

# MORPHOLOGICAL CHARACTERISTICS AND CLASSIFICATION OF SOILS DERIVED FROM DIVERSE PARENT MATERIALS IN CENTRAL CROSS RIVER STATE, NIGERIA

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## ABSTRACT

Variation in soil characteristics is usually a reflection of the difference in materials from which the soil was formed. This study sought to investigate the characteristics of soils formed on different parent materials with a view to classifying them. This study was carried out in selected soils derived from three major types of parent materials in central Cross River State, South Eastern Nigeria. A total of six (6) pedons were excavated, two (2) pedons in each of the identified parent materials. The parent materials were Sandstone-shale-siltstone intercalations. Basement complex and Basalt. The study indicated that soils derived from sandstone-shale-siltstone materials are characterized by ochric sandy loam and loamy sand epipedons with moderate medium sub-angular blocky structures. These soils are also light coloured with dominant hues of 7.5YR with hard to slightly hard and hard to very hard dry consistence at the surface and sub-soil respectively. Soils of basement complex are characterized by the possession of loamy sand epipedons with weak medium crumb and sub-angular blocky structures having predominantly dull yellowish brown and bright yellowish brown colours at the surface and sub-soils. The dry consistences of the surface soils are slightly hard while the sub-soils are hard to very hard. The Morphology of basaltic soils is characterized by sandy loam to clayed texture with strong medium to moderate medium sub-angular block structures. These soils are deep in effective depth and dark reddish brown in colour. Its dry consistence is usually hard to very hard to very hard. Soils of sandstone – shale-siltstone and basement complex origin are classified as Topic Tropustalfs while those of basalt origin are classified Topic Tropustults. Proper fertilization and irrigation programmes based on their inherent characteristics will make these soils more productive and enhance their potentials for sustainable agricultural use.

**KEY WORDS:** Parent materials, Soil Morphology and sustainability

## INTRODUCTION

Spatial variability and changes in many soil properties including morphological characteristics are common in the various regional soils of the world. Akamigbo and Asadu (1983) observed that parent material has very significant influence on the overlying soil when the soil is formed in-situ from the parent material. Common variability in the appearance of profiles dug close to one another is usually a reflection of the differences in materials from which the soil was formed (Resell, 1973). Different parent materials exhibit different coloration as well as their weathered products Ekwueme *et al.*, (1995) noted that most outcrops of schists are brownish in colour due to the effect of intense tropical weathering whereas fresh outcrops occurring in stream and river channels are greenish in colour. Nyong (1985) described shale as dark thin materials while Petters (1995) described shale as black to dark grey materials, and sandstones and mudstones as yellowish. Consequently, soils derived from these materials exhibit these colorations.

Amongst the Morphological properties, texture exhibits the greatest uniformity especially within short distances apart. Russell (1973) remarked that once formed. Soil texture remains relatively static over very long period of time. Most soils exhibits variable soil texture at the topsoil layers with an increasing fineness with depth (Amalu, 1998). Soil structure and consistence are highly variable morphological characteristics influenced by the soils mineral composition. Webster and Wilson (1980) Observed that iron-rich parent materials such as basalt and dolerite will weather to give soil high in iron and of good structure while granites low in iron but high in quartz will weather into weakly structured soil. Soil structure and texture influence its consistence characteristics.

The productive potential of any soil depends on its morphological characteristics Properties such as structure, texture, consistence etc influence the fertility status of soils.

These properties determine the cation exchange capacity, water holding capacity, aeration, porosity and temperature of the soil. The objectives of this study were to identify the morphological characteristics of soils of Central Cross River State, Nigeria and classify them in order to highlight their inherent potentials for increased productivity.

## MATERIAL AND METHODS

This study was carried out in selected soil derived from three major types of parent materials in Central Cross River State, Nigeria. Central Cross River State lies between longitudes 8<sup>00</sup> and 9<sup>10</sup> E and Latitude 5<sup>20</sup> and 6<sup>20</sup>N. It covers Yakurr, Abi, Obubra, Ikom, Etung and Boki Local Government Areas (Figure 1). These study sites were selected based on previous works of Ekwueme, *et al.*, (1995) and Bultrade and Investment Company Limited (1989) on the geology and geomorphology of South-Eastern Nigerian and Cross River State.

