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CHARACTERIZATION, CLASSIFICATION AND LAND SUITABILITY EVALUATION OF SOILS DERIVED FROM DIVERSE PARENT MATERIALS IN CENTRAL CROSS RIVER STATE OF NIGERIA FOR ARABLE CROPPING

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ABSTRACT

The physico-chemical characterization of soils derived from five parent materials in the humid tropics of South Southern Nigeria was studied. Soil properties such as texture, drainage, effective soil depth, nutrients status and reserves were employed for site suitability evaluation for arable cropping (cassava, maize and groundnut). Suitability classifications were arrived at by 'matching' the land qualities with the requirements of the land utilization type (arable cropping). The results indicate that soils of mapping unit (CRCI) derived from alluvium were moderately suitable (S2) for arable cropping, soils of basalt origin (CRC2) were marginally suitable (S3) for arable cropping, soils of sandstone-shale (CRC3) were moderately suitable (S2) for arable cropping, soils of granite origin (CRC4) and soils of gneiss origin (CRC5) were permanently not suitable (N2) for arable cropping on account of permanent limitation of steep slopes (7-18%) and rock outcrops (10-70%) of total surface. The soils were classified into three orders of the USDA Soil Taxonomy as Alfisols (soils derived from basalt, sandstone-shale, granite and gneiss), Ultisols (soils of granite origin) and inceptisols (soils of alluvium). These classifications were appropriately correlated with FAO/ UNESCO soil map of the world reference base (WRB) legend. Limitations observed in the study area included low pH, low nutrient status, steep slopes and gravely/rocky surface soils.

Key words: Characterization, Classification, land Suitability, Arable Cropping.

INTRODUCTION

The soils of Central Cross River State are derived from basalt, basement complex (granite, gneiss, quartzite and schist), sandstone-shale intercalations and alluvium (Ekwueme, 2005; Ibanga and Armond, 1992). Soils of central Cross Rivers State are rarely formed from a single parent material. Usually intrusions and pockets of extraneous materials may be found in areas dominated by a particular rock type (Ekwueme, 2003). Since parent material is one of the significant factors of soil formation, caution must be exercised in identify- ing the native rock or parent material and kind of pedogenic process giving rise to the soil under in- vestigation. Esu (2004) remarked that lack of in- formation on the soil resources of any region con- tributes to the problem of soil degradation and that of world food crises among others, due to wrong uses and poor management of land resources.

Based on its attributes and potential, every land is suitable for a particular land use. Land suitability evaluation is thus the process of assessing the suitability of land for a particular use (FAO, 1976).

Central Cross River State is an agrarian economy depending majorly on arable crops and other cash crops for economic sustenance. Variations existing in the properties of soils formed from diverse parent materials in Central Cross River have not been extensively studied. Hence there is insufficient information to characterize and assess their stability especially for arable cropping. This study essentially sought to characterize, classify and evaluate the suitability of these soils for rainfed arable farming.

MATERIALS AND METHODS

Site Description

The study area lies between latitudes 5020' and 6020'N and longitude 8000' and 9010'E. The mean annual rainfall of the area ranges from 2500-3500mm per annum. Mean annual temperature is always in the range 260C-310C. The relative humidity in the study area varies from 60-70% during the month of January to 70-80% in July. The sun rays are almost vertical over the study area resulting in high intensity solar radiation with a daily 3 -5 hours effective sunshine (Bulktrade and Investment Company Limited, 1989).

Sampling Design/Technique

Five mapping units (CRC 1-5) were identified and classified on the basis of parent materials (Ekwueme, 2005). A stratified random sampling technique was adopted in the study. Two toposequences, were selected per parent material. A total of 28 profile pits were excavated. The profile pits were positioned at the crest, middle slope and valley bottoms of the identified toposequences, except for soils of alluvium whose pits were positioned at the backswamp and levee positions. The toposequences were sited in ovonum and Ediba (Alluvium), Last Motor and Bendeghe Ekiem (Basalt), Ogada and Ekori (sandstone-shale), Kanyang and Ubang (granite) and Okokori and Nsodop (gneiss) Figure 1.

Field Work

The profile pits were dug at the most representative points of observation in each sampling location after identifying the toposequence. Morphological characterization was performed according to FAUO (1990) guidelines. Soil samples were taken from the profiles for routine physico-chemical analysis

Laboratory Analysis

Soil samples for particle size data and chemical analysis were air-dried, crushed and sieved through a 2mm mesh sized sieve.

Particle size analysis was determined by the pipette method (Klute, 1986). Soil credibility index was estimated by evaluating the ratio of sand and silt contents to clay content. Clay dispersion ratio was evaluated by determining the ratio of water dispersible clay to total clay (clay content).

