A Comparative Analysis of Morphological and Physico-Chemical Characterization of Soils of Southern Cross River State -Nigeria

Moses Abua[1]

[1] University of Calabar Calabar a Nigeria.

Received: 6 June 2012 Accepted: 30 June 2012 Published: 15 July 2012

Abstract

One basic requirement of special purpose soil classification is that the soil must be classified in terms of the properties that are relevant to their proposed use. Four transects, each 7km long were established in the eastern, western, southern and northern directions due to break in slope and creek of the land terrain. Nine profiles comprising two in each direction and the starting point were selected along the transects. The profiles were dug and described in accordance with (Soil Survey Staff, 2006 and FAO, 2003) standards. Each profile pit was described with particular reference to the depth, colour, structure, texture, roots, pores/space and other inclusions in the field. The soils of Akpabuyo are well-drained as evidenced by the absence of mottles throughout the subsurface soil horizons with Hue of 10YR being dominant in all the profiles studied while in Bakassi, one of the most striking features of all the soil profiles excavated is poor internal drainage as evidenced by the presence of mottling with dominant colours of soils varied from brown, very dark brown, dark to very dark grey and dark olive grey with predominant 5Y and 10YR hues.

Index terms— soil morphology, physico-chemical characteristics, transects and southern cross river state.

1 Introduction

ne of the basic requirements of any special purpose soil classification is that the soil must be classified in terms of the properties that are relevant to their proposed use (Gibbons, 1965;Gbadegesin, 1986). For instance, it is clearly not sufficient to state that soils are going to be classified for maize or cassava production, unless the soil properties determining the soil's suitability for maize or cassava production have been identified. However, the identification of the soil properties relevant to the proposed use cannot be carried out without relating the soil properties to some external measures of the proposed use, such as the yield of an agricultural crop (Gbadegesin, 1986;Gbadegesin et al., 1990).

According to the soil classification of USDA soil map of the world ??Arckerson et al., 1998; ??SDA, 1995; classified most of Nigeria soils on basement complex as alfisols and on sand stones as ultisols. This classification of Nigerian soil suggests basic similarities in soil reaction processes which are greatly modified by climatic and vegetation differences. Kang and Osiname (1972), ??biogba (2011), reported that micronutrients are deficient in soils of several parts of Nigeria, thus, most nutrient-balance studies focus on macronutrients and how these macronutrients varied with time and space in the soil. It is against this background that this study intends to draw a comparative analysis of soils of the coastal areas of Southern Cross River State -Nigeria.

2 II.

3 Objective of the Study

The objectives of the study are: 1. To characterize and classify the soils of the coastal and hinterland areas of Southern Cross River State in terms of morphology, physical and chemical properties; 2. To examine the degree of variability of the physical and chemical properties of soils of the study area.

O III.

4 Study Area

Akpabuyo Local Government Area (hinterland) is located between longitudes 8020'E and 8040'E and latitudes 4045'N and 5010'N of Greenwich Meridian. Bakassi Local Government Area (coastal) is located between longitudes 8030'E and 8039'E and latitude 4030'N and 4045'N. Bakassi Local Government is found along the Cross River estuary located at the south-east bank of the estuary characterized by mangrove swamps soil while Akpabuyo Local Government Area extends form the Great Kwa River along the "Atimbo" bridge head. The soils of Akpabuyo study site are derived from tertiary coastal plain sands of Pleistocene era while those of Bakassi are formed from alluvium in the quaternary period. Both soils are of the same geological material of sedimentary origin but of different formation (Fig. 1).

IV.

5 Materials and Method

Field Study: Four transects, each, 7km long, were established in the eastern, western, southern and northern directions due to break in slope and creeks of the land terrain. Nine representative profiles comprising two in each direction and the starting point were selected along the transects. The profiles were dug and described according to the provision of (Soil Survey **??**taff, 2006; **??**nd FAO, 2003) standards. Profile were dug to the depth of 150cm or 200cm except where a water table is struck or an impenetrable layer is encountered. Each profile pit was described with particular reference to the depth, colour, structure, texture, roots, pores and other inclusions of each natural horizons or layer present in the field. Soil samples taken from the different horizons were stored in polyethylene bags and transported in the laboratory for analysis.

