uptake. Odunze (2006) asserted that the pH range of 5.5-6.5 is optimum for the release of plant nutrients. Organic carbon in the flood plain soils was medium to high (6.30-20.50g/kg). High organic carbon content in the poorly drained soils of flood plain landform may be attributed to water logging condition which causes a relative accumulation of organic matter due to reduced microbial activities, less frequent and less severe translocation of mineralized products at the start of the rains.

Nsor and Akamigbo (2009) also reported high organic matter content for flood plain soils of Central Cross River State, Nigeria. Organic matter content is the most important property in sustainable soil productivity. The mean total nitrogen values of this landscape type were 3.75g/kg (Table 3) and was considered high. The high total nitrogen value of this soil unit might be due to high organic matter deposition and little or no leaching losses attributable to the clayey nature of the soils. Idoga *et al.* (2005) also reported high total nitrogen values for soils of Aliade plains of Benue State, high in clay content.

Available phosphorus in the flood plains landscapes in the study area was in the range 5.20-11.20 mg/kg, considered low to medium. Phosphorus is the second most critical element influencing plant growth and crop production. Phosphorus level in this soil unit is ideal especially for heavy P feeders such as maize.

Amongst the exchangeable cations calcium was medium (1.20-3.20cmol/kg), magnesium was high (0.67-2.40cmol/kg), potassium medium (0.14-0.30cmol/kg) and sodium was medium (0.16-0.37cmol/kg), Table 2. The medium to high levels of exchangeable cations of this landform type might be attributed to its alluvium origin which seasonally enriches these soils with organic debris and erosional sediments. Ahukaemere *et al.* (2016) also reported high exchangeable cations except sodium in rice producing soils of Abia State in South Eastern Nigeria on similar landscape. The cation exchange capacity (CEC) in the flood plains by NH_4OAc was low to medium (3.50-7.90 cmol/kg). This value falls within the range of medium fertility according to FMANR (1990). The analysis of micronutrients for flood plains landscape type in the study area indicated adequate levels of manganese (0.67-4.20 mg/kg), zinc (1.32-2.40 mg/kg) and iron (1.52-7.50 mg/kg). However, the flood plains had marginal level of copper (0.32-2.95 mg/kg). Generally, these micro nutrient levels are ideal for maize cultivation in the study area.