Soil pH was determined in a 1:2.5 soil: water suspension. Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Jackson, 1969). Available phosphorus was extracted by the Bray No. 1 procedure (Bray and Kurtz, 1945), and estimated by the molybdenum blue colour technique (Murphy and Riley, 1962). Exchangeable cations were extracted by leaching the soil with in ammonium acetate solution, Exchangeable K and Na in the extract were determined by flame photometry while exchangeable Ca and Mg were determined by the EDTA methodology. Exchangeable H and Al were determined by the titration method from an extract obtained using 1N HCl solution. The CEC was obtained by the summation method.

Productivity Evaluation Procedure

The Requier productivity index was adopted for use in the study. The actual productivity index

Table 1: Particle Size Analysis and Soil Erodibility Index of Representative Soil Pedons formed on Diverse Parent Materials in Central Cross River State, Nigeria

Parent Material	Soil Terrain	Horizon Designation	Horizon Depth (cm)	Clay %	Silt %	Fine Sand %	Coarse Sand %	Total Sand %	Textural Class	Soil Erodibility Index
Alluvium	Levee	Ape	0-10	51	4	24	21	45	SC	1.0
		Ba	10-35	51	25	18	6	24	C	1.0
		Bag	35-86	57	15	19	9	28	C	0.8
		Bhg	86-130	53	19	20	9	29	C	0.9
	Backswamp	Ap	0-12	27	29	17	17	44	L	2.7
		B	12-41	27	29	22	22	44	L	2.7
		Bhg	41-80	31	27	21	21	42	CL	2.2
		Btg	80-130	33	37	19	11	30	CL	2.0
Basalt	V. bottom	A	0-12	22	20	39	19	58	SCL	3.5
		AB	12-43	54	23	14	9	23	C	0.9
		Bt_1	43-94	63	12	17	8	25	C	0.6
		Bt_2	94-134	68	8	16	8	24	C	0.5
		Bt_3	134-178	66	10	17	7	24		0.5
		A	0-25	45	24	22	9	31	C	1.2
		Bt_1	25-61	67	20	15	5	23	C	0.8
		Bt_2	61-103	61	12	20	7	27	C	0.6
Sand stone - shale	Upper slope	Ap	0-23	22	33	30	15	45	L	3.5
		AB	23-65	36	19	19	26	45	SC	1.8
		BC	65-101	30	19	24	27	51	SCL	2.3
		BCt	101-139	36	13	11	40	51	SC	1.8
Granite	V. bottom	Ap	0-18	26	25	36	13	49	SCL	2.8
		Ba	18-42	30	25	331	14	45	CL	2.3
		Bgh_1	42-83	32	23	32	13	45	CL	2.1
	Upper slope	Ap	0-17	22	13	18	47	65	SCL	3.5
		BC	17-54	26	19	14	41	55	SCL	2.8
		BCt_1	54-92	36	13	20	31	51	SC	1.8
		BCt_2	92-134	36	13	14	37	51	SC	1.8
	V. bottom	A	0-23	16	9	24	51	75	SL	5.3
		AB	23-62	18	13	26	43	69	SL	4.6
		BCt	62-84	22	13	14	51	65	SCL	3.5
Gneiss	Upper slope	Ap	0-17	23	7	44	26	70	SCL	3.4
		BCv	17-41	7	15	25	53	78	LS	13.3
		BCt	41-92	31	19	13	37	50	SCL	2.3
	V. bottom	Ap	0-15	15	11	17	57	74	SL	5.7
		Bge	15-45	12	13	19	56	75	SL	7.3
		Bg	45-84	14	15	23	48	71	SL	6.1

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for soils in the study area was estimated using the equations below (Riquier el a!., 1970; Raji, 1999).

P1 = H x D x P x T x S x Fl……………… (1)

Where P1 productivity index. H = soil moisture, D = drainage, P = effective depth, T= texture, S

Table 2: Chemical Properties of Representative Soil Pedons Formed on Diverse Parent Materials in Central Cross River State

