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Land evaluation, characterization and classification of soil for the proposed oil palm plantation in Ekpri Ibami, Akamkpa Local Government Area, Nigeria.

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Abstract— *Land evaluation, characterization and classification of soil for the proposed oil palm plantation in Ekpri Ibami, Akamkpa Local Government Area, Nigeria was conducted on 50 ha of land using a combination of both conventional and digital survey methods. The objective of the research was to characterize, classify and evaluate the land for the proposed oil palm production. Three soil mapping units were identified (EKP I, EKP II and EKP III) and representative profile pits were dug in each mapping unit. Samples were collected from each pedogenic horizon. Soils morphological, physical and chemical properties were determined using appropriate methods. Results revealed that soils of all of the mapping are characterized by dark greyish brown colour with thin topsoil while yellowish red to strong brown mottles were observed at the subsoil. The soils are coarsed-textured with high sand, low silt, and clay fractions. The soils were strong to moderately acidic (4.8 to 5.3). The soils also have low inherent of natural fertility with low organic carbon content, total nitrogen, and moderately available phosphorus. Low effective cation exchange capacity and high base saturation which may have occurred in available forms in solutions in spite of the low cation reserves in the soil. The individual mapping units were classified as Arenic Eutrudept, Typic Hapludult and Aquic Paleudults for EKP I, EKP II and EKP III respectively. The land was then evaluated and classified based on its suitability for oil palm production. Parametrically, mapping units EKP I and EKP II were marginally suitable and EKP III not suitable for the proposed oil palm production. Non-parametrically, EKPI is moderately suitable, EKP II is marginally suitable and EKP III is not suitable, for growing oil palm. The prevailing limitations on the Ekpri Ibami landscape for oil palm production include fertility, wetness, and topography and soil physical properties. Fertility factor happened to be the most limiting factor in all the mapping units. And thus can be ameliorated through the application of organic manures, NPK fertilizer and liming to improve the nutrient status of the soil.*

Keywords— Land evaluation, characterization, classification, sustainable agriculture.

I. INTRODUCTION

Ekpri Ibami is an agrarian community where dwellers are mainly involved in arable and tree crops production, especially Oil palm with less emphasis on fishing, hunting, and mining of solid minerals. Despite the high agricultural potential of the area, there has been known little or no published land evaluation and soil characterization articles to make sure easy access and transfer of technology to areas with similar soils elsewhere. Due to the little or no information on land evaluation and soil studies in the location, the farmers are often compelled to grow their crops without adequate attention as a result,soils are not used for the purpose that best suits their properties.Land evaluation,however,approaches targeted towards sustainable agriculture and happens to be the starting point towards adequate information on land resources, which land evaluation,provides during soil characterization studies. In this process,soil resources must be studied in detail through processes of soil characterization and land ratings for the land utilization under consideration (Esu, 2004); such information highlights soil characteristics and conditions that are suitable for growing specific crops (Ogunkunle, 2005). It is therefore apt to evaluate soil mapping units obtained from a

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soil survey for Oil palm cultivation. Furthermore, adequate information is often generated during soil surveys to "determine the important characteristics of soils,classify them into mapping units,set up and plot on maps the boundaries between kinds of soils and to correlate and predict the adaptability of soils to various crops".

The earlier reporton the soils of Ekpri Ibami have revealedwell-drained soilswith coarse-textured,strongly acid reaction,moderate organic carbon, and nitrogen but low in available P and basic cations with quartz, kaolinite, and microcline as dominant minerals (Aki *et al.*, 2014). A similar report by Abua and Eyo (2013)of the same study revealed a coarse-textured in the surface horizonwith subsurface accumulation of clay and pH (H_2O) range of 5.4-6.8, but moderate organic carbon and total nitrogen,low available P and exchangeable bases. But, pH value of 3.8 was obtained by Attoe *et al.* (2016) in the Basement complex soils of Akamkpa with moderate organic carbon and total nitrogen but low available P and exchangeable cations as obtained by Aki *et al.*, (2014), and Abua and Eyo (2013). The soils,so, have high agricultural potentials but may needadequate soil management strategies.

Owing to the basic principles of conventional soil mapping,digital soil mapping (DSM) techniques, a world trending tool was adopted in this investigation.Digital soil mappingis a computer-assisted production of digital maps of soil types and properties. The method employsthe application of mathematical and statistical models that corroborate information from soil observation with information contained in correlated environmental variables (Dobos *et al.*, 2006) and uses GIS and computer programming to put into a quantitative framework the study of soils (McBratney *et al.*, 2003; Mckenkie and Ryan, 1999).

Oil palm production, which the soils are were investigated for, is one of the most important tree crops that have almost none of its parts as a waste. Its numerous importance has endeared the Federal Government of Nigeria to select it as a value chain crop; also, its cultivation and processing requires little skills and so can be cultivated by rural farmers with little supervision. This is probably the reason why most farmers in the locality grow the crop in either small or large scale. It is proposed to set up an Oil Palm estate at Ekpri Ibami thereby creating jobs for the dwellers.The study was aimed at evaluation, characterization, and classification of soil for the proposed Oil Palm plantation in Ekpri Ibami,Akampa Local Government Area of Cross River State.