Laboratory Analysis: The soil samples were airdried grinded and sieved through a 2mm sieve. Particle size was determined by the hydrometer method (Juo, 1979). Soils reaction (pH) was determined in 1:2 soil/water ratio by use of glass electrode pH meter. Organic carbon was determined by the Walkley and Black (1934) method while total nitrogen was by Kjeldahl digestion methods. Available phosphorus was determined by the Bray No. 1 method. Exchangeable cations were extracted with IN NH4OAc (pH 7); Calcium (Ca) and Magnesium (Mg) were determined by the EDTA titration method while Potassium (K) and Sodium (Na) were determined with a flame photometer **??**Black et al., 1965). Exchangeable acidity (H+ and Al3+) were determined by leaching the soils with IMKCI and titrating aliquots with 0.01M NaOH. Effective Cation Exchange Capacity (CEC) was determined by ammonium ion displacement method whereby IN NH4OAc, pH 7.0 was used as the extracting solution **??**Black et al., 1965)

6 Procedure for Data Analysis

Description statistics such as the range, mean, standard deviation and coefficient of variability (CV) were used. The statistics is relevant here because the samples are independent (do not depend on each other) and are normally distributed while the CV is used for measurements based on ratio scale i.e. a scale with an absolute zero origin and not on other scales of measurement with an arbitrary zero origin. Thus, in this study, the CV was used for comparison of variables measured on a ratio scale. The coefficient of variable (CV) is given as: This section presents the results obtained from the soil morphological and physico-chemical analysis carried out in transacts one and two representing Akpabuyo and Bakassi study sites under investigation. Morphological description of the nine (9) profiles is presented in Table 2. The soils morphological characterization was described in-situ with reference to the vegetation; drainage condition, soil colours, textures, consistence, horizon boundary, structure and inclusions (roots, ants, worms, charcoal, crickets, etc). The soils of Akpabuyo are well-drained as evidenced by the absence of mottles throughout the subsurface soil horizons in all the profiles studied. Abua and Edet **??**2007) One of the most striking features of all the soil profiles excavated in the Bakassi area is poor internal drainage as evident by the colour of the soils. Table **??**II gives account of the nine (9) soil profiles positioned along the starting point (P0), north (P1,P2), west (P7,P8), east (P5,P6) and south (P3,P4) transects of intervals of 3.5km along the transects at varying depth sequence down the profiles. Pedon's P1-P5 and pedon P8 were poorly to very poorly drained dominated by mottling with brown, very dark brown, dark gray to very dark gray and dark olive gray colours within the depth of l00cm.C.V. = x

The surface colour of the soils varied from very dark gray brown (10YR3/2) in profiles P1 and P3 while profiles P4 and P5 had munsell notation of 2.5YR 2.5/0 (black) Profiles P6-P9 had munsell notation of 10R 3/3 (dark brown) in the surface soils excepting profiles P2 with colour notation of 5YR 2.5/2 (dark reddish brown) (Table **??**I). The subsurface soils are characterized by dominant hues of 10YR, 2.5-Y, 7.5YR, 5YR reflecting various shades of yellow (10YR 5/4-yellowish brown; 10YR 2.5/2 -dark yellowish brown; and 10YR 6/8brownish yellow) and brown (10YR 4/3 -brown; 10YR 3/2-very dark brown; 2.5y 5/4 -light olive brown; 7.5 YR 5/6-strong brown; 10YR 3/3 -dark brown) within 200cm depth sequence (Table ??I). In all the pedons, mottles were absent as reflected by the non-hydromorphic nature of soils of the area.

In the Bakassi study area. dominant colours of the soils varied from brown, very dark brown, dark to very dark gray and dark olive gray with predominant 5Y and 10YR hues (pedons P1-P5 and P8) with chromas values less than 3 for pedons P1-P6 and 3 to 8 in pedons P7-P9 within 100cm of the pedons (Table ??). Pedons 1, 5 and 8 are saturated with water apparently due to the high water table and intermittent tidal inundation which makes them liable to flooding ??Akamigbo, 2001;Akpan-Idiok, et al., 2006).

Pedons P1 to P5 were observed to have subangular blocky structure within the different depth sequence in the area (Akpabuyo). Profiles P1 are weak (surface) moderate to coarse-textured within the depth of 40-122cm while it was moderate to medium within 122-200cm depth (Table ??). Profile P2 (north transect) were weak and coarse-textured. Thus, profiles P1-P5 are dominated by subangular blocky structure. The remainder (P6-P9) of the profiles had structural classes ranging from subangular blocky structure, crumb to granular structures. Crumbs structures were observed in P6 (32-61cm) of the east transect while granular structures were observed in profiles P8 and P9 of the south transect within the depth of 56-200cm (P9) and 46-200cm (P9). The profiles (P6-P9) were deep, weak, moderate with coarse to fine textures. This indicates that soils of the area are made up of coarse-textured colluvial and alluvia materials.

