CHARACTERISTICS AND SUITABILITY EVALUATION OF THE "WHITE SOILS" OF ETUNG LOCAL GOVERNMENT AREA FOR OIL PALM AND PLANTAIN PRODUCTION

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ABSTRACT
A semi detailed soil survey of the "white" soils of Etung LGA, Cross River State was carried out to characterize and assess the suitability of the soils for oil palm and plantain production using the linear and square root parametric models. The delineated mapping units classified as Kandiudalfs were deep (>100 cm in depth), well drained with loamy sand to sandy loam surface horizons overlying sandy clay loam to sandy clay subsurface horizons. The soils were extremely acid to strongly acid in reaction (pH 3.55 – 4.65), low effective cation exchange capacity (1.19 - 3.94 cmol kg^{-1}), moderate to high base saturation (30.97 – 97.32%), low to moderate exchangeable sodium percent (5.83 – 29.43%), moderate bulk density (1.22- 1.70 g cm^{-3}) and low to high saturated hydraulic conductivity (0.12 – 88.42 cm h^{-1}). The index of current productivity (IPc) ranged from 7.33 to 15.53 by linear model and ranged from 13.42 to 19.70 by square root model. The IPc values suggested that the soils were not currently suitable for the production of the two crops. The index of potential suitability (IPp) by linear model ranged from 29.32 to 62.10 and 38.29 to 65.46 by the square root model. Two pedons, CRET-1 and CRET-4 were potentially marginally suitable (S3) while pedons CRET-2 and CRET-3 were potentially moderately suitable (S2) for oil palm production. Application of appropriate quantity of organic manure or organo-mineral fertilizers is suggested for improving the current productivity status of the soils to its potential capacity.

Keywords: Oil Palm, plantain, Linear and Square Parametric models

INTRODUCTION
Etung Local Government Area of Cross River State is a major cocoa growing hub in Nigeria. The estimated total annual cocoa production from this local government area in 2004/2005 was 21777.4 metric tons, representing 6.8% of the total cocoa production in Nigeria (CRIN, 2008). However, there are two major soil types in this local government tagged "red" and "white" soils. Farmers prefer the red soil (Agbokim series) for cocoa production while the white (Ajassor) series is seldom used for cocoa cultivation.

In most cases, the white soils are used for the production of arable crops like cassava. Thus, the income earning potential of farmers on white soils is lower than those farming on red soils. Production of cash crops in term of input- output – benefit analysis gives a better economic return than other type of crops (Awoyomi, 1995). Improving the income generation capacity of the farmers using the "white soils" requires a suitability evaluation of these soils for the production of other cash crops like oil palm and plantain. A survey of the natural vegetation of the area suggests that plantain and oil-palm could be grown on the white soils. The climate as well as the terrain of the LGA is considered very favourable for the production of Oil palm and plantain. However, since the soil conditions is as important as the climatic condition in determination of the productivity of any land, it is the aim of this paper to evaluate the suitability of the "white soils" of Etung LGA for the production of oil palm and plantain as a step towards improving the income earning capacity of farmers cropping on the "white soils".

The best method of ensuring optimum output from our land resources is their allocation to the use for which they are most suitable (Fasina *et al*., 2007). Land evaluation aims at achieving optimum economic return from allocation of land resources without land degradation (FAO, 1976). Thus, crop – land suitability analysis has been used for achieving optimum utilization of the available land resources for sustainable agricultural production (FAO, 1993).

There are several methods for carrying out suitability evaluation assessments. These methods ranges from the cumbersome Fuzzy logic modeling (Braimoh, 2000) to the simple and easily adaptable FAO framework.(1976). All these methods have their strong and week points as extensively reviewed by Braimoh (2000). However, the parametric method, although subjective to some extent has been widely used (Hassan *et al.*; 2002; Menjiver *et al.*, 2003; Fashina *et al.*, 2007; Uddoh, 2008; Ajiboye *et al*; 2011) and reported to have comparatively valid result as those from Fuzzy Logic (Van Kuilenberg *et al.,* 1982; Bregt *et al.,* 1987; Leenhardt *et al.,* 1994). The parametric method of suitability assessment was therefore adopted for this study.