Parent Material	Soil Terrain	Horizon Designation	Horizon Depth (cm)	pH (H_2O)	Org. C ← gKg⁻¹	OM gKg⁻¹	TN →	Na^+	K^+ ← Cmolkg⁻¹	Ca^{2+}	Mg^{2+}	CEC	EA →	Av. P mgKg⁻¹	BS %
Aluvium	Levee	Ape	0-10	5.5	21.1	36.4	1.8	0.24	0.46	17.6	8.4	26.7	0.8	33.8	97.1
		Ba	10-35	5.2	7.0	12.1	0.7	0.24	0.26	18.0	10.0	28.5	2.2	14.9	92.8
		Bag	35-86	4.4	7.4	12.8	0.6	0.24	0.20	14.8	11.0	26.2	2.8	11.9	90.3
		Bhg	86-130	4.2	5.9	10.1	0.6	0.24	0.26	10.2	6.8	17.5	10.4	5.0	62.7
	backswamp	Ap	0-12	4.3	23.1	39.9	2.0	0.24	0.15	3.4	2.6	6.4	7.2	19.9	47.1
		B	12-41	4.1	14.5	24.9	1.4	0.24	0.05	2.0	1.8	4.1	5.2	7.0	44.1
		Bgh	41-80	4.3	7.4	12.8	0.8	0.18	0.10	1.4	1.4	3.1	5.6	10.0	35.6
		Btg_1	80-130	4.3	5.9	10.1	0.4	0.24	0.10	3.0	2.8	6.1	8.4	10.0	42.1
		Btg^2	130-170	4.5	5.9	10.1	0.6	0.22	0.10	3.6	3.8	7.7	8.4	11.9	47.8
Basalt	Upper slope	A	0-12	5.2	19.9	34.3	1.0	0.15	0.13	3.8	3.6	7.7	2.8	19.1	81.1
		AB	12-43	4.9	10.9	18.8	0.9	0.11	0.12	3.6	2.7	6.5	2.1	16.0	75.6
		Bt_1	43-94	4.8	5.6	9.6	0.5	0.12	0.13	3.3	1.8	5.1	1.9	12.6	72.9
		Bt_1	94-134	4.8	5.2	9.0	0.5	0.11	0.12	3.0	1.4	4.6	2.2	11.4	67.6
		Bt_2	134-178	4.7	5.0	8.6	0.4	0.10	0.09	1.6	1.1	2.9	2.0	11.1	59.2
		A	0-25	5.0	22.1	38.1	1.4	0.18	0.12	1.4	2.9	4.6	3.3	6.1	58.2
	V. bottom	Bt_1	25-61	5.3	10.5	18.1	0.9	0.18	0.06	1.2	2.2	3.6	2.8	5.3	56.9
		Bt_2	61-103	5.2	6.9	11.9	0.4	0.18	0.05	1.0	1.8	3.0	2.4	3.4	50.1
Sandstone-shale	Upper slope	Ap	0-23	4.5	18.8	32.4	0.7	0.06	0.31	5.4	4.2	10.0	2.4	2.0	80.4
		AB	23-65	4.5	9.6	16.6	0.7	0.06	0.20	5.2	3.2	2.0	2.0	Trace	80.9
		BC	65-101	4.7	5.0	8.6	0.5	0.6	0.26	6.4	2.4	1.9	1.9	Trace	79.3
		BCt	101-139	4.6	3.1	5.3	0.5	0.6	0.31	6.4	3.6	2.4	2.4	5.0	81.3
	V. bottom	Ap	0-18	5.1	18.0	31.0	1.1	0.06	0.15	11.4	7.0	18.6	1.4	4.0	93.1
		Ba	18-42	6.6	6.9	24.9	1.4	0.06	0.15	10.4	6.2	16.8	1.2	5.0	93.4
		Bgh_1	42-83	6.5	5.4	12.8	0.7	0.06	0.10	10.6	6.2	17.0	1.4	Trace	92.2
		Bgh_2	83-133	6.7	3.8	10.1	0.6	0.12	0.15	12.6	11.0	23.9	0.8	Trace	96.8
Granite	Upper shape	Ap	0-17	4.7	20.3	35.0	1.5	0.06	0.10	1.0	1.4	2.6	5.2	4.0	32.8
		BC	17-54	4.7	9.6	16.5	1.0	0.06	0.5	0.6	1.0	1.7	5.6	3.0	23.4
		BCt_1	54-92	4.7	5.0	8.6	0.4	0.06	0.5	0.6	1.2	1.9	7.2	Trace	21.0
		BCt_2	92-134	4.7	3.4	5.9	0.6	0.06	0.5	0.8	0.4	1.3	6.4	8.0	17.0
	V. bottom	A	0-23	4.7	16.9	29.1	1.4	0.06	0.15	1.8	0.8	2.8	3.6	12.9	43.8
		AB	23-62	4.7	6.9	11.9	2.1	0.06	0.05	0.8	0.8	1.7	3.6	Trace	32.1
		BCt	62-84	5.0	6.1	10.6	0.7	0.06	0.05	1.2	1.2	2.8	1.6	2.0	61.2
Gneiss	Upper slope	Ap	0-17	4.9	23.1	39.8	0.8	0.18	0.10	2.6	1.4	4.3	1.0	11.9	80.8
		BCv	17-41	5.0	10.2	17.5	0.8	0.12	0.05	1.0	1.2	2.4	1.6	10.0	59.3
		BCt	41-92	4.9	7.7	13.2	1.7	0.12	0.10	0.8	1.2	2.2	3.2	3.0	41.1
	V. bottom	A	0-15	4.8	3.8	6.6	0.6	0.12	0.05	2.0	1.4	3.6	1.6	4.0	49.6
		Bge	15-45	4.4	13.0	22.5	0.6	0.06	0.05	1.0	0.4	1.5	0.6	4.0	71.4
		Bg	45-84	4.7	6.5	11.2	0.8	0.06	0.05	0.8	0.8	1.7	0.9	Trace	65.4

= slope, FI = fertility index (consisting of several factors).