Table 3: Chemical Characteristics of Soils in the Study Area

Landform Type	Horizon Designation	Horizon Depth (cm)	pH (H ₂ O)	OC	TN	Avail. P	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	CEC	Al ³⁺	H ⁺	BS	Fe	Zn	Cu	Mn
				← g kg ⁻¹ →		mg kg ⁻¹	←			cmolk g ⁻¹			→	%	←	mg kg ⁻¹	→	
FP	Ap	0-16	5.70	20.50	4.60	11.30	0.24	0.16	2.00	1.20	7.90	0.95	0.25	81.00	7.50	1.75	1.75	3.89
	Bgh ₁	16-45	5.60	17.00	4.30	9.40	0.18	0.20	2.80	1.20	6.20	1.20	0.40	90.00	6.30	1.39	2.12	3.95
	Bgh ₂	45-78	5.50	14.10	3.60	7.50	0.26	0.15	2.00	1.20	5.90	0.85	0.20	85.00	5.40	2.11	2.85	4.10
	Bgh ₃	78-122	5.40	8.80	1.50	4.10	0.26	0.18	3.20	1.60	5.50	0.60	0.30	89.00	4.80	1.32	2.95	4.20
	Ap	0-11	5.60	18.00	6.50	10.30	0.35	0.20	2.50	1.08	7.00	0.48	1.22	61.00	3.59	2.35	0.78	1.99
	Bgh ₁	11 – 29	5.40	16.50	4.30	10.10	0.37	0.30	1.20	0.67	3.50	0.50	1.00	74.00	4.44	2.40	0.91	1.81
	Bgh ₂	29-54	5.20	9.40	3.00	8.50	0.24	0.23	2.50	1.60	5.50	0.38	0.93	84.00	3.96	2.08	0.53	0.86
	Bgh ₃	54-105	5.00	6.30	2.00	5.20	0.16	0.14	3.00	2.40	6.30	0.20	0.79	80.00	1.52	2.41	0.32	0.67
	Ap	0-23	3.60	15.60	5.30	9.10	0.23	0.13	1.40	1.60	5.10	1.00	1.90	65.90	15.00	1.80	2.82	2.70
	Bg ₁	23-41	3.80	14.10	4.60	6.20	0.27	0.18	1.80	2.00	6.20	0.97	1.48	68.50	14.20	1.36	2.14	4.90
IV	Bg ₂	41-69	4.00	9.30	0.70	7.70	0.21	0.12	2.20	1.60	5.80	0.40	0.70	71.20	12.10	1.07	3.19	5.30
	Bg ₃	69-130	4.30	6.30	0.60	5.60	0.33	0.28	1.40	1.60	6.10	0.30	0.80	59.20	10.00	1.12	4.20	4.60
	Ap	0-22	3.50	15.20	6.40	11.50	0.17	0.14	1.70	1.90	7.00	0.88	1.00	55.90	13.20	2.00	2.74	2.60
	Bg ₁	22-47	3.70	13.30	4.10	8.50	0.18	0.38	1.00	1.30	7.20	0.87	1.28	39.70	12.10	1.78	2.41	3.90
	Bg ₂	47-64	4.20	9.00	0.90	9.80	0.09	0.26	1.00	2.60	10.00	0.50	1.00	39.50	11.60	1.25	3.95	5.30
	Bg ₃	64-110	4.60	5.10	0.40	9.00	0.13	0.18	1.40	1.20	6.40	0.80	2.20	46.00	10.60	1.22	1.60	3.60
	Ap	0-13	4.70	11.30	1.00	4.60	0.06	0.37	2.80	1.70	14.30	0.40	2.75	34.10	1.50	2.60	1.15	3.30
GS	Bt	13-36	4.60	6.60	1.00	4.20	0.06	0.36	2.20	1.40	13.60	0.33	2.60	29.10	1.30	1.50	1.10	2.90
	Btv ₁	36-72	5.00	4.20	0.60	4.00	0.06	0.30	2.80	1.50	16.10	0.81	1.95	28.90	1.40	2.20	1.00	5.70
	Btv ₂	72-125	5.10	4.00	0.40	3.20	0.10	0.22	3.10	2.30	16.80	0.77	1.80	34.00	1.50	2.50	1.00	3.50
	Ap	0-10	4.90	10.00	0.70	6.20	0.07	0.35	2.50	1.10	12.50	0.90	2.00	32.20	1.60	3.00	1.11	2.60
	Bt ₁	10-29	5.00	5.30	0.50	5.50	0.05	0.24	2.00	3.20	15.80	0.65	2.45	34.70	1.70	2.20	1.00	2.60
	Bt ₂	29-43	5.10	4.20	0.30	5.20	0.06	0.28	3.30	2.40	17.40	0.44	2.50	34.70	1.30	2.30	0.66	2.10
	Bt ₃	43-94	5.00	4.30	0.20	4.30	0.11	0.31	3.30	2.70	18.70	0.30	2.70	34.30	1.00	1.40	0.70	1.10
	Ap	0-10	4.30	5.30	0.40	5.10	0.05	0.90	1.50	0.11	7.50	0.75	2.25	34.10	0.80	1.10	0.90	1.00
CR	AB	10-41	4.40	4.20	0.20	3.20	0.05	0.11	1.20	0.15	5.60	0.35	2.00	27.00	1.10	0.70	0.80	0.60
	Bt	41-63	4.60	4.30	0.30	3.10	0.10	0.14	1.30	0.16	7.00	0.30	2.15	24.30	1.00	0.80	0.40	0.60
	BC	63-95	4.60	4.80	0.10	4.00	0.10	0.13	1.40	0.20	7.50	0.25	2.30	24.10	1.00	0.50	0.50	0.40
	A	0-19	4.10	4.40	0.30	4.40	0.10	1.00	1.60	0.10	8.60	0.66	2.23	32.50	0.50	1.30	1.20	1.20
	AB	19-44	4.00	4.10	0.10	4.10	0.11	0.70	1.40	0.09	8.80	0.55	2.10	26.10	0.60	1.30	0.80	1.10
	BC	44-84	4.50	4.20	0.20	4.20	0.15	0.50	1.20	0.06	9.30	0.45	2.30	20.50	0.60	1.00	0.90	0.60