A total of six (6) profile pits (pedons) were excavated, two (2) in each of the three identified parent materials. The parent materials studied were derived from Basement complex, Sandstone-shale-siltstone intercalation and Basalt geology.

Morphological properties such as colour, structure, consistence, mottles, cutans, pores, concretions, horizon boundaries and designation were assessed and described according to procedures outlined in the FAO Guideline (FAO, 1977). The particles size distribution (Texture) was determined by the Bouyoucos hydrometer method (Klute, 1986). Soil pH was determined in a 1.2.5 soil: Water suspension using glass electrode pH meter. Organic carbon was determined by the dichromate wet oxidation method of Walkey and Black (Jackson, 1969). Available Phosphorous was extracted by the Bray N0. 1 procedure (Bray and Kurtz, 1945) and estimated by the molybdenum blue colour technique (Riley, 1962). Exchangeable cations (Ca<sup>++</sup>, Mg<sup>++</sup>, K<sup>+</sup>, Na<sup>+</sup>) were extracted by

leaching the soil with 1 N ammonium acetate solution (pH 7.0). Exchangeable K and Na in the extract were determined using a flame photometer while the exchangeable Ca and Mg were determined using the persenate titration method. Exchangeable H and Al were determined by the titration method from an extract obtained using 1N KCl solution (McLean, 1865). The cation -exchanged capacity (CEC) at pH 7 was estimated using the NH<sub>4</sub>OAc method (Jackson, 1969)

and finally the base saturation (BS) Percentage was determined using the relationship.

$$BS (\%) = \frac{\sum (\text{Exch. Bases})}{\sum \text{Exch. Bases} + \sum \text{Exch. Acidity}} \times 100$$