II. MATERIALS AND METHODS

2.1 Location of the Study

The study was conducted on Ekpri Ibami landscape on the coordinates (05°18'53''N, 08°13'25''E; 82-111 m ASL) within Akamkpa Local Government Area of southern Cross River State (Fig. 1). The area is within the humid tropical climate characterized by distinct wet and dry seasons. The mean annual rainfall ranges between 1500-3500 mm, relative humidity 80-90 % and mean annual temperature value between 25.4-27.5°C (NIMET, 2015). These datawere adapted from Calabar weather station of the Nigerian Meteorological Agency being situated within 100 km range of thesynoptic station as proposedby Afangide *et al.*(2010) (Table 1).

The location of the study is on a basement complex geological material of which 40% encapsulates the entire southern Cross Rivers State, Nigeriaspreading up to the African-pan basement complex of Cameroun highlands. The characteristics of the material showthe processes that form the underlying and the influence of the environment where which they occurred.

2.2 Vegetation and land use

The area is covered with secondary forest regrowth with few annual crops identified consist of *Zea mays, Manihot spp, Oryza sativa, Musa spp, Dioscorea spp*, and perennial crops such as *Carica papaya, Elaeis guineensis, Hevea brasiliensis*and *Irvingia gabonensis*. Dominant trees, climbers, and shrubs such as *Daniella oliveri, Ficus spp, Khaya senegalensis,Laxifora spp, Combretum spp,Alcohornea spp, Andropogon spp, and Digitaria spp*, are scattered almost evenly while African bamboo trees grow wildly near the streams and lowland areas.

2.3 Field Study

The research was conducted on a 50-hectare land. A semi-detailed survey was employed at a scale of 1:50 000 which enabled delineation of the boundary through the acquisition of (x), longitude (y) and elevation (z) [xyz]values with the aid of a German Etrex (2000) global positioning system (GPS) device.The xyz values were used to obtain the topographic sheet of the location. Digital terrain model (DTM) of the study area was created from the topographic map; slope map was extracted from the DTM which was classified into different categories.

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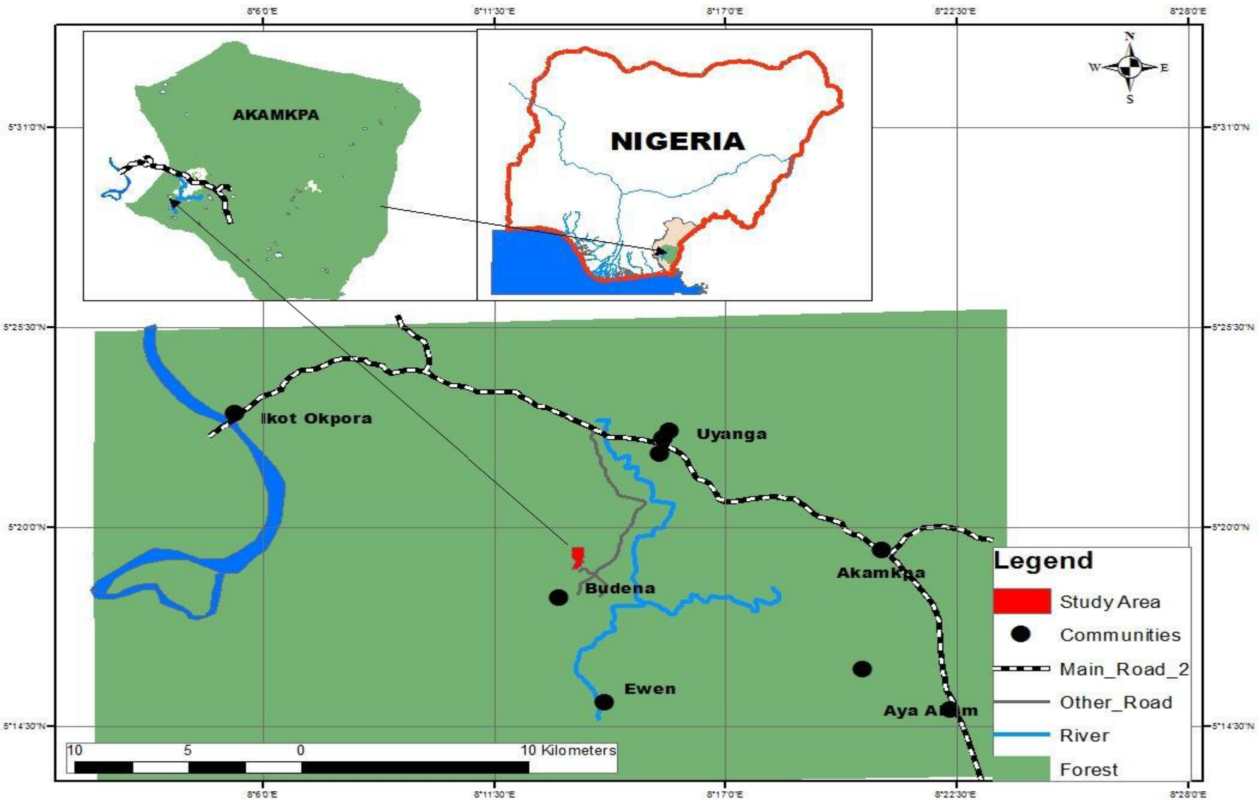

Fig.1: Location Map of the Study Area

Table.1: The Mean annual rainfall, humidity, temperature regime and sunshine duration between 1997 and 2014 in Calabar, Cross River State, Nigeria