The soils of inland valley landscapes in the study area had moderate acidity (pH 5.1-5.5). This might be due to seasonal enrichments from surrounding uplands of erosion sediments and organic matter. Higher pH in the top soil of this unit may also be attributed to the influence of organic matter through biogenetic cycling of bases and capillary rise in water within the basin. This process according to Mohammad (2011) reduces acidification of soils. Organic carbon for inland valley landscape was medium (5.10-15.60g/kg), Table 3. The high organic carbon of this soil unit might be due to increase deposition and mineralization of organic debris. This agrees with the findings of Nsor *et al.*, (2014) who stated that wetland soils usually had high organic carbon due to water logging, a condition impeding rapid mineralization of organic matter. Total nitrogen values were medium to high (0.40-6.40g/kg). This medium to high level of nitrogen may be due to high organic matter content and low leaching losses due to its clayey soil textures which beads the organic matter particles on the exchange sites. Available phosphorus level (6.20-11.50mg/kg) in the inland valley landform was considered low to medium. Akamigbo *et al* (2002) also reported low to medium levels of total nitrogen and available phosphorus in some fadama soils of Bauchi State, Nigeria. Amongst the exchangeable cations, low to medium levels of calcium (1.00-2.20cmol/kg), and magnesium (1.20-2.60 cmol/kg) were observed. Potassium (0.13-0.38 cmol/kg) was medium to high (Table 3). The cation exchange capacity for the inland valley landscape was in the range 5.10-10.00cmol/kg and was rated medium. The implication here is that these inland soils have moderate nutrient holding and supplying capacity. These values are comparable to values obtained by Nsor *et al.* (2014) for some selected inland valley soils of Central Cross River State. The analysis of available micro nutrient indicated toxic levels of iron (10.00-15.00 mg/kg), and adequate levels of zinc (1.07-2.00 mg/kg), Cu (1.60-4.20 mg/kg) and Mn (2.60-5.30 mg/kg), Table 3. These values of micro nutrients except iron are ideal for agronomic activities (McKenzie, 1992).

The soils of gentle slope landscape were strongly acid (pH 4.60-5.10) in reaction (Table 3). This might be due to intense leaching of basic

cations enabled by the coarse textured nature of these soils and high rainfall experienced in this area. Low organic carbon (4.0-11.30 g/kg) was observed in soils of the gentle slopes. The low organic carbon values in this soil unit might be due to low organic debris deposition, high temperatures rainfall and relative humidity (Usoro and Akpan, 2010), which favours its rapid mineralization and loss. Soil organic matter has been reported to have significant positive influence on the CEC, base saturation, structure, pH, buffering capacity, soil colour and water holding capacity of soils (Afu *et al.*, 2016, and Nsor *et al.*, 2014). The soils on gentle slopes had low total nitrogen (0.20-1.00 g/kg) values. The low nitrogen level is however suggestive of high nitrogen losses as a result of leaching of nitrates as well as crop removal. It was also associated with rapid mineralization of organic matter under an iso-hyperthermic soil temperature regime and an udic soil moisture regime. Available phosphorus values (4.00-6.20 mg/kg) were generally low in this landform type. This reflects the generally low phosphates reserves of many Nigerian soils, resulting partly from the low content of phosphate in sandstone and shale parent rocks of these soils (Best, 1982), but complicated by high phosphate fixing capacity of the soils (Aluko *et al.*, 2016). Amongst the exchangeable cations, calcium (2.20-3.30 cmol/kg), magnesium (1.10-3.20 cmol/kg) and potassium (0.22-0.37 cmol/kg) were low to medium. The low to medium levels of exchangeable bases in the soils of gentle slope landscape in the study area may be due to leaching and the dominance of shale over sandstone parent material (Best, 1982), good crop residue management, and gentle slope terrain characteristics which allows appreciable accumulation and mineralization of organic matter. Cation exchange capacity in this soil unit was high (12.50-18.70 cmol/kg), implying that the soils had a good nutrient reserve capacity. Available data on micro nutrients indicated adequate levels of Fe (1.00-1.70 mg/kg). Zn (1.40-3.00mg/kg) and Mn (1.10-5.70mg/kg). Copper (0.66-1.15 mg/kg) was deficient in this soil unit.