The fertility index (FI) was determined from the relationship given below:

FI = Sr x Om x Ce x Mr x Ap (2)

Where Sr = soil reaction, Om = Orange matter. Ce = cation exchange capacity, Mr = mineral reserves, Ap = Available Phosphorus.

The potential indices were computed after all anticipated soil amendment such as liming, fertilization, irrigation and drainage would have been applied to the soil. The potential productivity and fertility indexes were equally estimated using equations 1 and 2.

The coefficient- of improvement, Cl, which estimates the degree of improvement possible at currently acceptable cost, was estimated using equations 3

Cl = PPI/API (3)

Where Cl = coefficient of improvement, PP1 potential productivity index, API = Actual productivity index.

The values were converted to decimal and the resulting product re-converted to percentage. The following percentage ratings according to Requier 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 were assigned productivity classes as indicated below

Class 1 -(65-100%, Excellent)

Class 2 - (35-64%. Good)

Class 3 - (20-34%. Average)

Table 3: Average Physical land Characteristic of soils of Diverse in Central Cross River State

Parent Material	Slope (%)	Slope Rating	Drainage	Drainage Rating	Soil depth (cm)	Depth Rating	Texture	Texture Rating
Alluvium	0-2	N	Very poorly drained	NS	Fluctuates	M	CL,C	S
Basalt	2-4	S	Well drained	N	114	N	SCL,C	S
Sandstone-shale	4-7	M	Well drained	N	144	N	SL,SCL	M
Granite	7-18	NS	Well drained	N	105	N	SC,SL,SCL	M
Gneiss	7-14	NS	Well drained	N	133	N	SL,SCL	M

Key: N - None, S t= slight, m - moderate, NS = Non - suitable. CL = Clay loamy, C = clay. SCL = sandy clay loam, SL = Sandy loam. SC = Sandy clay.

Class 4 - (8-19%, Poor)

Class 5 - (0-8%. Extremely poor).

The productivity classes 1-5 are assumed to correspond to the FAO (1976) Land suitability classes of SI (high), S2 (moderate), S3 (marginal), N1 (currently not suitable) and N2 (permanently not suitable).

RESULTS AND DISCUSSIONS

The texture of the soils in the study area varied according to the different parent materials. Generally fine textured soils were observed in soils of alluvium and basalt. The soils of gneiss origin had

Table 4: Chemical Land Characteristics and Rating of Soils derived from Diverse Parent Materials in Central Cross River State.

Parent Material	Soil pH (H$_2$0)	Rating	Organic Carbon (g/kg^{-1})	Rating	Available Phosphorus mgkg^{-1}	Rating	CEC cmolkg^{-1}	Rating	Base saturation (%)	Rating	Mineral Reserve
Alluvium	Range 3.9-5.5		5.9-24.2		5.0-33.8		2.5-28.5		31.6-97.1		
	Mean 4.5	M	13.2	N	14.4	S	15.6	M	65.7	M	S
Basalt	Range 4.3-5.6		3.9-25.8		3.4-24.9		2.4-9.7		33.8-82.9		
	Mean 4.8	M	11.8	N	10.5	S	4.6	S	63.9	N	S
Sandstone-shale	Range 4.5-6.9		3.1-32.4		trace-7.4		4.5-23.9		72.8-96.8		
	Mean 5.1	S	8.3	N	4.0	M	12.4	N	85.1	N	N
Granite	Range 45-5.1		4.8-32.9		trace-13.9		1.3-8.3		17.0-88.5		
	Mean 4.8	M	11.3	N	4.3	M	2.8	M	46.8	S	S
Gnesis	Range 4.2-4.9		4.2-23.1		trace-11.9		0.9-4.8		41.0-80.8		
	Mean 4.6	M	10.4	N	4.1	M	2.4	M	54.0	N	S

Key N=None, S=Slight, M= Moderate

medium to coarse textures whereas coarse texture soils were encountered in soils derived from granite and sandstone-shale intercalations. This collaborate the findings of Ritter (2006) and Ibanga (2006) who remarked that soils developed over sandstone and granite have coarse textures whereas the weathering of basalt yields soils with fine texture while gneiss results in soils with variable textures (Table 1).