MATERIALS AND METHODS

The surveyed area cover about 21,000 hectares and include the soils of Ajassor village, Ajassor Mission, Okoroba, Ogaranjor plantation, Ekwatai, part of Bikpare, Effraya, and Ekimaya. The flexible grid survey method was used. Four soil profile pits were dug to represent the encountered mapping units within the 'white' soils of Etung LGA. The profiles were located at Ajassor village, Ogaranjor plantation and Effraya. Soil samples were taken from the pedogenic horizons of these profile pits. The collected samples were air dried and passed through 2 mm sieve before the samples were used for laboratory analyses.

The percentage gravel content was also calculated (vol./vol.).,
The particle size analysis was carried out using the hydrometer method (Bouyoucous, 1962) while the textural classes was determined using the textural triangle (FAO, 2006). The organic carbon was determined using the wet oxidation method (Walkley, 1947).The exchangeable cations were extracted with normal neutral ammonium acetate (N NH_4AOc pH 7.0). Potassium (K) and sodium (Na) content of the extracts were determined by flame photometry while the magnesium and calcium content of the extracts were determined by EDTA titration method. The available P in the soils was extracted using Bray-1 and the P concentration in the extract was determined on spectrophotometer using the vanado-molybdate blue method (Murphy and Riley, 1962). The available micronutrients were extracted with 0.04M EDTA and their concentration in the extract determined with atomic absorption spectrophotometer (AAS). The CEC of clay was estimated as CEC (clay) = CEC (soil) – ((3.5× %OC)/Clay %). The data generated from the above analyses were used with the morphology of the soils for the soil classification.

Land evaluation procedure

Two methods of land suitability evaluation (FAO frame work and parametric) were used to assess the suitability of the soils for the production of oil palm and plantain. The pedons were placed in suitability classes by matching their characteristics (Tables 4 and 5) with the land suitability requirements for oil palm (Table 1) and plantain (Table 2) using the rating of limiting characteristics

Table 1: Land requirements for the production of Oil palm (*Elaeis guinensis*)

Land requirements/ Land characteristics	Land Suitability Class S1	S2	S3	N1
Climate (c):				
Annual rainfall (mm)	1700 – 2500	1450 – 1700 2500-3500	1250 – 1450 3500-4000	1000-1250
Length of dry season (Months)	<2	2 – 3	3 – 4	>4
Mean annual temp. (°C)	25 – 28	22 – 25 28 – 32	20 – 22 32 – 35	>35
Topography (t):				
Slope (%)	<8	8 – 16	16 – 30	>30
Erosion hazard(eh)	Very low	Low –moderate	Severe	Very Severe
Wetness (w)*:				
Flooding	F0	F1	F2	>F2
Drainage	Moderate	Moderate-Poor	Poor-mod. Rapid	Very poor – Rapid
Soil Physical Characteristics (s):				
Texture (surface)	fine - medium	medium - slightly coarse	Coarse	very coarse
Surface stoniness (Vol. %), 0-10cm	<5	5 – 15	15 – 40	40 – 45
Rock out crops (%)	<5	5 – 15	15 – 25	25 – 30
Soil depth (cm)	>100	75 – 100	50-75	50 – 45
Coarse material (%)	<15	15 – 35	35 – 55	>55
Fertility (f):				
Cation exchange capacity (cmol-kg^{-1}) clay	>16	12-16	8 – 12	5 – 8
Base saturation (%)	>20	15- 19	10 – 14	<10
pH H_2O	5 - 6.5	4.2 – 5 6.5 – 7	< 4.2 >7.0	< 4
organic carbon (%), 0-15cm	> 0.8	0.5 - 0.8	0.3 - 0.5	< 0.3
Alkalinity (ESP)	-	-	-	-

Modified from: Djaenudin *et al*., (2003

Table 2: Land requirements for the production of Plantain (*Musa spp*)