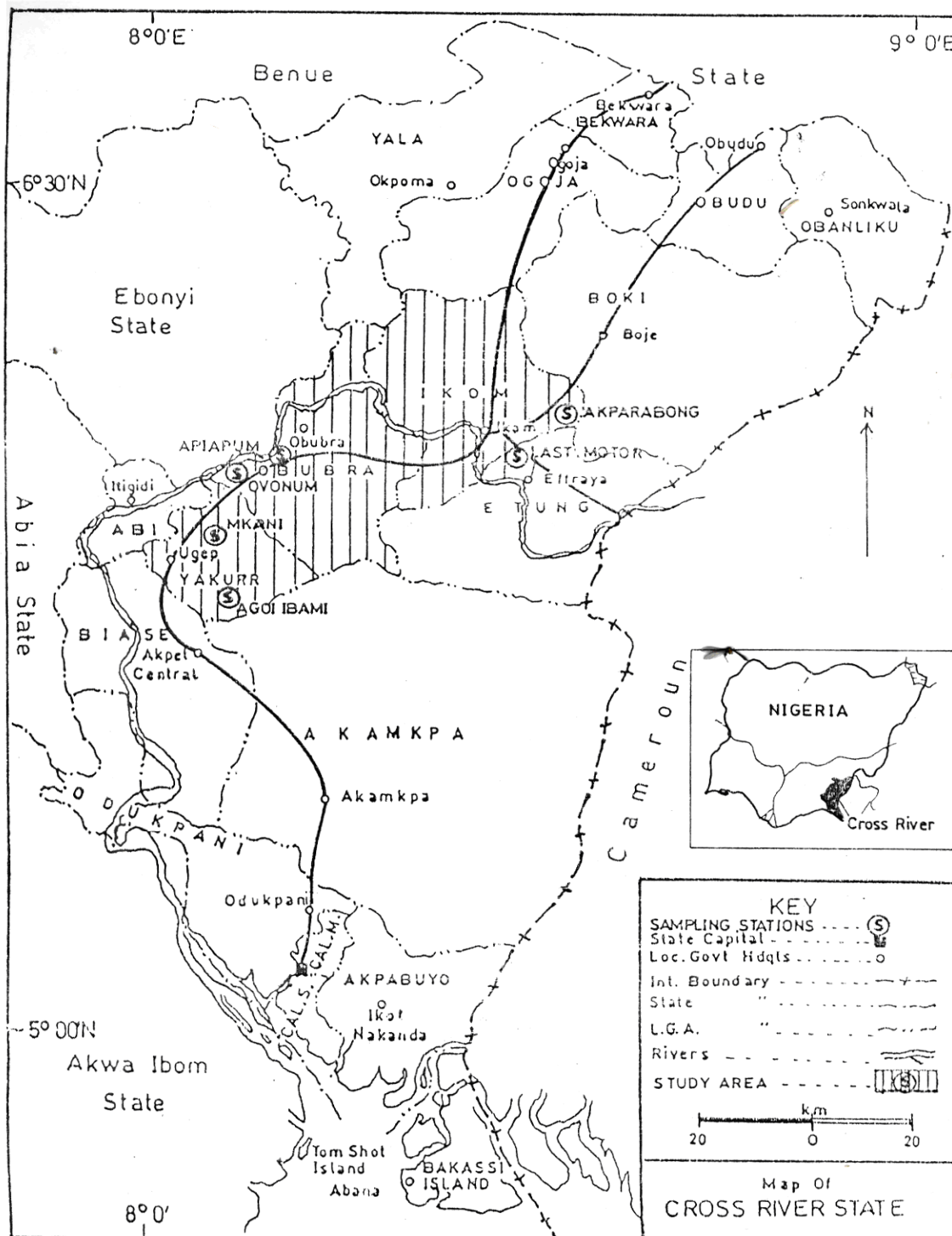


Fig 1: Map of Cross River State Nigeria showing Sampling Stations/ study Area

## RESULTS AND DISCUSSIONS

**Morphological Characteristics**

The morphological descriptions of the pedons studied are presented in Table 1. Under moist condition, the soils pedons 1 and 2 derived from sandstone-shale – siltstone intercalations are light coloured (dull brown to bright brown) with dominant hues of 7.5 YR. Occasionally, the sub-soils were orange coloured. The soils are characterized by ochric sandy loam and loamy sand epipedons with moderate medium sub-angular blocky structures. The surface aggregates are fragile and can readily shatter under rainfall of moderate to high intensity thus making them vulnerable to erosion (Hudson, 1995). The dry consistence was hard to slightly hard at the surface and hard to very hard at the sub-surface. Under moist conditions, the soils were firm to friable at the surface and the sub-soils firm to very firm.

The was consistence for surface horizons was sticky to slightly plastic and sticky plastic while the sub –soils were very sticky plastic due to high illuviation of clay giving rise to argillic sub-surface diagnostic horizons (Esu, 1999). Common to many, fine to medium root dominated the pedons. The pore distributions decreased with increasing soil depth (Table 1). The horizon boundary characteristics were gradual and wavy.

Under moist conditions, soil derived from the basement complex (granite, gneiss, quartzite and schist) materials were characterized by dull yellowish brown and dull brown surface colours. The sub-soils were yellowish brown, bright yellowish brown and orange (FDALR, 1990). These soils possess ochric loamy sand epipedons with weak medium crumb and sub-angular blocky structures. The dry consistence of the surface soils were hard to very hard. Under moist conditions basement complex soils were very friable at the surface but were friable, firm to very firm at the sub-surface. The friable to very friable consistence of these soils suggest a rapid permeable property that is significant in assessing the suitability of soils for irrigation (Hudson, 1995). Wet consistence of the soils revealed that the soils were non-sticky and plastic or slightly sticky and non-plastic at the surface whereas the sub-soils were sticky and plastic to non-sticky and plastic (Table 1). The study indicates that common medium, few fine, few medium and many medium root occurred in all pedons studied (Table 1). The horizon boundary characteristics were either clear or gradual and wavy.

The soils derived from basalt parent material were all reddish brown, dark reddish brown, bright reddish brown and bright brown (Table 1). These soils were deep, sandy loam to clay with strong medium to moderate medium sub-angular blocky structures (Eshett, 1987). There was a progressive increase in clay with depth in all the pedons studies. The consistence were hard to very hard (dry); firm (moist); and sticky – plastic to very sticky- plastic (wet). The clay content presented for basaltic soil in Table 1, give reasonable grounds for suspecting the presence of argillic horizon, which relates to increasing clay content down the profile due to illuviation – illuviation processes (Esu, 1999). Many medium, many medium – coarse, many fine – medium and few fine roots dominated the pedons. The pore distribution decreased with increasing soil depth, with some deep cracks occurring at great depth of the soil (up to 110 cm). The horizons boundaries were commonly gradual and wavy.