The soil pH in the study area ranged from (pH 3.9-6.9) averaging 4.5, 4.8, 5.1, 4.8 and 4.6 for soils derived from alluvium, basalt, sandstone - shale, granite and gneiss parent materials, respectively (Table 2). The low pH (3.9-6.9) values in the study area are as a result of the high rainfall of 2500-3500mm as reported by Bulktrade and Investment Company Limited (1989) which results in extensive leaching of bases from the soils rooting zones; acid rains and crop removal (Amalu, 1998). These low pH values (high acidity) are indicative of potential micronutrient toxicity problems as equally observed by Enwezor et al., (1981). The low pH values especially in soils of granite, gneiss and sandstone-shale is due to the low content of carbonate minerals (Ca/Mg carbonates) in these parent rocks which according to Mullen et al., (2007), and Akamigbo and Asadu (1993) results in acidic soils.

Values of organic carbon ranged from 3.1 to 32.9gkg-l, averaging 13.2 gkg-1 for soils derived from alluvium, 11.8 gkg -1 for soils of basalt origin, 8.3gkg-1 for sandstone-shale derived soils, 11.3gkg-1 for soils of granite origin and 10.4gkg-1 for soils developed over gneiss parent material (Table 4). The low to medium level of organic carbon of soils in the study area may be due to high clay dispersion ratios and erodibility indexes of most of the soils as also observed by Hudson (1995). The clay dispersion ratio in the study area was in this order of parent materials: sandstone-shale > granite > gneiss > basalt > alluvium. The implication of clay dispersion trends

Table 5: Rating of land qualities and characteristics for Arable Cropping

Land qualities and characteristics	Class requirements and limitation			
	S1(None)	S2(Slight)	S3(moderate)	N1 and 2 (non suitable)
Topography(t):				
Slope	0-2	2-4	4-6	>6
Wetness (w):				
Flooding	Nil	Very slight	Slight	Moderate to very severe
Drainage	Well moderate	Imperfect	Poor	Poor-very poor
Rooting condition (z)				
Surface Texture	SL,L,CL,CSi	VC,VFC,SCL	SL,LF,S	Cm,mSiC,cS,S
Structure	Strong	Moderate	Weak	Structureless
Soil depth (cm)	70	70-40	40-20	<20
Nutrient Availability (f)				
CEC ($Cmolkg^{-1}$)	>5	5-3.5	3.5-2.0	<2
Base Saturation (%)	>50	50-35	<35	
pH (H_20)	6.0-8.2	5.0-6.0	4.0-5.0	<4.0
Available phosphorus ($mgXg^{-1}$)	>20	20-10	<10	

Source: Adapted from, Sys *et al.*, (1991) observed in the study area to pedogenesis is that soils derived from alluvium and basalt with CDR below the critical limited of 0.5 tend to develop faster (high mineralization) with distinct horizons than soils derived from sandstone-shale, gneiss and granites with high CDR prone to leaching and frequent loss of top soils.

Available phosphorus ranged from 1.1 to 33.8 mgkg-1, averaging 14.4mgkg-1 for soil derived from alluvium, 10.5 mkg-1 for soils of granite origin and 4.1 mgkg-1 for soils derived from gneiss parent materials (Table 2), These values were rat-

Table 6: Mean and Range of important Physico-chemical Properties of soils derived from Diverse Parent material in Central Cross River state, Nigeria

Soil Parent Material		Sand (%)	Silt (%)	Clay (%)	PH (H_2O)	Org. C (gkg^{-1})	Total N (gkg^{-1})	Ca	Mg	K	Na $Cmolkg^{-1}$	CEC	EA	BS (%)	AV.P $mgKg^{-2}$
Alluvium	R	29-45	4-37	31-37	3.9-5.5	5.9-24.2	0.4-2.4	1.4-19.1	1.2-13.2	0.05-0.49	0.19-0.24	2.5-28.5	0.8-10.4	31.6-97.1	5.0-33.8
	$\bar{x}$	36	21	43	4.5	13.2	1.1	8.9	6.4	0.21	0.22	15.6	4.9	65.7	14.4
Basalt	R	21-71	6-24	23-67	4.2-5.4	3.9-25.8	0.2-2.2	0.6-5.0	1.4-4.4	0.05-0.20	0.16-0.18	2.4-9.7	1.2-4.8	33.8-82.9	3.4-24.9
	$\bar{x}$	41	14	45	4.8	11.8	1.0	2.1	2.3	0.08	0.17	4.6	2.5	63.9	10.5
Sandstone-shale	R	43-66	19-33	16-36	4.5-6.9	3.1-32.4	0.4-1.4	2.8-12.6	1.8-12.1	0.05-0.38	0.05-0.11	4.5-23.9	0.5-3.6	72.8-96.8	Trace-7.4
	$\bar{x}$	52	21	27	5.1	8.3	0.7	7.2	4.9	0.22	0.07	12.4	1.8	85.1	4.0
Granite	R	50-75	9-19	15-36	4.6-5.8	4.8-32.9	0.5-2.8	0.5-5.6	0.4-2.4	0.03-0.16	0.05-0.06	1.3-8.3	1.1-7.2	17.0-88.5	Trace-13.9
	$\bar{x}$	61	13	26	4.8	11.3	1.2	1.6	1.1	0.07	0.06	2.8	3.5	46.8	4.3
Gneiss	R	43-78	7-19	7-39	4.2-5.0	4.2-23.1	0.3-1.7	0.4-2.6	0.4-1.6	0.04-0.21	0.04-0.24	0.9-4.3	0.6-4.0	41.0-80.8	Trace-11.9
	$\bar{x}$	63	14	23	4.6	10.4	0.8	1.2	1.0	0.08	0.14	2.4	2.1	54.0	4.1