The soils structure in the Bakassi area was mostly massive (structuresless), reflecting poor drainage conditions of the profiles during the period of sampling as exemplified in pedons P1-P5 and pedon 8 (Table ??II). Pedons P6, P7 and P9 exhibited varied structural trend probably due to distance away from the water bodies and apparently low water table. Such poorly drained soils showed considerably amounts of clay contents as they were sticky and plastic (Table ??II). Soil structures in pedons P6, P7 and P9 showed slight variability as they were weakly developed in pedons, albeit with fine clay accumulation beyond 100cm depth. The lack of structural development in the surface and subsurface horizons of pedons P1-P5 and P8 could be ascribed to the effect of ground-water table (Udo et al., l993). Besides, they are weak, fine with sub-angular blocky to granular structures (Table ??II).

In Akpabuyo study area, the consistency of surface soils was non-sticky and non-plastic; firm and moist to dry and loss, dry and slightly hard (Table ??I, P1-P9). The subsurface horizons also exhibited consistency at various degrees from non-plastic and non-sticky firm and moist both at wet consistence; loose and slightly hard as dry soils do not contain a reasonable amount of clay fractions.

In terms of consistency, some of the samples collected from the prescribed study site (Bakassi) varied from slightly sticky and plastic (moist conditions); moist and firm at non-waterlogged condition.

In Akpabuyo, the texture of the epipedons varied from sandy loam, sand to loamy sand fractions (Table ??I) (P1-P9). The texture of subsurface horizons ranged from sandy clay loam, sandy loam, clay loam to gravelly (east transect) in texture (Table ??l, P1-P9).

Soil textures show mild variability in Bakassi. Surface textures varied from clay through loam to sandy loam, while subsurface textures are commonly clay loam to sandy loam (Table ??II). Pedons 5 and 8 are dominated by clay contents in all the surface and subsurface horizons (Table ??). Albeit few of the profiles showed dissimilar trends variation in terms of textures at different depth sequence in the area. These variations may be due to differences in parent material and topography ??Akamigbo,2001).

In term of inclusions, surface soils (P1-P9) profiles had an abundance of roots of all kinds, namely medium, fine and many coarse roots. At the subsurface, coarse, medium, few fine roots were observed along profiles in the east transect. It was observed that the first horizons in the east transect were fibrous roots matlayers and they possessed many coarse medium and fine roots from the epipedon (Table ??I). Besides many fine micro and macro pores were seen at the surface soils of the profiles. The occurrence or abundance of pores in soils is significant, because soils with many fine pores are much more aerated, and better drained than one with few, very fine pores (Esu, 1999). Other inclusions observed in the Akpabuyo area were charcoals, ants, crickets, snails, worms to termites. Visual observations of charcoal in some of the profiles strongly indicate the influence of anthropogenic activity in the study site.

Horizon delineation within the nine (9) profiles was based on colour of the soils. The distinctness and the outline of horizons within the surface horizons carried from clear smooth to gradual diffuse boundaries (Table ??I). Conversely, the subsurface soil horizons boundaries ranged from clear smooth, gradual diffuse to diffuse smooth boundaries within the depth sequence of horizon boundaries across the transects (Table ??I, P1-P9).

Among soil inclusions in the Bakassi study area were the sapric, common fine roots, (surface soils), few fine roots (subsurface) smell of crab, periwinkle and worms (Table ??II). Distinctions and the outline of horizons within the profiles to diffuse smooth boundaries (Table ??II).

7 VII.

8 Soil Classification

Using both field and laboratory analytical results, the soils are classified according to the American system of Soil Taxonomy (Soil Survey ??taff, 1992 ??taff, , 1998 ??taff, , 2006) and the FAO/UNESCO (1988) of the world soil map legend. Consequently, the present study aptly attempts a classification of the soils underlying Akpabuyo and Bakassi terrain given their morphological description in the foregoing sections (see Tables 2 and 3).