Land requirements/ Land characteristics	S1	Land Suitability Class S2	S3	N1
Climate (c):				
Annual rainfall (mm)	1250 – 1750	1750 – 2000	2000 - 2500	>2500
		1000 – 1250	750 - 1000	<750
Length of dry season (Months)	<2	2 – 3	3 – 4	>4
Mean annual temp. (^oC)	20 – 23	23 – 30	30 - 40	>40
		18 – 20	15 - 18	< 15
Topography (t):				
Slope (%)	<8	8 – 16	16 - 30	>30
Erosion hazard(eh)	Very low	Low –moderate	Severe	Very Severe
Wetness (w)*:				
Flooding	F0	F1	F2	>F2
Drainage	Good – Moderate	Moderate-Poor	Poor-mod. Rapid	Very poor – Rapid
Soil Physical Characteristics (s):				
Texture (surface)	fine – medium	medium - slightly coarse	coarse	very coarse
Surface stoniness (Vol. %), 0-10cm	<5	5 – 15	15 - 40	40 – 45
Rock out crops (%)	<5	5 – 15	15 - 25	25 – 30
Soil depth (cm)	>100	75 – 100	50-75	50 – 45
Coarse material (%)	<15	15 – 35	35 - 55	>55
Fertility (f):				
Cation exchange capacity (cmol-kg^{-1})	>16	12-16	8 – 12	5 – 8
Base saturation (%)	>35	20 – 35	15 – 20	10 – 15
pH H_2O	5 – 6	4.5 – 5	< 4.2	< 4
		6 - 7.5	>7.5	
organic carbon (%), 0-15cm	> 1.2	0.8 - 1.2	0.5 - 0.8	0.3 - 0.5
Alkalinity (ESP)	<15	15 – 20	20 - 25	> 25

Modified from: Djaenudin *et al*., (2003)

Table 3.: Rating of limiting characteristics

Symbol	Definition	Land Index
S1	None	70.0 – 100
S2	Slight	55.0 – 69.0
S3	Moderate	40.0 – 54.0
N1	Severe	20.0 - 39.0
N2	Very severe	0.00 – 19.0

The suitability class of a pedon was that indicated by its most limiting characteristic following Liebig's Law of minimum as adopted by FAO in agriculture, which states that crop yield will be determined by the plant nutrient in lowest supply (FAO, 1983) and this was applied to the performance or suitability of a soil type (Ogunwale *et al*., 2009).

Secondly, the indices of current (IPc) and potential (IPp) suitability were computer using the linear and square root parametric models of land evaluation (Uddoh, 2008; Ajiboye *et al*., 2011) from the suitability ratings of the parameters selected for the quantitative land evaluation. The group of land qualities considered for evaluation include: climate (c), topography (t), drainage characteristics (w), soil physical characteristics (s) and soil chemical fertility (f). The soil fertility (f) was assessed using the soil reaction (pH in water), cation exchange capacity of the clay fraction, base saturation, organic carbon content and exchangeable sodium percentage (ESP). In computing the potential suitability (Ipp), the potential fertility factors which include chemical properties such as the cation exchange capacity, base saturation, pH and organic matter content (Ogunkunle, 1993) were excluded. In tropical soils with low activity clay like Kaolinite, there are several reports that indicated that the CEC of such soils can be improved by management practices such as the addition of organic matter and soil amendment with biochar (Bruno *et al*., 2002).

The current and potential suitability were computed linearly using index of current (actual) productivity (IPC) of Storie (1933)

$IP_C = A \times B/100 \times S/100 \times C/100 \times \ldots F/100$ ----- (i)

Where, IP_C is index of current (actual) productivity, A the overall least rating characteristic and B, C..... are the least rating characteristic for each land quality group.

The current and potential suitability (IP_P) was similarly computed using the potential index of productivity.