Year	Rainfall (mm)	Dry-bulb air temperature (^{o}C)	Relative Humidity (%)
1997	3282.9	26.9	84.8
1998	2512.6	27.6	83.3
1999	2673.1	27.5	84.7
2000	2678.6	27.2	85.1
2001	3073.6	26.9	82.9
2002	2691.4	26.7	83.3
2003	2113.7	27.5	83.3
2004	1729.1	27.5	85.2
2005	2583.3	27.3	82.7
2006	2951.8	26.9	84.2
2007	2417.5	26.1	84.6
2008	1931.3	26.7	83.7
2009	1401.1	26.7	81.8
2010	2003.7	26.8	82
2011	2969.8	26.1	82.5
2012	4364.1	27.2	86.3
2013	3506.4	26.9	86.4
2014	3433.3	25.4	86.3
Mean	**2684.3**	**26.9**	**84.1**

Source: National Meteorological station (NIMET) Calabar (2015)

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Each slope category became a soil mapping unit.A systematic special purpose grid system detailed soil survey was adopted for ground-truthing of the computer delineated mapping units to establish the actual soil boundaries on the field. Rigid auguring at 50 m x 50 m intervals was made, physical and morphological properties were recorded for use in demarcating the mapping unit's boundaries.

2.4 Soil sampling and preparation

Three (3) mapping units, EKP I, EKP II and EKP III were identified. A pedon was cited on each mapping unit to the depth of 200 cm except interfered by an impenetrable layer or water table. The soils were described according to the guidelines of USDA-NRCS (Soil Survey Staff, 2002) as modified by Ibanga (2003) and Esu (2010). Undisturbed core cylinder samples were collected for bulk density and porosity determinations. Samples were then taken from each pedogenic horizon, bagged, labelled and transported to the laboratory for analysis. Prior to analysis, the samples were air dried, gently crushed and sieved through 2 mm sieve.

2.5.1 Laboratory analysis

The particle size distribution was determined using the Bouyoucos hydrometer method (Gee and Bauder, 1986) and the percent sizes later used to ascertain the soil textural class with the aid of the soil textural triangle provided by USDA. Soil pH was determined potentiometrically in the soil–water ratio of 1:1 (Udo *et al.*, 2009) and organic carbon was determined by the Walkley and Black wet oxidation method. Exchangeable cations were extracted using 1N NH_4OAc (pH 7.0) and, exchangeable Ca^{2+} and Mg^{2+} determined by atomic absorption spectrophotometry (Thomas, 1982) while Na^+ and K^+ were determined by flame photometry. Effective cation exchangeable capacity was determined by summing up the exchangeable bases and exchangeable Al^{3+} as outlined by Udo *et al* (2009). Base saturation was obtained by expressing the sum of exchangeable cations as a percentage of the cations exchange capacity (IITA, 2000) using the formula; **B.S =** $\left[\frac{TEB}{ECEC}\right]$ **X 100 (%).**

2.6 Soil Classification

The pedons were classified based on USDA Soil Taxonomy (Soil Survey Staff, 2010). The Soil Taxonomy was based on the properties of the soil as were found during the study. The physical, chemical and morphological properties and general site information were used as criteria to classify the soil to the subgroup level.

2.7 Land evaluation

The land evaluation was carried out according to the guidelines provided by Sys (1985) (Table 2). This is to make sure the reduction in the risk of production through the matching of the requirements of land use to the land qualities. Three (3) soil units were placed in the suitability classes by comparing the data obtained in the area under study for oil palm production to Oil palm requirement information. The evaluation was both conventional (non-parametric) (FAO, 1976) and parametric methods (Ogunkunle, 1993; Udoh *et al.*, 2006). For the non-parametric evaluation, pedons were first placed in suitability classes by matching their characteristics with the established requirements. The aggregate suitability classes were indicated by the most limiting characterist (c(s) of the soil units. For the parametric method, each characteristic was rated and the index of productivity (IP) for each pedon was calculated using the square root method equation:

$$\mathbf{IP} = A x \sqrt{B/100 \, x C/100 \, x \ldots x F/100}$$

Where: A is the overall lowest characteristic rating and B, C,…F is the lowest characteristic ratings for each land quality group (Udoh *et al.*, 2006). "Five land quality groups climate (c), topography (t), soil physical properties (s), wetness (w) and fertility (f) were used in this method of evaluation" (Table 2). "Only one member characteristics in each land quality group will be used for calculation purpose because there are usually strong correlations among members of the same group" (Ofem *et al.*, 2016). "Five levels of limitations were used, no limitation (0), slight limitation (1), moderate limitation (2) severelimitation (3) and very severe limitation (4)" (Table 3). One "limitation level was attributed to each land characteristic. The final (aggregate) suitability classes were determined by the number and intensity of the limitation(s)", and the most unfavourable characteristic determined the suitability classification. Suitability classes S1, S2, S3, N2, and N1 were established as reported by Ofem *et al* (2016). For actual (current) productivity index, all the lowest characteristic ratings for each land quality group were substituted into the index of productivity equation above. But, in the case of potential productivity index, it was assumed that the corrective fertility measure would no longer have fertility constraints. So, other qualities except for fertility (f) were used to calculate the potential productivity index. "Suitability classes S1, S2, S3, and N are equivalent to IP values of 100 – 75, 74 – 50, 49 – 25 and 24 – 0, respectively".

III. RESULTS AND DISCUSSION

3.1 Morphological and physical properties:

Threesoil mapping units were identified in the study area denoted by EKP I, EKP II and EKP III.