ed medium for soils of alluvium and basalt parent materials and very low for soils derived from sandstone-shale, granite and gneiss. The very low to medium values of available phosphorus in the study area is probably due to the low phosphorus (<1%) in all parent rocks studied as reported by Best (1982) and complicated by the high phosphate fixing capacity of the soils (Udo, 1977).

Values of cation exchange capacity in the study area range from 0.9 to 33.0 cmolkg-1, averaging 15.6cmolkg-1 for soils derived from alluvium, 14.6 cmolkg-1 for soils of basalt origin, 12.4cmolkg-1 for soils developed over sandstone-shale, 2.8cmolkg-1 for soils of granite origin and 2.4cmolkg-1 for soils derived from gneiss (Table 2). The high CEC values of soils derived from alluvium and sandstone-shale is the direct consequence of their possession of medium levels of organic matter (Foth, 1990). The low CEC in soils of granite of gneiss parent materials is indicative of the low levels of colloids (Clay and humus) of these soils (Enwezor et al., 1981).

The percentage base saturation of the soils in the study area in the range of 17.0 to 97.1%, averaging 65.7% for soils derived from alluvium, 63.9% for soils derived from basalt, 85.1% for soils of sandstone-shale origin, 46.8% for soils derived from granite and 54.0% for soils of gneiss origin (Table 4). These values are rated high for soils derived from sandstone-shale, medium for soils developed on alluvium, basalt and gneiss but low for soils of granite origin. This result indicates that the soils in the study area will release cations to growing crops in this order of availability, Sandstone-shale < alluvium ≤ basalt < gneiss. < granite. These observations collaborate the findings of Eshett (1987); Amalu (1998); and Enwezor et al., (1981) working on soils of similar parent materials, who observed that Ca and Mg are the predominant cations in most soils because of their adsorption power. Furthermore, their studies revealed that soils of basalt, shale, sandstone origin dominated in Ca and Mg contents.

Taxonomic Classification of the Soils

CRCI (Soils derived from Alluvium)

The soils of this mapping unit at the back swamp have Histic epipedons as evident in structural units less than 30 cm diameter, high base saturation (by NH4OAc) > 50% or more, high organic carbon content and cambic sub-horizons. They have Aquic moisture regime and are therefore classified under the Inceptisol soil order and as Aquepts at the sub-order level. At the sub group level these soils are classified as Histic Humaquepts due to the presence of Histic sub surface diagnostic horizon (Soil Survey Staff, 2010).

The levee soils were classified as Vertic Dystrudepts at the sub-group level due to their possession of minor cracks (about 5mm) wide within 125cm of soil depth. The F AO/UNESCO equivalent of Histic Humaquepts is Eutric Fluvisols and Vertic Dystrudepts is Dystric Fluvisols,

CRC 2 (Soil derived from Basalt).

The upland soils of basalt parent material (Crest and middle slope) of this mapping unit possess Kandic and argillic sub-surface diagnostic horizons and occur under Udic soil moisture regime qualify placing these soils under Alfisol soil order and as Udalfs at the sub-order level of USDA Soil Taxonomy (Soil Survey Staff, 2010). Due to their possession of more than 50% colours with 2.5YR or redder throughout the entire kandic horizon they, qualify as Typic Rhodudalfs of the sub-group level.

The lowland soils of basalt parent material (Valley bottom) of this mapping unit posses sandy skeletal soil particle size class and about 5% or more zone of plinthization hence these soils are classified under Alfisol soil order and as Arenic

Plinthic Kandiudalfs at the sub-group level. The FAO/UNESCO equivalents of Typic Rhodualfs and Arenic Plinthic Kandiudalfs Vertic Luvisol and Eutric Plinthosols respectively.

CRC 3 (Soils derived from Sandstone-Shale).

The upland soils of sandstone-shale parent material possess kandic and argillic sub-surface diagnostic horizons with base saturation more than 50% by NH4OAc. These soils occur under Udic moisture regime and thus qualify them as Alfisols and Udalfs at the order and sub-order levels. Their possession of skeletons on faces of peds qualify them as Kandiudalfs at the great group level. At the sub-group level these soils are classified as Typic Kandiudalfs (Soil Survey Staff, 2010).