The IPc and IPp were similarly computed using the square root model as stated below:

IPc = A× ----- (ii)

Where, A the overall least characteristic rating and B, C.....F are the least rating characteristic for each land quality group

Over all suitability class ratings S1, S2, S3 and N are equivalent to IPc values of 100-75, 74-50, 49-25, and 24-0, respectively

RESULTS

Climate of the area

There is currently no meteorological station in Etung Local Area. However, there is a standard station at Ikom, which is less than 10 km away from the area where this research was conducted. The data collected from the meteorological station at Ikom was used for this evaluation work (Ajiboye *et al*., 2015).

The rainfall pattern in the area is single maximum with the highest mean monthly rainfall of about 625 mm occurring in August. Mean total annual rainfall ranged from 2700 – 3100 mm, while the mean monthly rainfall frequency was also highest in August with about 24 – 28 rainy days. December usually has the least rainy days lasting between 3 – 5 rainy days.

Topography

The landscape on which soils were located was gentle undulating with slope angles variation between 2 and 6 percent. The elevation of the area ranged between 89 – 134 m above the sea level.

The Soils

Four mapping units were delineated from the survey exercise. These mapping units were denoted as CRET-1, CRET-2, CRET-3 and CRET-4. The four representative profile pits were classified as Kandiuldalfs. Pedons CRET-2 (N 05.84383, E 008.85451) and CRET-3 (N 05.86185, E 008.73636,) were classified as Typic Kandiudalfs while pedons CRET-1 (N 05.85845, E 008.82173) and CRET-4 (N 05.86014, E 008.72630) were classified as Arenic Kandiudalf. The soil of this area is often referred to by the local farmers as “white soil” because of the colour which is not as red as the second soil type used for cocoa plantation in the area. The second soil type is called the “RED” soils by the local communities of the area because of the “Rhodic” (2.5YR- 10R) colour of the soil series.

Soil characteristics

The physical, morphological and chemical properties of the mapping units are presented in Tables 4 and 5 below.

These soils were developed on cretaceous sedimentary sandstone. The soils were deep, well drained with gravels (quartz) at some horizons (mostly second or third horizons) below the surface. These soils were deep (> 100 cm), well drained, yellowish brown (10YR 5/6) to very dark gray (5YR 3/1), loamy sand to sandy loam surface overlying white (2.5Y 8/2) to yellowish red (5YR 5/8) and sandy clay loam to sandy clay subsurface. All the pedons have gravels content > 10% at some depth between 50 and 150 cm. However, some of the pedons in this series (CRET-2 and CRET-3) were endoskeletic (>40 % gravels). The subsurface clay contents of the soils ranged from 20 – 42%. The soils had moderate bulk density (1.22 -1.70 g cm^{-3}), hydraulic conductivity (0.12- 88.42 cm hr^{-1}) and total porosity (29 -43.2%). The hydraulic conductivity which was lower than the average rainfall intensity (15-30 cm h^{-1}) especially in the months of July – October could predispose the soils to flooding and erosion. The soil reaction ranged from extremely acid to very strongly acid (3.55 – 4.65) both in the surface and subsurface horizon. The effective cation exchange capacity (1.19 – 3.94 cmol kg^{-1}) was low; the base saturation was low - high (30.97 – 97.32 cmol kg^{-1}) and the exchangeable sodium percent (ESP) ranged from 5.83 - 29.43%.

The available phosphorus (Bray-1 P) content of the soils were low in most horizons of all the pedons (<8 mg kg^{-1}). Also, the soils had moderate to high Fe (42.55 -83.67 mg kg^{-1}) in the surface horizons and moderate – low Fe in the subsurface horizons. The Mn (0.49 – 63.46 mg kg^{-1}) and boron (0.37 – 4.68 mg kg^{-1}) content of the soils were low –