Soil mapping unit EKP I: The soils are very deep (>100 cm), located at the crest region of the landscape with an elevation value of 108 m above sea level (Table 4).The Ap

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horizon of the soil was observed to be thin (16-17 cm) with an extensive thick B-horizon which may be attributed to eluviation-illuviation processes (FitzPatrick, 1986; Orimoloye *et al*., 2010). The soil were very dark greyish brown (10YR 3/2) with no mottles at surface while the subsurface soils varied from yellowish red (5YR 5/8) ta reddishsh colour (2.5YR 4/6) with mottles occurring within the depths which may be attributed to periods of wetting which had led to inadequate aeration or reduction during the periods of the year, leading to oxidation-reduction reactions. The soils are weakly structured and there is evidence of layers with weak pedogenic processes in the field. The soils are coarse-textured with high sand content = 623.5 g/kg, low silt = 99.0g/kg and low clay = 277.5 g/kg and a sandy loam texture in the surface horizon and sandy clay loam in the subsurface horizon. The high silt/clay ratio indicates a high intensity of weathering (Young, 1976). Bulk density values varied from 1.2 g/cm^3 at the surface horizon to 1.5 g/cm^{3}in the subsurface horizon (Table 5). These values will allow root penetration, and good aeration, water movement for best crop production (Esu, 2010).

Table.2: Modified Land Suitability Requirements for Oil Palm Based on Land Characteristics

Parameters	**Suitability class**				
	S1	**S2**	**S3**	**N1**	**N2**
Land Qualities	100-75	74-50	49-25	24-15	14-0
Climate (c)					
Annual Rainfall (mm)	>1700	1450-1700	1250-1450	-	<1250
MAT(°C)	>22	20-22	18-20	-	<18
Relative humidity (%)	>70	65-70	60-65	-	<60
Topography(t)					
Slope (%)	0-8	8-16	16-30	>30	-
Wetness(w)					
Flooding	Fo	F1	F2	-	F3
Drainage	Perfect, well	Mod. Well	Poor, aeric	Poor, drainable	V. poor, not drainable
Soil Physical properties(s)					
Texture	Cl, Scl, L	Scl	Scl-Lfs	Any	C,Cs
Structure	Blocky	-	-	-	massive, single grain
Depth (cm)	>100	50-100	25-50	-	<25
Fertility(f)					
ECEC (cmol/kg)	> 8.0	5-8	< 5	-	-
Base Sat. (%)	>35	20-35	< 20	-	-
pH(H_2O)	5.5-6.0	5.5-6.0	6.5-7.0	< 4.0,>7.0	< 4.0,>7.0
OC(%)(0-15 cm)	>1.2	1.2-0.5	0.5-0.3	0.3-0.2	< 0.2

Flooding: Fo, No flooding; F1, 1-2 flooding months in>10 yrs; F2, Not more than 2-3 months in 5 yrs out of 10 yrs; F3, 2-4 months almost every year; F4, >4 months in almost every. Texture: Cl, clay loam; Scl, Sandy clay loam; L, Loam; Lfs, Loamy fine sand; c, Clay; Cs, Clayey s and MAT= Mean annual temperature.

Source: Sys *et al*. (1991)

Table.3: Ratings of limiting characteristics.

Limitation	Rating
Slight to none	100 – 90
Slight	89 – 70
Moderate	69 – 50
Severe	49 – 35
Very Severe	34 – 0
Can be corrected	34 – 20
Cannot be corrected	19 – 0

Soil mapping unit EKP II: It is well deep (>100 cm) with sandy loam texture and they occupy the middle slope of the landscape under study at an elevation of 102 m. The soil colour is characterized with a distinct dark yellowish brown (10 YR 4/4) at the surface horizon coming down to yellowish brown (10 YR 4/6) in the subsurface. Dark red (10 R 3/6) coloured mottles was observed in the subsurface layer and this may be as a result of poor aeration leading to oxidation-reduction reactions. Structural aggregates varied from weak medium granular in the surface and moderate medium coarse subangular blocky in the subsurface. Silt/clay ratio revealed that the soils possess high weathering potentials (>0.15). Bulk density varied from 1.1 g/cm^3 in the surface horizon to 1.5 g/cm^3 in the subsurface horizon. These values obtained have been reported to be suitable for agricultural purposes (Esu, 2010).

Soil mapping unit EKP III: It covered the lower slope of the landscape and situated at the elevation of 82 m above sea level. The soils are poorly drained with depth <50 cm. The hue values were 10 YR and 7.5 YR in the surface and subsurface layers giving a variation of colour, very dark grey-brown and strong brown, this result is similar with the report by Dengiz *et al*. (2012). Also, there was the occurrence of yellowish red (5 YR 4/6) mottle in the subsurface layer which indicates poor drainage conditions. Structural aggregates varied from moderate medium subangular blocky to weak fine granular in the surface and from moderate fine subangular blocky to weak fine medium granular in the subsurface horizon. The soils are predominantly sandy loam texture with particle size distribution (sand= 703.2 g/kg, silt=102.9 g/kg and clay= 203 g). Silt/clay ratio revealed that the soils have high weathering potential (>0.15). Bulk density values ranged from 1.1 g/cm^3 in the surface horizon to 1.5 g/cm^3 in the subsurface horizon.