The soils of crest landscapes in the study area were strongly acid (pH 4.0-4.60). This might be due to rapid removal of organic matter by

erosion accelerated by its steep slope (7-12%) factor as well as enhanced leaching losses of basic cation due to intense rainfall in the study area. This observation corroborates Nsor and Adesemuyi (2016) who also encountered strong acid conditions in crest topographic positions in their characterization of a toposequence at Ishiagu, Eastern Nigeria. Organic carbon in the crest landform type in the study area was low (4.10-5.30 g/kg), Table 3. The low level of organic carbon could be attributed to rapid top soil removal which prevents build-up of organic matter due to slope factor (Sharu *et al.*, 2013). Total nitrogen content was also rated low (0.10-0.40 g/kg). Available phosphorus content of the crest landform type was generally low (3.10-5.10 mg/kg), Table 3. This reflects the generally low phosphorus reserves of most Nigeria soils, resulting partly from the sandstone parent rocks poor in phosphates (Best, 1982) and also from low organic matter content of this landform type (Sharu *et al.*, 2013).

Amongst the exchangeable cations, calcium (1.20-1.60 cmol/kg) and magnesium (0.06-0.20 cmol/kg) were low. Exchangeable potassium was low to medium (1.00-0.90 cmol/kg). Cation exchange capacity values by NH_4OAc method were low to medium (5.60-9.30 cmol/kg), Table 3. The low organic matter in the crest landform may have influenced and contributed to the low to medium CEC in this soil unit. Afu *et al.*, (2016) also observed that organic matter had a greater effect on CEC than clay colloids, in tropical soils. The study indicated deficient to marginal levels of Fe (0.50-1.10 mg/kg), Zn (0.50-1.30 mg/kg), Cu (0.40-1.20 mg/kg) and Mn (0.60-1.20 mg/kg), in this landform type.

Classification of Soils in the Study Area

The soils in the study area were classified according to the USDA soil taxonomy and correlated to the FAO/UNESCO Legend. The soils of floodplains had high base saturation, histic epipedons and a cambic sub surface diagnostic horizons. The flood plain soils were thus placed under the Inceptisol soil order. Their Aquic soil moisture regime placed them as Aquepts at the sub order level. At the great group level, they were classified as Humaquepts due to their high organic carbon content. Their

possessions of histic epipedons qualify placing them as Histic Humaquepts at the sub-group level. The FAO/UNESCO equivalent is humic cambisols

The inland valley soils were characterized by high base saturation greater than 50 % by NH_4OAc method, mollic epipedon and cambic sub surface diagnostic horizons. These properties qualify the placement of the inland valley soil unit in the study area under the Inceptisol soil order. Their aquic moisture regime placed them as Aquepts at the sub order level. At the great group level, these soils were classified as Epiaquepts due to episaturation (prolonged water logging) of this soil unit. The existence of numerous cracks wider than 5mm within 120cm of soil depth, that are 30cm or more deep for some part of the year, qualify placing the inland valley soils as Vertic Epiaquepts at sub group level. The FAO/UNESCO equivalent is Vertic cambisols.

The soils of the gentle slopes had base saturation of less than 35 % by NH_4OAc method and possessed kandic and argillic (Bt) sub surface diagnostic horizons with plinthites in their sub soils, hence they were placed under the Ultisol soil order (Soil Survey Staff, 2014). Their occurrences under Udic soil moisture regime qualify them as Udults at the sub order level. At the great group level, the soils of gentle slope pedons were classified Kandiodults due to their possession of kandic sub surface diagnostic horizons (regular decrease in organic carbon with increasing soil depth). Occurrence of plinthites in their sub soil horizons qualified the placement of these soils as Plinthic Kandiodults at the sub group level. The FAO/UNESCO equivalent of Plinthic Kandiodults is plinthic Acrisols.

The soils at the crest landform also had medium to high base saturation, greater than 35 % by Ammonium acetate (NH_4OAc) method and possessed kandic and argillic (Bt) sub surface diagnostic horizons. These soils were thus placed under the Alfisol soil order. Their Udic moisture regime qualifies them as Udults at the sub order level. The soils were further classified Kandiodults at the great group level and as Arenic Kandiodults due to their coarse textured nature. The FAO/UNESCO equivalent of Arenic Kandiodults is Albic Arenosols

Suitability Evaluation of Soils in the Study Area for Maize (*Zea mays*)

The suitability evaluation of soils in the study area was obtained by matching the land characteristics studied with agronomic requirements of three varieties of maize. This was achieved by using the guidelines suggested by FAO (1976); Khiddir, (1986) and Sys *et al.* (1990) for land evaluation and ideal agronomic requirements for maize (Iken and Amusa, 2004). The suitability evaluation methods used were the non-parametric (Simple Limitation Method) and a parametric (Square root method).