Table 4:Soil Physical and morphological Properties

Profile	Depth	Sand	Silt	Clay	%gravel	Texture	Ks	BD	Pore	Colour	Structure	Consist	Mottles
CRET-1	0-37	86.40	2.80	10.80	2.78	LS	8.61	1.26	43.2	5 YR 3/1	Me, Mo, Sbk	Fr	
CRET-1	37-93	77.00	5.40	17.60	6.25	SL	12.39	1.47	35.03	10 YR 4/4	Me, Mo, Sbk	Fr	
CRET-1	93-123	57.00	9.40	33.60	17.78	SCL	0.81	1.7	32.34	7.5 YR 4/6	Me, St, Abk	Vfi	10 YR 6/6 F, Fi, D, Fn
CRET-1	123-180	62.40	4.80	32.80	12.94	SCL	0.12	1.64	32.7	7.5 YR 4/6	Me, St, Abk	Vfi	10 YR 4/8 M, Me, Cl, P
CRET-2	0-30	78.00	5.40	16.60	0.47	SL	11.48	1.37	37.91	10 YR ¾	Me, Mo, Sbk	Fr	
CRET-2	30-70	69.00	5.40	25.60	6.98	SCL	0.68	1.53	30.18	10 YR 5/4	Co, St, Sbk	Vfi	
CRET-2	70-90	63.00	4.40	32.60	59.74	SCL	1.07	1.84	29	10 YR 5/4	Me, We, Abk	Fi	5 YR 5/6 C, Vf, D, Fn
CRET-2	90-180	55.00	9.40	35.60	4.88	SCL	0.94	1.55	38.08	10 YR 5/6	Me, St, Abk	Vfi	10 YR 6/4 M, Me,Cl,P
CRET-3	0-22	85.00	3.40	11.60	4.60	LS	3.91	1.36	30.09	10 YR 3/2	Fi, We, Sbk	Fr	
CRET-3	22-103	68.00	2.40	29.60	73.89	SCL	88.42	1.53	30.45	10 YR 4/4	Co, Me, Sbk	Vfi	
CRET-3	103-133	55.00	5.40	39.60	45.00	SC	20.34	1.52	25.96	7.5 YR 6/6	Co, St, Sbk	Efi	10 R 5/8 C, Vf, D, Fn
CRET-3	133-180	50.40	6.80	42.80	21.21	SC	2.01	1.64	33.5	5 YR 5/8	Co, St, Sbk	Efi	10 R 4/8, M, Me, S, P
CRET-4	0-55	79.00	5.40	15.60	20.83	SL	15.32	1.22	36.41	10 YR ¾	Me, Mo, Sbk	Fr	
CRET-4	55-85	76.40	2.80	20.80	16.13	SCL	13.17	1.42	33.32	10 YR 5/3	Co, St, Sbk	Vfi	
CRET-4	85-94	84.40	2.80	12.80	3.51	LS	0.94	1.41	37.55	2.5 Y 8/2	Co, St, Abk	Efi	
CRET-4	94-165	87.00	3.40	9.60	16.28	S	9.96	1.64	36.32	2.5 Y 8/2	Co, St, Abk	Efi	

BD= Bulk Density; Ks= Saturated hydraulic conductivity; Pore = Total Porosity; Consist = Consistency. Texture:- S= sand; LS = Loamy Sand; SL = Sandy Loam; SCL = Sandy Clay Loam; SC = Sandy Clay; C = Clay.

Consistency:- Vfr = Very friable, Fr = Friable, Fi = Firm, Vfi = Very firm, Efi = Extremely firm;

Structure (Size, grade, type); Size:- Fi = Fine, Me = Medium, Co = Coarse; Grade :- We = Weak, Mo = Moderate, St = Strong; Type :- Sbk = Sub Angular Block, Abk = Angular Blocky;

Mottles:- F= few; C= common; M= many; Fi = fine; Vf = very fine; Me = medium; Co = coarse;; fn = faint; S = sharp; Cl = clear; D = distinct; P = prominent