3.2 Chemical properties of the soil mapping units

The chemical properties of the soil mapping unitsidentified on Ekpri Ibami landscape are presented in Table 6. The soil pH distribution in the soil units followed an irregular increase and decrease with depth. The mean pH (H_2O) were 5.3, 4.8 and 4.9 in soil mapping unit EKP I, EKP II and EKP III, respectively. Negative delta pH (ΔpH) obtained in the soils showed that all the layers of the soils profiles possessed net negative surface charges and such that they can retain basic nutrients for subsequent release into soil solution for plant uptake. Organic carbon and total nitrogen gave an irregular increase ana decreasese in values with depth. Means of organic carbon were 0.56 %, 0.47% and 0.2 % for EKP I, EKP II and EKP III respectively. While the means of total nitrogen content in the proposed land were 0.18 %, 0.04 % and 0.02 % for EKP II and EKP III respectively. Organic carbon content and total nitrogen were rated low as they fall within thin the critical limit of<1.5 % and < 0.2% respectively(Enwezor *et al*.,1989).

Table.4: Morphological properties of EKP I soil mapping unit

Horizon	Depth (cm)	Munsell-colour (moist)	Mottling	Texture	Structure	Consistence	Boundary	Other characteristics
EKP I		**N05˚ 19' 16.84" ; E008˚ 13' 36.1" ; 108 m ASL**						
Ap	0-17	10YR 3/2, vdgb		SL	1mcgr	w ss, f, p	cs	Porous, many fine medium roots, Common medium roots; Iron concretion, animal faecal, termite hill, quartzite inclusion.
Bw1	17-62	5YR 5/8, yr		scl	1msbk	wss, f, p	gs	Many medium pores, many common fine medium roots, weathered rock mica flakes, quartz inclusion, termites, earthworms and ants activities.
Bw2	62-122	5YR 5/8, yr	m (10R 3/6, dr)	scl	2msbk	w ss, f, p	ds	Few medium pores, many common fine medium roots, ants activities.
Crt	122-200	2.5YR 4/6, r	m (10R 3/8, yr)	scl	2msbk	wss,f, p	cs	Many coarse pores, few medium roots, ants activities clear, few thin cutans at ped faces, many iron concretions.
EKP IIN05˚ 19' 11.3" ; E008˚ 13' 36.8" ; 102 m ASL								
Ap	0-8	10 YR 4/4, dyb		SL	1mgr	wss	cs	Fine-coarse medium pores very fine size, few medium roots fine size, ants termites, earthworm and frogs,
Bt1	8-53	10 YR 4/4, dyb		SL	2mcsbk	ws	cd	Many medium pores, many common fine medium roots, weathered rock mica flakes, quartz, termite activities.
Bt2	53-114	10 R 5/6, yb	10 R 3/6, dr	SL	2msbk	wvs	gs	Many fine and medium pores, fine medium coarse roots, fine mica flake and many ants.
Crt	114-200	10 YR 5/6, yb	10 R 3/6, dr	SL	2msbk	wvs	cs	Fine medium coarse roots, few pores; fine mica flakes.
EKP III	**N05º 18' 56.8"; E008˚ 13' 25.1" ; 82 m ASL**							
Ap	0-15	10 YR 3/2, vdgb	nm	Sl	2msbk	wss, sp,f	cs	Many medium pores, many fine roots, many wormholes, termite activities observed.
Bt1	15-25	7.5 YR 5/6,	nm	Scl	2fsbk	wss, p,f	dw	Few thin clay cutan at ped faces, many

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		sb						medium pores, many fine roots, termites, ant holes.
Bt2	25-42	10 YR 4/6, db	m(5 YR 4/6, yr)	Sl	2fsbk	wss, p,f		Many medium pores, many fine roots, termites, frogs.

Colour- vdgb: very dark greyish brown, yr: yellowish red, r: red, drb: dark reddish brown, rb: reddish brown, dr: dusky red, **Mottles**-m: mottled **Texture**- SL: sandy loam, scl: sandy clay loam, ls: loamy sand, **Structure**- 1: weak, 2: moderate, 3: strong, m: medium, f: fine, c: coarse, gr: granular, sbk: subangular blocky, pl: plate-like, **Consistence**- wssfp: wet, slightly sticky, friable, plastic, wssp: wet, slightly sticky, ws: wet, sticky, **Boundary**- cs: clear smooth, **ASL**: above sea level.

Table.5: Physical properties of soil unit EKP I

Horizon	Depth (cm)	Particle Size Distribution gkg^{-1}			Textural Class	Silt: Clay	Gravel (% vol)	Bulk density (g/m^3)	Porosity (%)
		Sand	Silt	Clay					
EKP IN05° 19' 16.84" ; E008° 13' 36.1" ;108 m ASL									
Ap	0-17	766.4	83.6	150	SL	0.56	7.7	1.2	55
Bw1	17-62	614.8	65.2	320	SCL	0.20	11.5	1.5	43
Bw2	62-122	616.4	103.6	280	SCL	0.37	64.8	1.5	43
Crt	122-200	496.4	143.6	360	SCL	0.40	63.7	1.4	47
Range		496.4-766.4	65.2-143.6	150-360		0.20-0.56	7.7-64.8	1.2-1.5	43-55
Mean		623.5	99.0	277.5		0.3825	36.9	1.4	47
EKP IIN05° 19' 11.3" ; E008° 13' 36.8" ; 102 m ASL									
Ap	0-8	635.2	134.8	230	SL	0.59	72.0	1.1	58
Bt1	8-53	695.2	142.8	162SL	SL	0.88	0.0	1.4	43
Bt2	53-114	712.2	97.8	190SL	SL	0.51	57.0	1.5	43
Crt	114-200	575.2	44.8	380	SL	0.12	50.0	1.5	47
Range		575.2-712.2	44.8-142.8	162-380		0.12-0.88	0.0-72.0	1.1-1.5	43-58
Mean		654.5	105.1	241		0.54	44.8	1.4	47.8
EKP III	**N05° 18' 56.8"; E008° 13' 25.1" ; 82 m ASL**								
Ap	0-15	754.8	123.6	150	SL	0.82	40.9	1.1	62
Bt1	15-25	619.6	120.4	260	SCL	0.46	67.4	1.4	47
Bt2	25-42	735.2	64.8	200	SL	0.32	0.0	1.5	43
Range		619.6-754.8	64.8-123.6	150-260		0.32-0.82	0.0-67.4	1.1-1.5	43-62
Mean		703.2	102.9	203		0.53	36.1	1.3	51