According to the criteria of the USDA system, pedons AP0, APNT1, APET1, APST1, and APST2 located about 0km, 3.5km and 7km on either transects within Akpabuyo terrain fits into order Ultisols because of the strong acid condition, low base status, low ECEC and perhaps, absence of argillic horizons. With yellowish brown soil colour particularly in pedons AP0 (40-200cm depth), APNT (within the depth of 27-105cm), hue of 10YR coupled with medium organic carbon content, the pedons are placed in the suborder Ustults.

Due to the warm soil temperature of the region, the pedons are placed in Tropustults great group and Typic Tropustults Subgroup. The FAO/UNESCO soil legend classification equivalent of Typic Tropustults is Dystric Acrisols. Moreso, pedons AP0, APNT1, APNT2, APWT1, APWT2, APET1, APET2, APST1 and APST2 located along the transects within the Akpabuyo terrain are placed in the Entisols order owing to the absence of diagnostic horizon young (silt/clay ratio>0.20) with no evidence of morphological profile development.

Pedon APET2 located 7km east transect within a valley exhibited exceptional attributes as the profile was almost by sand within the depth of 0-57cm of the profile, which may be attributed to the deposition of eroded sediments, albeit it is placed in the Entisols order for little evidence of diagnostic horizon other than an ochric epipedon. According to the criteria of USDA Soil Taxonomy **??**Soil Survey Staff, 1992, the soils are qualified Typic Ustifluvents due to little evidence of diagnostic horizons, organic carbon above 0.20% of the varying depth sequence, Ustic moisture regime of the terrain and warm soil temperature. The soil equivalent according to the criteria of the FAO/UNESCO (1988) legend is Eutric Fluvisols due to little evidence of pedogenic horizons, organic carbon content greater than 0.20% and the Ustic moisture regime of the ecological zone.

Conversely, pedons BP0, BPNT1, BPNT2, BPWT1, BPWT2, BPET1, BPET2, BPST1 and BPST2 located along the starting point, north, west, east and south transects measured 0km, 3.5km and 7.0km on either transects were studied at Bakassi axis. The prescribed area albeit is situated in an environment characterized by peraquic/aquic moisture regimes in most parts of the year. All the pedons underlying the terrain (BP0-BPST2) have high percentage base saturation in addition to the evidence of clay accumulation in the subsurface and argillic horizons. The aquic moisture soil regime further places these soils in the suborder, Aqualf. Pedons BPWT1, BPWT2, BPET1 and BPST1 located 3.5km, 7.0km and 3.5km respectively along west, east and south transects and qualified Typic Fluvaquent and Typic Endoaquent according to the criteria of the USDA Soil Taxonomy (Soil Survey **??**taff, 1992 **??**taff, , 2006)) and Eutric Fluvisols owing to the absence of diagnostic horizons, aquic moisture regime, reduced matrix below Ap horizons, hue of 10YR and low chroma of 2 or less, irregular decrease of organic carbon and clay contents decrease with the profile depth, and low pH values within the profiles. Pedons BPo, BPNT1, BPNT2, and BPST2 were placed Aeric Endoaquent because of the gleyed horizons (2. 5Y) though of varying depth sequence probably as a result of the influence of the groundwater table. The irregular decrease/increase in the organic carbon content within the profile placed these pedons under the great group of Fluvaquent.

In the FAO/UNESCO (1988) soil legend, pedons BPo-BPST2 (all pedons in the terrain) are qualified Luvisols owing to the high base saturation status coupled with the presence of arqillic horizon. They are further classified as Gleyic Luvisols because of the hydromorphic characteristics, albeit at varying depth sequence of the profiles (Fitz Patrick, 1980). Pedons BP0, BPNT1, BPNT2 and BPST2 along designated transects of Bakassi region qualified as Gleysol and Eutric Regosol because it is derived from unconsolidated parent materials exclusive of recent alluvial deposits, and having hydromorphic properties at different depth sequence. Besides, it is further classified as Eutric Gleysol on account of percentage base saturation exceeding 50.