## CHEMICAL CHARACTERISTICS

The results of the chemical characteristics of the soil studied are presented in Table 2. The soil reaction ranged from pH 4.6 to pH 5.9 indicating that the soils were commonly very strongly to moderately acid in reaction. These high acidic content of these soils is tactical of most upland soils of Eastern Nigeria, because of the high rainfall and intensive leaching experienced in the area (Amalu, 1998).

The result also revealed that soils derived from sandstone –shale- siltstone intercalation were low in organic carbon and total nitrogen with values ranging from 3.0-to 10.3 –g/kg; and 0.1-to 0.6-g/kg respectively. These low values are due to the volatilization of carbonates and nitrates as result of constant bush burning experienced in the area (Ibanga, 2002). The study also indicated that available phosphorus content ranged from 1.42-to 5.56- mg/kg, and was rated low. Amongst the exchangeable cation, calcium ranged from 1.0- to 3.6 – cmol/kg, rated low to medium, magnesium ranged from 0.6- to 2.7- cmol/kg rated medium to high; potassium ranged from 0.07 – to 0.15-cmol/kg, rated low to medium; while sodium ranged from 0.05 to 0.013 - cmol/ kg and was rated low. Cation exchange capacity ranged from 4.76 –to 11.06- cmol/kg and was rated low to medium.

The chemical characteristics of Basement complex soils represented by pedons 3 and 4 are presented in Table 2. The result showed that organic carbon content ranged from 1.4 – to 11.9 – g/kg rated low to medium, total nitrogen ranged from 0.1- to 0.6- g/kg, rated low. Available phosphorous was low (1.38 – 4.69 – mg/kg). Values of exchangeable cation indicated that calcium was low to medium (1.6 – to 4.0 – cmol/kg); magnesium was medium to high (1.0-to 2.8 – cmol/kg); potassium was low to medium (0.09- to 0.18 – cmol/kg); while sodium was medium to high (0.07 – to 0.13 – cmol/ kg). The cation exchange capacity (C. E. C.) values were rated low to medium (5.07 – to 11.71-cmol/kg).

The basaltic soils had medium to high values for organic carbon (8.6-to 19-9-g/kg) and medium to high values for organic matter that was due to the high leaf litter accumulation having been under fallow for more than four (4) years. Values of total nitrogen were rated low (0.3 – to 1.0-g/kg). This is due to the high nitrogen losses as a result of leaching of nitrate and crop removal. Available phosphorous content ranged from 2.76 – to 4.44 – mg/kg, and rated low. These low values of phosphorous are as a result of the low  $P_2O_5$  percentage (0.35%) content of Basaltic parent materials (Best, 1982); and further complicated by the high fixing capacity of soils dominated by expanding clays (Russell, 1973). The soils had low to medium levels of calcium (1.2 –to 3.8 –mg/kg); medium to high magnesium (0.6 – to 2.6 – cmol/kg), and low values of potassium (0.08 – to 0.13 cmol/kg) and low values of sodium (0.05 – to 0.10 –cmol/kg). The cation exchange capacity (CEC), was low to medium (4.24 – 10.03-cmol/kg). The low to medium values of CEC are indicative of the low nutrient reserves caused by high intense leaching resulting from the high rainfall experience in the area (Jones, 1973).

In view of the above, the soil derived from basement complex and sandstone – shale-siltstone intercalation can be managed through appropriate split fertilization programmes especially of the primary nutrients (nitrogen, phosphorus and potassium) and overhead (sprinkler) irrigation techniques. Basaltic soils can best be managed through proper basal fertilization and drip irrigation method. These management practices would make the soils more productive and enhance their potentials.