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Table.6: Chemical properties of the soil mapping unit

Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	ΔpH	Org.C (%)	TN (%)	C: N	Avail.P ($mgkg^{-1}$)	Exchangeable Ca	Mg	K	Na	Exchangeable ($Al^{3+}+H^+$)	ECEC	BS %
EKP I	N05° 19' 16.84" ; E008° 13' 36.1" ; 108 m ASL)														
Ap	0-17	5.0	4.9	-0.1	0.60	0.04	15	20.6	2.2	1.40	0.14	0.48	0.9	5.12	82.0
Bw1	17-62	5.6	4.4	-1.2	0.74	0.06	12	17.3	1.6	1.00	0.10	0.08	1.6	4.34	64.0
Bw2	62-122	5.1	4.8	-0.3	0.50	0.03	17	20.8	2.6	1.50	0.37	0.37	1.7	6.54	74.0
Crt	122-200	5.6	4.7	-0.9	0.40	0.03	13	15.4	1.2	0.80	0.10	0.08	1.6	3.74	58.0
Range		5.0-5.6	4.4-4.8	0.1-0.9	0.40-0.74	0.03-0.06	12-17	15.4-20.6	1.2-2.6	0.50-1.50	0.10-0.37	0.08-0.48	0.9-1.7	3.74-6.54	58.0-74.0
Mean		5.3	4.7	-0.6	0.56	0.18	14	18.5	1.9	1.18	0.18	0.25	1.4	4.94	69.5
EKP II	**N05° 19' 11.3" ; E008° 13' 36.8" ; 102 m ASL**														
Ap	0-8	4.8	4.3	-0.5	0.60	0.03	20	24.7	3.0	1.5	0.46	0.47	1.7	7.10	76.0
Bt1	8-53	4.9	4.1	-0.8	0.63	0.05	13	11.4	1.4	1.0	0.09	0.07	1.8	4.40	59.0
Bt2	53-114	4.1	4.0	-0.1	0.30	0.04	15	23.8	3.3	1.5	0.44	0.47	0.8	6.50	44.0
Crt	114-200	5.5	4.5	-1.0	0.36	0.02	18	14.2	1.4	0.8	0.09	0.08	2.3	4.70	51.0
Range		4.8-5.5	4.1-4.5	0.1-1.0	0.30-0.63	0.02-0.05	13-20	11.4-24.7	1.4-3.3	0.8-1.5	0.09-0.44	0.07-0.47	0.8-1.8	4.40-7.10	44.0-76.0
Mean		4.8	4.2	-0.6	0.47	0.04	17	18.5	2.3	1.2	0.27	0.27	1.7	5.70	58.0
EKP III	**N05° 18' 56.8"; E008° 13' 25.1" ; 82 m ASL**														
Ap	0-15	4.9	4.1	-0.8	0.2	0.01	20	16.5	1.0	0.8	0.09	0.07	2.2	4.20	47.0
Bt1	15-25	4.4	4.2	-0.2	0.4	0.03	13	13.2	2.3	1.7	0.35	0.34	0.4	5.10	92.1
Bt2	25-42	5.5	4.6	-0.9	0.1	0.01	10	12.9	2.6	1.0	0.07	0.06	1.5	5.30	71.0
Range		4.4-5.5	4.1-4.6	0.2-0.9	0.1-0.4	0.1-0.03	10-20	12.9-16.5	1.0-2.6	0.8-1.7	0.07-0.35	0.06-0.34	0.4-2.2	4.20-5.30	47.0-71.0
Mean		4.9	4.3	-0.6	0.2	0.02	14	14.2	2.0	1.2	0.17	0.16	1.4	4.90	70.0

The mean values of the carbon/nitrogen ratio for the soils were 14, 17 and 14 for EKP I, EKP II and EKP III respectively. The small or narrow C: N (<25) (Paul andClark, 1989) will positively influence microbial activities to ensure rapid mineralization of organic matter with the consequent release of nutrient elements into the soil solution for crop plant assimilation (Akpan-Idiok *et al*.,2012) thus the carbon-nitrogen ratio of the soils falls within the given range. The available phosphorus content followed an irregular increase and decrease with depth in all the mapping units with the mean values of 18.5 mg/kg, 18.5 mg/kg and 14.2 mg/kg for EKP I, EKP II and EKP III respectively. Phosphorus content in soils was rated medium for mapping unit EKP I and EKP II and low for EKP III when compared with the critical value of 15 mg/kg (Enwezor *et al*., 1990 & Adepetu, 2000).