The occurrence of the lowland soils of these mapping units under Aquic moisture regime qualified placing them under Alfisols soil order and as Aqualfs

at the sub-order level. Due to their possession of sandy particle size throughout a layer extending from the mineral soil surface to the top of the kandic horizon at depth of 50cm to 100cm, these soils are classified as Arenic Kandiaqualfs at the sub-group level. The FAO/UNESCO equivalent of Typic Kandiudalfs and Arenic Kandiaqualfs is Arenic Luvisols and Euric Fluvisols.

CRC 4 (Soils of Granite Origin)

The upland soils of granite origin possess kandic sub-surface diagnostic horizons. These soils have low base saturation less than 35% by NH4OAc with very gravely sub soils, and occur under Udic moisture regime, qualify their placement under the Ultisol soil order and as Udalfs at the sub-order level. Their possession of Kandic sub-surface horizons and more than 50% of colours with hue of 2.5YR, qualify these soils as Kandiudults at the great group level. These soils are further classified as Rhodic Kandiudults at the sub-group level due to their having low CEC less that 24cmlkg-1 by NH4OAc.

The occurrence of the low land soils of this mapping unit under aquic moisture regime and possession of horizons having at least 25cm thick layers within 100cm of the mineral soil surface with recognizable bioturbation, qualifies these soils as Vermaqualfs at the great group level. These soils are classified as Typic Vermaqualfs at the sub-group level (Soil Survey Staff, 2010). The FAO/UNESCO equivalent of Kanhaplic Rhodustalfs and Typic Vermaqualfs is Hapiic Luvisols and Dystric Fluvisols respectively.

CRC 5 (Soils of gneiss origin)

The upland soils of gneiss origin were characterized with ochric surface and argillic sub¬surface horizons. These soils have medium base saturation (>50% by NH4OAc) and occur under Udic moisture regimes. These soils are thus classified under the Alfisol order. Their possession of evidence of plinthization, qualify their classification as typic plinthudalfs at the sub-group level. The presence of recognizable bioturbation in the top soils of valley bottom pedons and their occurrence under Aquic moisture regime, qualify the low land soils of gneiss origin as Typic Vermaqualfs at the sub-group level. The FAO/UNESCO equivalents of Typic Plinthudalfs and Typic Vermaqualfs is Eutric plinlhosols and Eutric Fluvisols respectively.

Land Suitability Evaluation for Arabic Cropping.

All the soils in the study area were observed to occur within zones with the ecological requirements for arable crops as was deduced from rainfall and other climatic data of the study area (Udoh et al., 2005). The arable crops under consideration include cassava, maize and groundnut.

The actual productivity index of soils derived from alluvium representing about 14.1% of the study area was 38% and rated moderately suitable (S2) for arable crops (Table 7). However if the limitations of poor drainage and high acidity are removed, a potential productivity index of 76% is possible thus making these soils highly suitable (SI) for arable cropping. The low coefficient of improvement (Cl) is indicative of the low cost with which these soils can be improved to a higher suitability class.

The actual productivity index of soils of basalt origin representing about 5.7% of the study area was 23% and rated marginally suitable (S3) for arable crops. However, if the limitations of low pH and poor fertility are corrected through liming and fertilization, a potential productivity of 81% is achievable, thus making these soils highly suitable (SI) for arable cropping (Table 7).

Soils of sandstone-shale origin representing 55.3% of the study area had an actual productivity index of 9% and rated currently not suitable (Nl) for arable crops on account of root zone limitation and poor fertility status. The removal of these limitations through appropriate erosion control mechanisms and proper fertilization will make the soils moderately suitable (S2) for arable crop (Table 7).

The actual productivity of soils developed from granite representing 3.3% of the study area was 10.81% and rated permanently not suitable (N2) for arable crops on account of poor rooting zone (coarse fragment contents), very steep slope (7-18%) and rock outcrops (10-70%) of total surface. Only the application of fertilizer which can correct the poor fertility status is feasible, thus it is only possible for these soils to be improved to currently not suitable (Nl) for arable crops (Table 7).

The soils of gneiss origin representing 21.6% of the study area had actual productivity index value of 3% rated permanently not suitable (N2) on account of poor fertility and steep slope (7-14%). However if the fertility limitation is tackled through adequate manuring, fertilization, and erosion control, it is possible for these soils to have a potential productivity index of 22% and could be