Table 1: Some Morphological and Chemical Characteristics of Soils Derived from Diverse Parent Materials in Central Cross River State, Nigeria

Horizon Designation	Depth (cm)	Colour (moist)	Texture	Structure	Consistence			Roots	Pores	Horizon Boundary	Clay %	Organic matter (g/kg)	Base Saturation (%)
					Dry	Moist	Wet						
<b>SOILS DERIVED FROM SANDSTONE-SHALE –SILTSTINE INTERCALATION</b>													
PEDON 1 (MKPANI)													
Ap	0-15	7.5YR 5/4	SL	2m sbk	h	f	s-sp	mf	mf-m	gw	8	10.2	45.16
AB	15-42	7.5YR 5/6	SL	2c sbk	h	f	sp	cf	cf	gw	12	9.5	36.97
Bt 1	42-73	7.5YR 6/6		3c sbk	vh	vf	vs-p	cf	cf	gw	28	5.2	50.5
Bt2	73-109	7.5YR 6/6	SCL	3c sbk	vh	vf	vs-p	fc	mc		36	7.6	48.28
PEDON 2 (APIAPUM)													
A	0-27	7.5YR 3/4	LS	2m sbk	sh	fr	ss-p	mc	mm	gw	3.5	17.8	61.34
Bt	27-62	7.5YR 5/4	SCL	2m sbk	h	f	sp	mm	cf	gw	20.3	8.8	56.98
BCt	62-106	7.5 YR 5/6	SCL	3m sbk		f	vs-p	ff	cf		22	6.6	59.07
<b>SOILS DERIVED FROM BASEMENT COMPLEX</b>													
PENDON 3 (AGOI IBAM)													
A	0-32	10YR 5/4	LS	1m cr	sh	vfr	ns-p	cm	mf	cw	3.7	20.6	75.54
Bt 1	32-71	10YR 5/8	SCL	1m sbk	h	f	sp	ff	fc	gw	27.7	5.2	40.56
Bt 2	71-110	10YR 6/8	CL	2m sbk	h	f	vs-p	fm	cm		30.7	4.5	39.35
PENDON 4 (AKPARA BONG)													
Ap	0-23	7.5YR 6/3	LS	1m sbk	sh	vfr	ss-np	mm	cf	gw	3.7	5.2	65.29
B	23-48	7.5YR 6/6	LS	1m cr	h	fr	ns-p	mf-m	fm	aw	4.7	2.4	57.54
BC t	48-89	7.5YR 6/6	SCL	2m sbk	vh	vf	sp	ff	cn		24.7	4.8	61.3
<b>SOILS DERIVED FROM BASALT</b>													
PENDONS 5 (LAST MOTOR)													
A	0-17	2.5YR 4/6	SL	3m sbk	h	f	sp	mm	cf	gw	19.7	34.4	58.29
Bt1	17-49	5YR 5/6	C	2m sbk	h	f	sp	mm	fc	gw	55.4	18.8	40.18
Bt 2	49-101	5YR 5/6	C	2m sbk		f	vs-p	cm	fm	gw	63.4	9.3	29.17
Bt 3	101-161	5YR 5/6	C	2m sbk		f	sp	ff	ff		67.4	8.6	30.19
PENDONS (EFFREYA)													
A	0-14	2.5YR 3/3	C	3m sbk	v-h	f	vs-p	mm-c	mm	gw	41.4	17.8	64.14
Bt 1	14-65	2.5YR 4/6	C	2m sbk		f	vs-p	mf-m	cm	gw	57.4	17.1	49.54
Bt 2	65-114	2.5YR 4/6	C	2m sbk		f	vs-p	ff	Fm		65.4	6.2	45.76