The exchangeable bases of the all soil mapping units were low. Exchangeable Ca dominated the soil exchange site. A similar result was reported elsewhere (Fasina *et al*., 2006 & Noma *et al*., 2004). Means of exchangeable acidity were 1.4 cmol/kg, 1.7 cmol/kg and 1.4 cmol/kg for EKP I, EKP II and EKP III respectively. This showed that preponderance of exchangeable (Al^{3+} + H^{+}) played a major role in soil acidity in the humid tropical soils of Ekpri Ibami. Effective cation exchange capacity values of the sois of Ekpri Ibami landscape were 4.94 cmol/kg, 5.70 cmol/kg and 4.90 cmo/kg for EKP I, EKP II and EKP III respectively. The ECEC were generally low as they fall within the critical value of (<8 cmol/kg) as provided by FAO, (1976) for soils of the ecological zone. This shows that the soils at their natural pH remain low in cation exchange and has low ability to retain nutrients (Yakubu, 2006). The means base saturation of the different mapping units were 69.5 %, 58.0 % and 70.0 % for EKP I, EKP II, EKP III respectively. A similar result was obtained by Abua and Eyo (2013) and Bulktrade (1989)in soils of Akamkpa. Meanwhile, according to FAO (1999) base saturation > 50% is regarded as fertile and rated high while<50% are regarded as not fertile soil and rated low. With the high base saturation, the basic nutrients must have occurred in available forms in soil solution in spite of the low cation reserves in the soil.

3.3 Soil classification

The soil morphological, physical and chemical properties were used to classify the soil unit according to USDA (2010). The mapping units identified at Ekpri Ibami landscape proposed for Oil palm production and denoted by EKP I, EKP II and EKP III and discussed as follows:

EKP I: This group of soil showed a moderate level of weathering and lacks the extensive amount of clay accumulation. They were identified with a weak horizon and with the presence of a cambic diagnostic horizon along with an ochric epipedon and moist colour value of 3 or more. Soils are developed on colluvial deposits. The soil is characterized with a weak coarse granular structure at the surface, improperly drained down the soil depth during the rains and are placed in the order of **Inceptisols**. With udic moisture regime occurring within the study location, the soil fits into the **Udepts** suborder and with a base saturation of 50 % in one or more horizons at a depth between 25 and 75 cm, they are further placed into **Eutrudepts** great group. The soils were further classified as **Arenic Eutrudept** at subgroup category due to the irregular decrease in organic-carbon content between a depth of 25 cm and at a depth of 125 cm.

EKP II: With the presence of argillic horizon and low base saturation less than 50% (with NH_4OAc) in with the depths 20 and 100 cm from the surface mineral soils. Thus qualified to be placed in order **Ultisol** and great group **Hapludult** and subgroup **Typic Hapludult**, according to USDA Soil Taxonomy classification.

EKP III:with increasing depth, do not have a clay decrease of 20 percent or more (relative) from the maximum clay content and so fit into **Paleudults** at the great group level and at subgroup level classified as **Aquic Paleudults.**

3.4 Land evaluation for the proposed oil palm production

3.4.1 Land qualities and land use requirement for oil palm production

3.4.1.1 Climate (c)

Climate parameters considered in the study were annual rainfall, mean annual temperature, and relative humidity. In Akamkpa LGA of Cross River State rainfall is a sufficient factor for oil palm production and has a mean annual rainfall of 2000mm (NIMET, 2015). The mean annual temperature and relative humidity in this region are greater than 25 º C and 80% respectively as shown in Table (7). The climatic characteristics were rated 100 % since they exceed 2000 mm, 25ºC and 75% provided by Sys (1985) for S1.

3.4.1.2 Topography (t)

The topography of the study area was on strongly undulating landscapeswith EKP I mapping unit occurring on relatively flat terrain (0-8 %), crest region. EKP II and EKP III mapping units were located at a convexly shaped angle with gradient range of 8-16 %. According to the criteria set by Sys (1985) for oil palm production EKP I is

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rated highly suitable (S1) while EKP II and EKP III are moderately suitable (S2) (Table). But, soils of EKP III may pose harvest and transportation challenges. Contour farming and strip cropping should be adopted along the slope gradient with reduced grazing and removal of vegetation. This practice will check erosion in EKP II mapping unit.

Table.7: Suitability class scores of the pedons Oil palm cultivation

Parameters	**EKP I**	**EKP II**	**EKP III**
Climate (c)			
Annual Rainfall (mm)	S1(100)	S1(100)	S1(100)
MAT(°C)	S1(100)	S1(100)	S1(100)
Relative humidity (%)	S1(100)	S1(100)	S1(100)
Topography(t)			
Slope (%)	S1(100)	S2(65)	S2(70)
Wetness(w)			
Flooding	S1(100)	S1(100)	S3(49)
Drainage	S1(85)	S1(85)	N1(20)
Soil Physical properties(s)			
Texture	S1(90)	S2(50)	S2(60)
Structure	S1(75)	S1(75)	S1(75)
Depth(cm)	S1(100)	S1(100)	S3(44)
Fertility(f)			
ECEC(cmol/kg)	S3(47)	S2(60)	S3(44)
Base Saturation (%)	S1(80)	S1(70)	S1(90)
pH(H_2O)	S2(55)	S2(50)	S3(40)
OC(%)(0-15 cm)	S3(48)	S3(45)	S3(49)
Aggregate Suitability			
Potential	S3(38.1)	S3(26.3)	N2(10.9)
Actual (current)	S3(37.3)	N1(23.6)	N2(9.9)

3.4.1.3 Wetness (w)

In terms of soil wetness, the characteristics considered under this land quality group were flooding and drainage. They were no flooding problems in EKP I and EKP II mapping units as they were very well drained and had no characteristics of limiting drainage probably due to the sandy and gravelling properties of the soilsand were rated 100 % (S1) for both flooding and drainage. But EKP III mapping unit is influenced by the inflow of water from the streams and rated between 25-49% (S3) for flooding and drainage.