The results indicate that climatic elements (rainfall and temperature) of the study area were highly suitable (S1) for maize cultivation and were both scored 95 %. In terms of drainage, the flood plains and inland valley soils were rated marginal and scored 60 %. The gentle slopes and crest were rated moderately (85 %) and highly (95 %) suitable for maize. This was in line with the findings of IITA (2001) who postulated that maize performs better in well drained soils. Slope was rated highly suitable (S1) for flood plains and inland valleys, moderately suitable (S2) for gentle slopes and marginal for the crest locations, (Table 5). Soil textures in the entire study area were rated highly to moderately suitable for maize production. Effective soil depths were marginally (60 %) at the flood plains and inland valleys and moderate (85 %) at the gentle slopes and crest landforms.

The medium to high organic carbon contents of the flood plains, inland valleys and gentle slopes were rated moderately to highly suitable (85-95 %) whereas its low content at the crest landform was rated marginally suitable (60 %) for maize cultivation in the study area. Available phosphorus, an important nutrient element required by maize for fruiting (IITA, 2001), was rated moderately suitable (85 %) at the flood plains and inland valleys but rated marginal (60 %) at the gentle slope and crest landforms in the study area.

Cation exchange capacity and base saturation were both rated moderately suitable (85 %) and highly suitable (95%) respectively in all landform types in the study area for maize cultivation.

Aggregate suitability evaluation by limitation method indicates that the entire soils in the study area were marginally suitable (S3) for maize production. The suitability evaluation for maize by square root were the same as that obtained using limitation method for all landscape types except for the crest that indicated currently not suitable (N1) for maize production (Figure 2).

Table 4: Land Quality Rating for Sustainable Maize (*Zea Mays*) Production

Land Qualities Group	Land Characteristics	Unit	S1 95% (1)	S2 85%(2)	S3 60%(3)	NI 40% (4)
Water Avail	M.A. Rainfall	mm	2500-1800	1800-1100	1100-500	<500
Temperature Regime	M.A.T	°C	35-18	18-16	16-14	<14
Wetness (w) Oxygen Availability	Soil Drainage		WD	Imp.dr.	PD	VPD
Fertility F						
Nutrient	Org.C (0-15cm)	(g/kg)	12-7	7-5	5-2	<2
Availability	Available P	mg/kg	>25	6-25	<6	Any
	pH		5.5-7.5	5.0-5.5	4.0-5.0	<4.0
Nutrient Retention	CEC	cmol/kg	24-16	16-3	>3	<3
Soil physical characteristics (S)	B.S	%	>35	35-20	20-15	<15
Water Retention	Top Soil		SiL,	SiCL		
	Texture		L,SCL,CL	LS,SL	C	S
	Soil					
Rooting Condition	Depth	cm	>75	>50	>20	<20
Salinity	E.C	mscm ⁻¹	0-4	4-6	6-8	>8
Topography (t)	Slope	%	0-4	4-8	8-16	>16

Sys *et al.*, 1991; Mongkolsawat, *et al.*, 1999

Table 5: Suitability Class Scores of the Study Area for Maize (*Zea mays*)

Land qualities/characteristics	Flood plains	Inland valleys	Gentle slope	Crest
Climate (c):				
Annual rainfall	95 (S1)	95 (S1)	95 (S1)	95 (S1)
Average Temperature	95 (S1)	95 (S1)	95 (S1)	95 (S1)
Wetness (w):				
Drainage	60 (S3)	60 (S3)	85 (S2)	95 (S1)
Topography (t):				
Slope	95 (S1)	95 (S1)	85 (S2)	60 (S3)
Soil Characteristics (s):				
Soil texture/structure	95 (S1)	95 (S1)	85 (S2)	85 (S2)
Soil Depth	60 (S3)	60 (S3)	85 (S2)	85 (S2)
pH	85 (S2)	85 (S2)	60 (S3)	60 (S3)
Total nitrogen	85 (S2)	85 (S2)	60 (S3)	60 (S3)
Organic carbon	95 (S1)	95 (S1)	85 (S2)	60 (S3)
Available P	85 (S2)	85 (S2)	60 (S3)	60 (S3)
CEC (soil)	85 (S2)	85 (S2)	85 (S2)	85 (S2)
Base saturation	95 (S2)	95 (S2)	95 (S2)	95 (S2)
Aggregate suitability by limitation	S3	S3	S3	S3
Productivity index by square root method	28.8	28.8	20.5	15.3
Rating	S3	S3	S3	N1