Table 5:Soil Chemical properties

Profile	Depth	pHw	OC	TN	C/N	TEA	Mg	Ca	K	Na	ECEC	CECclay	BS	ESP	Avail-P	Fe	Mn	Cu	Zn	B
	(cm)		(%)	(%)		Cmol kg^{-1} ←						→	(%)	(%)	mg kg^{-1} ←					→
CRET-1	0-37	5.40	0.94	0.089	10.56	0.10	0.34	2.37	0.11	0.21	3.13	2.83	96.81	6.70	2.75	74.82	51.78	0.93	0.13	0.28
CRET-1	37-93	5.35	0.76	0.077	9.88	0.20	0.06	0.95	0.06	0.21	1.48	1.33	86.49	14.27	15.92	54.83	63.46	0.36	0.10	0.65
CRET-1	93-123	5.25	0.58	0.065	8.94	0.20	0.56	2.50	0.09	0.26	3.62	3.56	94.48	7.29	4.63	50.73	4.35	0.32	0.04	1.49
CRET-1	123-180	5.45	0.62	0.068	9.18	0.20	0.64	2.66	0.16	0.28	3.94	3.87	94.92	6.99	2.43	17.61	6.82	0.00	0.03	1.21
CRET-2	0-30	4.50	0.25	0.043	5.85	0.60	0.26	0.57	0.14	0.26	1.83	1.78	67.20	14.37	1.90	83.67	6.21	0.00	0.05	0.35
CRET-2	30-70	4.35	0.65	0.07	9.35	1.00	0.20	0.12	0.13	0.22	1.67	1.58	40.12	13.16	4.14	78.61	2.77	0.00	0.14	0.37
CRET-2	70-90	4.55	0.4	0.053	7.58	1.40	0.44	0.51	0.21	0.32	2.87	2.83	51.28	11.00	21.88	42.76	1.15	0.00	0.18	0.46
CRET-2	90-180	4.35	0.04	0.029	1.39	2.20	0.28	0.09	0.31	0.26	3.13	3.13	29.79	8.19	1.28	13.48	1.94	0.00	0.05	0.91
CRET-3	0-22	5.15	1.01	0.094	10.78	0.10	0.46	2.88	0.08	0.22	3.73	3.43	97.32	5.83	2.35	42.55	10.01	0.00	0.07	1.18
CRET-3	22-103	4.20	0.14	0.035	3.96	0.10	0.14	0.51	0.09	0.35	1.19	1.17	91.60	29.34	15.01	80.36	4.40	0.00	*	1.27
CRET-3	103-133	5.45	0.04	0.029	1.39	1.10	0.31	0.48	0.09	0.36	2.35	2.35	53.16	15.23	14.54	17.08	0.64	0.00	0.06	1.10
CRET-3	133-180	5.35	0.36	0.05	7.18	1.10	0.35	0.20	0.08	0.34	2.08	2.05	47.03	16.37	1.28	14.65	1.59	0.00	0.05	4.86

CRET-4	0-55	4.75	0.9	0.086	10.43	0.80	0.11	0.33	0.09	0.26	1.59	1.39	49.81	16.33	3.52	46.97	3.16	0.30	0.06	3.37
CRET-4	55-85	4.75	0.76	0.077	9.88	1.00	0.13	0.28	0.12	0.29	1.81	1.68	44.87	15.77	6.20	36.16	2.58	0.11	0.07	2.66
CRET-4	85-94	5.05	0.4	0.053	7.58	1.10	0.08	0.05	0.11	0.25	1.59	1.48	30.79	15.57	1.28	12.30	1.95	0.00	*	1.52
CRET-4	94-165	4.85	0.51	0.06	8.48	1.10	0.21	0.09	0.08	0.28	1.76	1.57	37.51	16.09	1.28	0.39	0.49	0.00	0.07	3.34

moderate while the Cu (0.00 – 0.93 mg kg^{-1}) and Zn (0.03 - 0.18 mg kg^{-1}) content of the soils were very low.

Land evaluation for oil palm production

All the pedons had index of current productivity (IPc) less than 24.00 by both linear and square root models and were classified as currently not suitable (N) for production of oil palm (Table 6). The IPc value for pedons CRET-1 and CRET-4 was 11.25, while pedons CRET-2 and CRET-3 had IPc values of 9.0 and 15.3 respectively by the linear parametric models. Using the square root model, the IPc values for the four pedons were 16.77 for CRET-1, 13.42 for CRET-2, 19.70 for CRET-3 and 16.77 for CRET-4.
The major limitations of these soils include among others, the low effective cation exchange capacity of the soils, the sandy nature of the surface soil, the pH which was also suboptimal and the moderate susceptibility of the soils to erosion hazard.