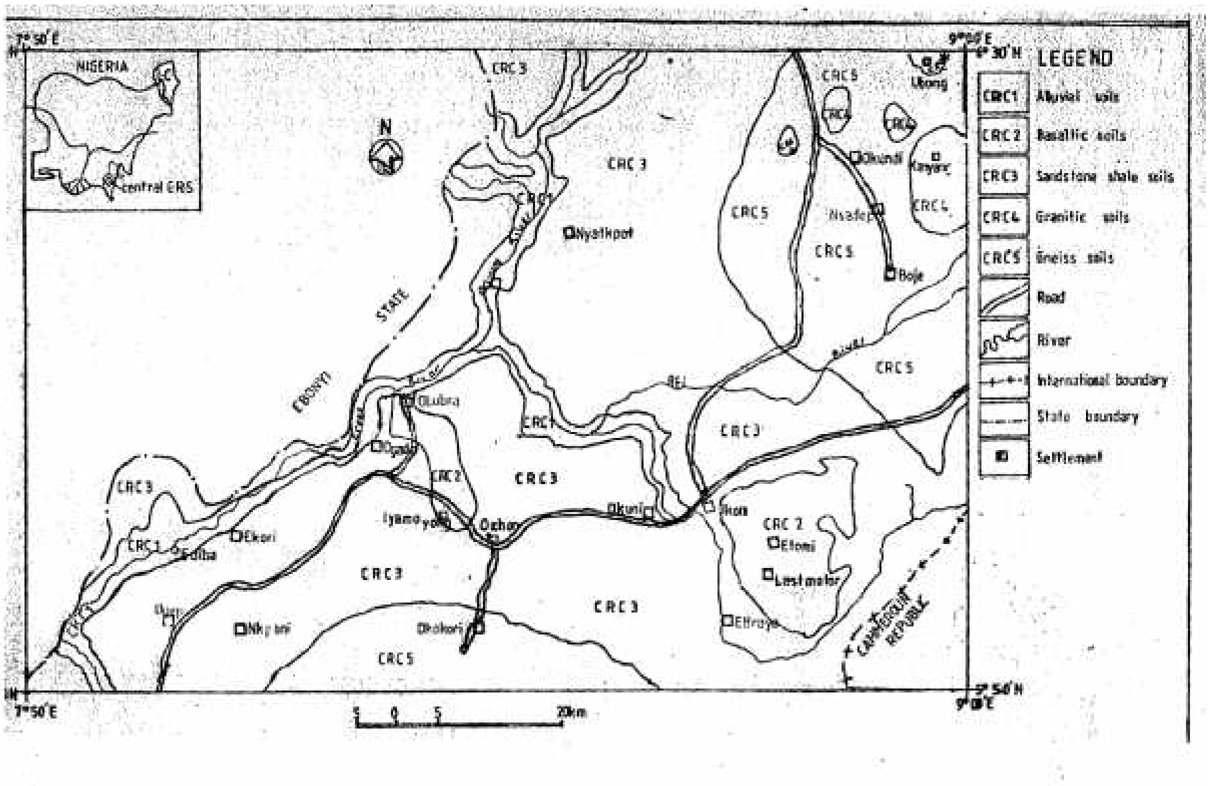

Figure 1: Land Suitability Map of Central Cross Rivers State for Arable Cropping

Table 7: Actual and Potential Land Suitability Classification of the Soils Mapping units for Arable Cropping

Soil Parent Material	Soil Mapping Unit	Approximate Land Area (km^2)	Actual Land Suitability class	Potential Land Suitability
Alluvium	CRC1	10.654.9	S2w	S1
Basalt	CRC2	4307.3	S3f	S1
Sandstone-shale	CRC3	41788.5	N1fz	S2z
Granite	CRC4	2493.7	N2tzf	Ntz
Gneiss	CRC5	163322.5	N2tzf	S3tz

Key: w =wetness, f = fertility, z =root zone limitation, t=topography (steep slope).

rated marginally suitable (S3) for arable crops. The detailed suitability map is shown in Figure 1.

The high coefficient of improvement for soils derived from granite and gneiss is indicative of the fact that these soils require high cost for their improvement, which is not cost effective and not advisable, for the cultivation of arable crops, the suitability of the soils studied is in this order of preference of parent materials: alluvium > basalt > sandstone-shale > gneiss > granite. However other uses could be made of soils of low degree of suitability. The land occupied by these soils can be put to afforestation programme / tree crops. The percentage occurrence of the soil orders in the study area is about 80.2% (Alfisols), 14.1% (Inceptisols) and 5.7% (Ultisols). Their percentage occurrences in the study area are CRC 1 (soils derived from alluvium) 14.1%, CRC 2 (soils of basalt origin) 5.7%, CRC 3 (soils derived from sandstone-shale) 55.3%, CRC4 (soils of granite origin) 3.3% and CRC 5 (soils of gneiss origin) 21.6%.

CONCLUSION

Soil characterization, classification, suitability evaluation and mapping are the necessary ingredients required for enhanced productivity of our soils. This will ensure food security as well as for the assessment of availability of environmental conditions for various uses, thus ensuring environmental sustainability. Land suitability evaluation enables more accurate and useful predictions to be made for specific purposes and eliminates costly and avoidable mistakes, hence incidence of soil degradation emanating from land misuse will be reduced.

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