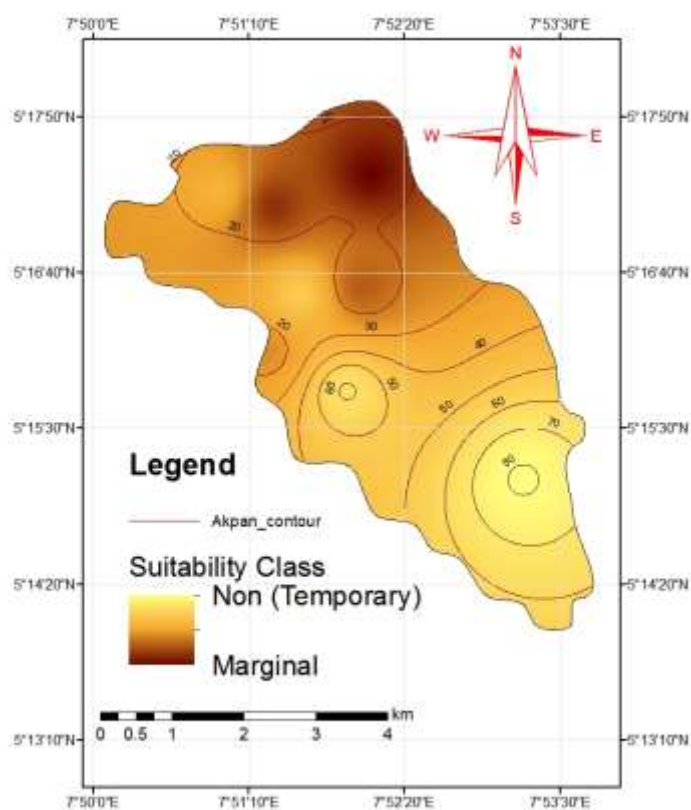


Figure 2: Suitability Map of the Study Area for Maize (*Zea mays*)

Fertility Capability Classification of Soils in the Study Area

Fertility capability classification (FCC) of soils in the study area was done to further interpret the soil taxonomy and provide additional evaluation of the soils under study as modified by landforms directly relevant to crop

cultivation especially maize. Consequently the FCC of Ikot Esidem in Ibiono Ibom L.G.A., South Southern Nigeria essentially assessed the capability of soils of diverse landforms for the cultivation of maize. The fertility capability classification (FCC) for the soils in the study area is presented in Table 6 and 7.

Table 6: Checklist Showing Type, Substrata Type and Modifiers for Soils in the Study Area

Landform Type	Type	Substrata Type	Modifiers									Aggregate FCC
			g	g ⁺	v	k	i	e	d	h	i ⁺	
Flood plains	L	C	+	+	+	-	-	-	-	-	-	LCgg ⁺ v
Inland valleys	L	C	+	+	+	-	-	-	-	-	+	LCgg ⁺ vi ⁺
Gentle slopes	S	C	-	-	-	-	+	-	+	+	-	SCidh
Crest	S	C	-	-	-	-	+	-	+	+	-	SCidh

Key: S = Loamy sands and sands, L = < 35% clay but not loamy sands or sands, C = > 35% clay, g = gleying, mottles, saturated with water for > 60 days in most years, d = dry udic environment, e = low CEC of plough layer h = acidic, pH in H₂O between 4 and 5, i = (Fe-P fixation) or low P, k = K-deficiency, exch. K < 0.2 cmolkg⁻¹ v = vertic properties, g⁺ = prolonged water logging, i⁺ = iron toxicity

Table 7: Fertility Capability Classification of Diverse Landform Types in Ikot Esidem, Ibiono Ibom L.G.A., Akwa Ibom State, Nigeria