Evaluation of the potential suitability (IPp) by the linear model indicated that pedons CRET-1 and CRET-4 which had IPp values of 45.00 respectively were potentially marginally suitable (S3) for the production of oil palm. However, the IPp values for pedon CRET-2 and CRET-3 (62.10) indicated that these mapping units were potentially moderately suitable (S2) for the production of oil palm.
Although the IPp values computed using the square root model was slightly higher than that of linear model, the potential suitability classes of the pedons remained the same. Thus, pedons CRET-1 and CRET-4 which had IPp value of 47.43 were potentially marginally suitable for oil palm production while pedons CRET-2 and CRET-3 were potentially moderately suitable for oil palm production.

Table 6 : Suitability ratings of land characteristics for Oil Palm production.

Land requirements/ Land characteristics	CRET-1	CRET-2	CRET-3	CRET-4
Climate (c):				
Annual rainfall (mm)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Length of dry season (months)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Mean annual temp. (^oC)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Topography (t):				
Slope (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Erosion hazard(eh)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)	90 ($S1_2$)
Wetness (w)*:				
Flooding	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Drainage	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Soil Physical Characteristics (s):				
Texture (surface)	50 (S3)	69 (S2)	69 (S2)	69 (S2)
Surface stoniness (Vol. %), 0-10cm	100 (S1)	100 (S1)	100 (S1)	50 (S3)
Rock out crops (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Soil depth (cm)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Coarse material (%)	100 (S1)	100 (S1)	69 (S2)	69 (S2)
Fertility (f):				
Cation exchange capacity ($cmol\text{-}kg^{-1}$) clay	25 (N1)	25 (N1)	25 (N1)	25 (N1)
Base saturation (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
pH H_2O	100 (S1)	65 (S2)	85 ($S1_2$)	85 ($S1_2$)
organic carbon (%), 0-15cm	100 (S1)	20 (N1)	100 (S1)	100 (S1)
Actual Suitability (Linear) (IPc)	**11.25 (N)**	**9.00 (N)**	**15.53 (N)**	**11.25 (N)**
Actual Suitability (Square root) (IPc)	**16.77 (N1)**	**13.42 (N)**	**19.70 (N)**	**16.77 (N)**
Potential Suitability (Linear) (IPp)	**45.0 (S3)**	**62.10 (S2)**	**62.10 (S2)**	**45.0 (S3)**
Potential Suitability (Square root) (IPp)	**47.43 (S3)**	**65.46 (S2)**	**65.46 (S2)**	**47.43 (S3)**

Land evaluation for plantain production

The index of current productivity (IPc) value was 7.33 for pedon CRET-1 and 8.80 for the remaining pedons (CRET-2, CRET-3 and CRET-4) by linear models and were classified as currently not suitable (N) for production of plantain (Table 7). Similarly, the IPc values obtained from the square root model which was 13.54 for pedons CRET-1 and 14.83 for the remaining pedons indicated that the soils were currently not suitable (N) for the production of plantain. In addition to the factors (potential fertility and surface texture) that were identified as the major constrains for oil palm production on these soils, the average annual rainfall in the area is an additional limitation for the production of plantain. According to Ritung et al (2007), rainfall exceeding 2500 mm per annum is unsuitable for the production of plantain. Thus, assuming that all the fertility problems associated with these soils are improved using appropriate technologies (addition of appropriate fertilizers and adoption of appropriate soil management techniques), the potential suitability index (IPp) computed using the linear model were 29.32 for CRET-1 and 40.74 for the remaining pedons. Using the square root model, the IPp value for CRET-1 was 38.29 while the remaining pedons had IPp value of 52.84. This suggests that with improvement in the soil fertility management, pedon CRET-1 will become marginally (S3) suitable for plantain production. Similarly, linear model showed that the remaining pedons will be marginally suitable for plantain production while the square root model showed that these pedon will be moderately suitable upon good management for plantain production.