**Table 1: Key**

1. TEXTURE: S= sand, LS= loamy sand, SL = sandy loam, SCL = sandy clay loam, C= clay
2. STRUCTURE: 1 = weak, 2= Moderate, 3 = strong, f = fine, m= medium, c = coarse, cr = crumb, sbk = sub-angular blocky.
3. COLOUR: 7.5YR 5/4 = Dull brown, 7.5YR 5/6 = Bright brown, 7.5YR 6/6 = Orange, 7.5YR 3/4 = Dark brown, 10YR 5/4 = Dull yellowish brown, 10YR 5/8 = yellowish Brown, 10YR 6/8 = Bright Reddish brown, 2.5 YR 5/6 = Dark Reddish brown.
4. CONSISTENCE: h =hard, vh = very hard, sh = slightly hard, f= firm, vf= very firm, fr = friable, vfr =very friable, s-sp = sticky – slightly plastic, sp = sticky plastic, vs-p = very sticky – plastic, ss – p = slightly sticky – plastic, ns – p = non sticky- plastic, ss – np = slightly sticky- non- plastic, ns-p = non sticky-plastic.
5. ROOTS: mf = many fine, cf = common fine, fc- few coarse, mc = many coarse, mm = many medium, ff = few fine, cm = common medium, fm=few medium. mf –m = many fine medium, mm-c= many medium – coarse.
6. PORES: mf – m = many fine – medium, cf = common fine, mc= many coarse, mm= many medium, mf = many fine , fc =few coarse cm= common medium, fm = few medium, ff-few fine.
7. BOUNDARY: g = gradual, a = abrupt, w = wavy, c = clear

Table 2: Some Chemical Properties of representative Profiles

Horizon Designation	Horizon thickness (cm)	pH (H O)	Organic carbon g/kg	Total N g/kg	Available phosphorus mg/kg	Exchangeable cations			Na	H+Al	CEC
						Ca	Mg	K Cmol/kg			
<b>SOILS DERIVED FROM SANDSTONE –STONE –SILTSTONE INTERCALATION</b>											
<b>PENDON 1 (MKPANI)</b>											
Ap	0-15	4.85	5.9	0.5	4.81	1.4	1.2	0.11	0.09	3.4	6.2
AB	15-42	4.9	5.5	0.5	4.99	1	0.6	0.09	0.07	3	4.76
Bt 1	42-73	5	3	0.2	5.56	1.6	0.8	0.09	0.06	2.5	5.05
Bt 2	73-109	4.89	4.4	0.4	5.5	1.8	0.6	0.07	0.05	2.7	5.22
<b>PENDON 2 (APIAPUM)</b>											
A	0-27	5.31	10.3	0.6	5.21	3	1.9	0.08	0.1	3.22	8.33
Bt	27-62	5.02	5.1	0.4	3.03	2.8	2.5	0.11	0.1	4.16	9.67
BCt	62-106	4.56	3.8	0.1	1.42	3.6	2.7	0.15	0.08	4.53	11.06
<b>SOIL DERIVED FROM BASEMENT COMPLEX</b>											
<b>PENDON 3 (AGOIBAMI)</b>											
A	0-32	5.32	11.9	0.6	4.69	4	2.4	0.15	0.12	2.16	8.83
Bt 1	32-71	4.74	3	0.1	2.06	1.8	2.8	0.09	0.06	6.96	11.71
Bt 2	71-110	4.85	2.6	0.2	1.38	2	1.8	0.1	0.07	6.12	10.09
<b>PENDON 4 (AKPARABONG)</b>											
Ap	0-23	5.92	3	0.2	2.06	2	1	0.18	0.13	1.76	5.07
B	23-48	5.9	14	0.1	2.25	1.6	1.2	0.17	0.12	2.28	5.37
BCt	48-89	5.03	2.8	0.2	1.5	3.6	1.8	0.15	0.09	3.56	9.2
<b>SOILS DERIVED FROM BASALT</b>											
<b>PENDONS 5 (LAST MOTOR)</b>											
A	0-17	5.28	19.9	1	4.44	3.8	1	0.13	0.1	3.6	8.63
Bt 1	17-49	4.93	15.9	0.9	3.31	1.2	2.6	0.12	0.1	6	10.03
Bt 2	49-101	4.98	10.4	0.5	3	1.4	0.8	0.13	0.1	5.9	8.33
Bt 3	101-161	4.9	10	0.4	2.96	1.4	1	0.09	0.07	5.92	8.48
<b>PENDON 6 (EFFRAYA)</b>											
A	0-14	5.4	10.3	1	4.38	2.6	1.2	0.1	0.07	2.22	6.19
Bt 1	14-65	5.1	9.9	0.8	2.94	1.4	0.6	0.08	0.06	2.18	4.32
Bt 2	65-114	5.44	8.6	0.3	2.76	1.2	0.6	0.09	0.05	2.3	4.24

### Taxonomic Classification of the soils

The soils under investigation were classified according to the USDA soil taxonomy (Soil Survey Staff, 1994) and correlated with the FAO/ UNESCO legend of World Reference Base (WRB) system. FAO/UNESCO, 1974). These two systems are commonly used in Nigeria for soil classification and mapping.