3.4.1.4 Soil physical properties (s)

Soil physical properties considered were texture, structure and soil depth. Comparing the land qualities (Table 2). All the mapping units were rated between 40 – 90 % for both soil texture and structure. But, soil texture is generally optimum for oil palm production with moderate to high suitability. EKP I = S1, EKP II = S2 and EKP III= S3.

3.4.1.5 Soil fertility (f)

The soils effective cation exchange capacity by summation, base saturation (BS) and organic carbon were evaluated as potential fertility characteristics they are not easily altered. The matching scores as shown in Table (6) showed that the ECEC values of the three mapping units were marginally suitable (S3) the criteria required for oil palm production as suggested by Sys (1985) with an average score of 49 % while the base saturation is highly suitable (S1) with suitability scores between 80-100 %. The pH of the different mapping units was moderately suitable (S2). The organic carbon scores showed that the EKP I, EKP II and EKP III are moderately suitable (S2) and pose greater fertility challenge in the production of oil palm, so, requires the increase in organic matter content.

3.5 Oil palm Suitability

The aggregate scores, S3(38.1), S3 (26.3) and N2 (10.9) are potentially suitable scores for EKP I and EKP II and EKP III respectively. While S3 (37.3), N1 (23.6), N2 (9.9) are actual (current) suitable scores. Table (8) presents the non-parametric and parametric rating of the different soil mapping units.

Potential Suitability: EKP I and EKP II are marginally suitable for oil palm production and must, need continuous conservation and crop management practices such as appropriate and adequate fertilizer application, contouring, minimum tillage etc to ensure increased yield while conserving the soil nutrient level while EKP III is not suitable.

Actual (Current) Suitability: the aggregate scores showed that EKP I is marginally suitable while EKP II and EKP III are not suitable.

Table.8: Suitability classification of the mapping units

Mapping units	Potential		Current	
	Nonparametric	Parametric	Non parametric	parametric
EKP I	S2f	S3(38.1)	S2f	S3(37.3)
EKP II	S3fs	S3(26.3)	N2tfs	N1(23.6)
EKP III	N2wf	N2(10.9)	N2wf	N2(9.9)

f=fertility limitation; w=wetness limitation; s=soil physical characteristic limitation; t= topography

3.6 Soil management practices for Oil palm production at Ekpri Ibami

The soils of Ekpri Ibami in Akamkpa Local Government Area of Cross River represented with mapping units EKP I, EKP II and EKP III were generally good for the agricultural purpose. But, their specific limitations have placed them into different suitability classes. The general management practices are as follows;

3.6.1 Maintenance of soil fertility

The basic cations such as Ca, Mg and K appear to be very low in the soils of the study area due to high rainfall resulting into leaching of these cations out of soil solum (Esu, 2005). So, the proper soil management strategist to conserve or improve the fertility may include spreading of crop residues on the soils after harvesting, the inclusion of grasses and legumes during fallow.

3.6.2 Adoption of conservation practices

For best production; it is recommended that the practice of annual burning of bushes and plant residues at the start of farming, extensive grazing of the bushes by livestock and the felling of trees be discouraged while contour farming and strip cropping along slopes be encouraged to reduce the speed of runoff and subsequently reduce erosion and leaching in the area.

3.6.3 Organic manures and chemical fertilizer application

Oil palm requires balanced and the sufficient amount of micro and micronutrients for production. The study shows that the soil mapping units are generally low in soil basic nutrient yielding marginally to moderate suitability. However, to ameliorate the nutrient status of the soil adequate application of fertilizer in a split dosage at 3 months interval should be adopted (FDDD, 1989). Farmyard manure (FYM) of 75 to 100 kg or 90 to 100 kg of green manure and 5 kg neem cake should be added per each oil palm tree along the second dose of fertilizer. The practice will also reduce soil water erosion in the study area and will return the much-needed plant nutrient element to the soil (Esu, 2005; Onyekwere *etal.*, 2001; Akpan-idiok, 2012).

IV. CONCLUSION

Three mapping units (EKP I, EKP II and EKP III) derived from basement complex parent material of Akamkpa Local Government Area were mapped, characterized, classified and evaluated for its suitability for oil palm cultivation. The soils were strong to moderately acidic (4.8 to 5.3). The soils also have low inherent of natural fertility with low organic carbon content, total nitrogen, and moderately available phosphorus. Low effective cation exchange capacity and high base saturation which may have occurred in available forms in solutions in spite of the low cation reserves in the soil.

Parametrically, mapping units EKP I and EKP II were marginally suitable and EKP III not suitable for the proposed oil palm production. Non-parametrically, EKPI is moderately suitable, EKP II is marginally suitable and EKP III is not suitable, for growing oil palm. The prevailing limitations on the Ekpri Ibami landscape for oil palm production include fertility, wetness, and topography and soil physical properties. Fertility factor happens to be the most limiting factor in all the mapping units. And thus can be ameliorated through the application of organic manures, NPK fertilizer and liming may also improve the soil fertility status. At EKP III which is seen to be limited by wetness

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and drainage, proper drainage channels should be constructed since the proposed tree crop requires well-drained soil to encourage microbial biomass. Also, waterlogging crops can be grown in the area.

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