Table 7: Suitability ratings of land characteristics for Oil Palm production.

Land requirements/Land characteristics	**CRET-1**	**CRET-2**	**CRET-3**	**CRET-4**
Climate (c):				
Annual rainfall (mm)	69 (S2)	69 (S2)	69 (S2)	69 (S2)
Length of dry season (moths)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)
Mean annual temp. (^oC)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)
Topography (t):				
Slope (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Erosion hazard(eh)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)	85 ($S1_2$)
Wetness (w)*:				
Flooding	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Drainage	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Soil Physical Characteristics (s):				
Texture (surface)	50 (S3)	69 (S2)	69 (S2)	69 (S2)
Surface stoniness (Vol. %), 0-10cm	100 (S1)	100 (S1)	100 (S1)	50 (S3)
Rock out crops (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Soil depth (cm)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
Coarse material (%)	100 (S1)	100 (S1)	69 (S2)	69 (S2)
Fertility (f):				
Cation exchange capacity (cmol-kg^{-1}) clay	25 (N1)	25 (N1)	25 (N1)	25 (N1)
Base saturation (%)	100 (S1)	100 (S1)	100 (S1)	100 (S1)
pH H_2O	100 (S1)	65 (S2)	85 ($S1_2$)	85 ($S1_2$)
organic carbon (%), 0-15cm	100 (S1)	40 (S3)	100 (S1)	100 (S1)
Alkalinity (ESP)	100 (S1)	100 (S1)	75 ($S1_2$)	75 ($S1_2$)
Actual Suitability (Linear)	**7.33 (N)**	**8.8 (N)**	**8.8 (N)**	**8.8 (N)**
Actual Suitability (Square root)	**13.54 (N)**	**14.83 (N)**	**14.83 (N)**	**14.83 (N)**
Potential Suitability (Linear)	**29.32 (S3)**	**40.74 (S3)**	**40.74 (S3)**	**40.74 (S3)**
Potential Suitability (Square root)	**38.29 (S3)**	**52.84 (S2)**	**52.84 (S2)**	**52.84 (S2)**

DISCUSSIONS

There was apparent deficiency of all the macronutrient in these soils. This could have resulted from both the nature of the parent material (cretaceous sedimentary sandstone) and high incidence of rainfall (intensity and total amount) which could have resulted in rapid leaching of the cations (FFD, 2011; Akpan-Idok and Ogbaji, 2013). The predominantly low yield of plantain and the characteristic rapid yield decline under field conditions was usually attributed to soil fertility constraints (Irizzarry *et al*., 1989; Swennen, 1990 and IITA, 1995). Even though the base saturation was high, this was due to the low effective cation exchange capacity of the soil. Thus the soil will benefit from application of fertilizers containing appreciable quantity of Ca and Mg since the pH of the soils was acidic (FFD, 2011). To avoid over application of these nutrients, a situation that will lead to toxicity, the use of organic and green manures have been suggested (Abubakar *et al*., 2004). It is our opinion however, that a suitable combination of organic and inorganic fertilizer at appropriate rates after careful laboratory and field studies will be of tremendous importance in solving the problems of low fertility of these soils (Ojeniyi, 2010).

CONCLUSION AND RECOMMENDATION

All the pedons were currently not suitable (N) for production of oil palm and plantain by both linear and square root models eventhough the IPp values computed using the square root model was slightly higher than that of linear model. Pedons CRET-1 and CRET-4 were potentially marginally suitable (S3) for the production of oil palm while pedons CRET-2 and CRET-3 were potentially moderately suitable (S2) for the production of oil palm. For plantain production, pedon CRET-1 was potentially marginally suitable while pedons CRET-2, CRET-3 and CRET-4 were potentially moderately suitable for plantain production. Because of the low ECEC, low fertility status and high rainfall pattern (intensity and quantity), we recommend the use of organic manure for improving the fertility status of these soils for sustainable production of oil palm and plantain.

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