The low pH, low to medium cation exchange capacity and the presence of argillic horizons in the soils derived from basement complex and sandstone – shale- siltstone intercalated parent materials qualified classifying these soil Alfisols (Soil Survey Staff, 1994). The soil moisture regime is ustic with a hyperthermic soil temperature regime, hence these soils can be classified as ustalfs at the sub-order level. Their occurrence under tropical climatic conditions permits their placement as Tropustalfs in the Great Group level. In view of the fact that these soils are widespread in Central Cross River State, and their characteristics coarse texture, the soils can further be classified at the sub-group level as Typic Tropustalfs. The Federal department of Agricultural Land Resources (FDALR) 1990, classified similar soils occurring under udic moisture regime as Typic Tropudalfs. Further classification of these soils based on the USDA soil Taxonomy

as the family level is presented in Table 3. The FAO/UNESCO legend or WRB system classification equivalent of Typic Tropustalfs is luvisols.

Basaltic soils with low pH values, low to medium cation exchange capacity and having soils with high shrink-swell properties with deep wide cracks and high base saturation qualified these soils to be classified as ultisols (Soil Survey Staff, 1994). Their existence in a region of ustic soil moisture regime with a hypothermic soil temperature regime suggests their placement as ustults at the sub-order level while their occurrence in the Tropics permits their classification as Tropustults in the Great Group level. In consideration of its characteristics reddish-brown coloration, enormous rooting depth and its geographic spread in Central Cross River State, South Eastern Nigeria, permits its further classification as Typic Tropustult at the sub-group level. The family level classification of these soils is presented in Table 3. Eshett (1987) classified the basaltic soil of Ikrom as Typic Trophumults, fine clayed whereas Esu (2005) remarked that ultisols are associated with basaltic parent materials. The FAO/UNESCO legend equivalent of Typic Tropustult is vertisols (Table 3).

**Table 3: Taxonomic Classification of the Soils**

PEDON	PARENT MATERIAL	USDA SOIL TAXONOMY	FAO/UNESCO LEGEND (WRB)
1.	Sandstone –shale-siltstone	Typic Tropustalf sandy clay loamy isohyperthermic	Luvisols
2.	Sandstone-shale -siltstone	Typic Tropustalf sandy clay loamy isohyperthermic	Luvisols
3.	Basement complex	Typic Tropustalf clay loam isohypermic	Luvisols
4.	Basement complex	Typic Tropustalf loamy sand isohyperthermic	Luvisols
5.	Basalt	Typic Tropustult clayey isohyperthermic	Vertisols
6.	Basalt	Typic Tropustult loamy sand isohyperthermic	Vertisols

### CONCLUSION

Soil derived from different parent materials are distinct in a number of morphological characteristics such as colour, texture, structure, consistence, nature of pores and chemical characteristics such as Ph, content of organic carbon, total nitrogen, available phosphorus, exchangeable cation, cation exchange capacity and base saturation.

Soils derived from sandstone-shale –siltstone intercalations and basement complex parent materials were coarse textured and poorly structured. These soils tend to have low water holding capacities and low cation exchange capacities but are easy to cultivate. On the other hand basaltic soils are well structured; cool and hard to cultivate; fine textured with high water holding capacity. These characteristics highlighted are pre-requisite requirements whenever soil management practices such as irrigation, liming, maturing and fertilizer application are being contemplated.

The USDA soil taxonomy grouping of the soils studied revealed that the soils formed on sandstone-shale-siltstone intercalations and basement complex materials were classified as Typical Tropustalfs while those of basaltic origin were classified as Topic Tropustult. The FAO/UNESCO legend or world reference base (WRB) system classification equivalents are luvisols and verticals respectively (Table 3).

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