Landform Type	Aggregate FCC	Approximate Land Area (% of Total Study Area)	Description
Flood plains	LCgg ⁺ v	10.8ha (14.1 %)	Loamy (silty clay loam top soils having > 35% clay sub soils, prolonged water logging with mottled sub soils (aquic moisture regime), showing slight vertic properties.
Inland valleys	LCgg ⁺ vi ⁺	38.5ha (50.3 %)	Loamy (silty loam) top soils having >35% clay sub soils, prolonged water logging with mottled sub soils (aquic moisture regime), showing vertic properties with potentials of iron toxicity.
Gentle slopes	SCidh	21.6ha (28.2 %)	Sandy (loamy sands to sandy loams) top soils with clay (>35% clay) sub soils. They have fertility challenges of low available P, high acidity (pH between 4 and 5) and udic dry environment.
Crest	SCidh	5.7ha (7.4 %)	Sandy (sandy loam) top soils having >35% clay sub soils. They have fertility problems of low Avail. P, strong acidity and dry udic environments.

The soils of flood plains in the study area covering an area of about 10.8 ha representing 14.1 % of the study area belong to loamy (L) type and clay (C) substrata type. Soils of this landform unit were associated with modifiers g, g+ and v, indicating challenges of prolonged water logging or poor drainage and vertic properties. Furthermore maize an aerobic crop can be grown under good water control or drainage management in this landform type.

The soils of inland valleys covering an area of about 38.5 ha, representing 50.3 % of the study area belonged to loamy (L) type top soils and clay (C) sub strata type. Its modifiers were g, g+, v and i+, indicating that the soils were constraint with prolonged water logging (poor drainage), vertic soil properties and potential iron toxicity. However, the iron toxicity of inland valley soils can be ameliorated through periodic aeration (drainage). Maize can also be cultivated here under good drainage practice.

The soils of gentle slopes landform of about 21.6 ha representing 28.2 % of the study area belonged to the sandy (S) type and clay (C) substrata type. These soils were associated with modifiers I, d and h, indicating fertility problems of low available phosphorus, dry udic environment and high acidity (low pH). The soils of this land form type are marginally suitable for maize cultivation. These soils require good management practices for enhanced productivities. Such practices should include manuring, fertilization with NPK 10:20:20, irrigation and liming.

The soils of crest landforms unit covering and estimated area of about 5.7 ha (7.4 % of the study area), belonged to sandy (S) type top soils and clay (C) sub-strata type. Its modifiers are i, d and h, just like the gentle slopes and have similar characteristics except slope gradient and high risk of erosion. This unit is marginally adapted for maize cultivation under efficient soil management practices including erosion control.

SUMMARY AND CONCLUSION

Most soils under agricultural land use are at great risk of misuse and subsequent degradation due to increasing demand and population pressure. This essentially hinders sustained national development. Consequently, for the potentials of agricultural land to be maximized for the production of food and fibre,

there is need to have an understanding and a balanced view of the most suitable options the land can be profitably utilized.

Soil characterization and evaluation guarantees sustained productive capacity of soils. However, it must be noted that over time, the continuous use of a previously evaluated soil for an ideal utilization declines. Consequently, the soils in Ikot Esidem, Ibiono Ibom L.G.A of Akwa Ibom would require continuous periodic evaluation and management for sustainable production of maize. Land suitability evaluation should be a basis for site selection to expand maize production in the study area.

RECOMMENDATIONS

Based on soils information obtained in this study, the following soil management approaches are recommended for soils in the study area.

- The flood plain sand inland valley soils having wetness as its major limitation can be improved for production of maize through efficient water table control and management. This measure would include efficient drainage mechanism to enhance the production of maize.
- The application of organic (poultry droppings, pig waste, compost etc) and inorganic fertilizers (NPK 15:15:15, single super phosphate etc) are recommended for soils on gentle slopes and crest landforms as these would add adequate nutrients to the soil thereby boasting the yield of maize in the study area.
- Application of organic manure and making of raised (high) mounds and ridges in soils of flood plains and inland valleys would help lighten heavy (clay) soils and improved drainage. This will favour the cultivation of maize in the wet land soils of the study area.
- Agronomic measures such as establishment of vetiver grass hedges, construction of ridges across the slope and zero tillage would help ameliorate erosion hazard in the highly erodible soils of crest landforms.

- The practice of leguminous intercropping could be used to beef up the nutrient status of soils in the study area.
- The application of lime based on periodic soil test is also recommended to enhance the availability of essential nutrients to crops, especially maize in the study area.

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