9 VIII. Physico-Chemical Characteristics of Soils

Whereas in the coastal area the EC values varies from 0.88 to 30.65 dsm'1 (surface soils) and 38.70 dsm-1 subsurface soils). Organic Carbon Contents with mean values of 1.83% and 0.65 for surface and subsurface soils respectively while total nitrogen had means of 0.72% and 0.73% respectively for surface and subsurface soils with SD = 0.18 surface and 0.12 for subsurface soils. The available p (means = 5Mgkg-1 and 6mgkg-1) for surface and subsurface soils respectively with SD = 0.73 -0.80, CV = 30.05, SD = 2.64 and 1.31 with the corresponding CV of 52.70% and 21.92% respectively. In the hinterland area, exchangeable bases were as follows: Ca with means of 2.44 Cmol/kg-1 and 2.33 Cmol/kg-1, mg (means = 1.15 and 1.08 Cmol/kg-1), k (means = 0.14 and 0.10 Cmol/kg-1), Mg (means = 0.06 and 0.05 Cmol/kg-1) in both the surface and subsurface soils respectively. Exchangeable bases contents of soils in the hinterland include Ca (means = 9.54 and 9.99 Cmol/kg-1), k (means = 0.10 and 43.01), Na (means = 0.30 and 0. 55 Cmol/kg-1) and Mg (means = 59% and 55%) for surface and subsurface soils respectively.

Base saturation in the hinterland area ranged from 39% to 75% surface and between 36% to 74% subsurface soils with means of 59% and 55% respectively (SD = 12.61 -10.32; CV = 21.37 -18.76%) respectively for surface and subsurface soils. The base saturation values for the coastal area varied from 81 to 97% (surface soil) and between 74 to 97 sub soils respectively with mean values of 90% and 88% surface and subsurface soils, while the SD = 5.29 and 6.74% and CV = 5.88% and 7.66% for surface and subsurface soils respectively. Base saturation was high (> 60%) in most soil sampled. This indicates that the soils are prolific to sustain arable crop production in the area under consideration. With such levels of base saturation, basic nutrients must have occurred in available forms in the soils solution regardless of the mean cation (range: 59 -55%) reserves in the soils.

In the hinterland area, the soils are moderately coarse-textured in the surface while the subsurface has light accommodation of fine clay fraction. With high sand fraction exceeding 70%, mean salt content below 15%, the soil have weak surface aggregation. Such soil may lack adsorptive capacity for basic plant nutrients and may be susceptible to erosion menace. In the coastal area, the sand fraction accounted for more than 50% in both top and sub soil. With silt fraction greater than 15% for both top and sub soils indicate that the soils have strong surface aggregation and may not be vulnerable to erosion hazard.

The mean surface and subsurface values for bulk density in the hinterland (1.18mgm-3 and 1.42mgm-3) and its corresponding pore space of 55.51% and 62.26% respectively reflect the textural classes of the study sites. Being soils with weak surface aggregation, adequately aerated and good drainage conditions, it is recommended for the cultivation of arable crops including cassava production while in the coastal area, the mean values of bulk density are 1.22 and 1.54mgm for surface and subsurface soils respectively. In the hinterland area, moisture content increases with depth in both the surface and subsurface soils from 10.63 to 19.20% and 8.19 to 19.42% respectively. Such moisture levels are moderate for crops production in the ecological zone while in the coastal area, moisture contents of the study site under investigation ranged from 18.10 to 44.18% with means of 31.10 and 24.81% respectively in the surface and subsurface soils (Table **??**). Such moisture contents are appreciable though may be lethal to some arable crops in the ecological zone.

The soil reaction in the hinterland is acid with means of 5.3 and 5.2 in the surface and subsurface soil respectively. The standard deviation and the coefficient of variability ranged from 0.24 to 0.18% and 4.52 to 3.46% in surface and subsurface soils respectively. In the coastal area the soil pH is strongly acidic with means of 3.5 and 3.1 respectively in surface and subsurface soils. The standard deviation (SD) and the coefficient of (CV) of 0.78 and 0.46% and 22.27 and 14.71% respectively for surface and subsurface soils.

In the hinterland area, electrical conductivity (EC) values ranged from 0.30 to 0.088dsm-1 (surface) and 0.011 to 0.078dsm-1 (subsurface). Organic carbon had mean values of 7.95 and 7.6% for surface and subsurface soils respectively. Total nitrogen contents for surface and subsurface soils had means of 0.08% and 0.05% respective with (SD = 0.02). Available Phosphorus (means= 28Mgkg 1 and 41MgKg-1) surface and subsurface soils respectively with SD of 18.08 surface and 18Mgkg-1) surface and subsurface soils and (CV = 52.70% and 21.92%) surface and subsurface soils respectively.

10 IX.

11 Conclusion

The morphological features of the prescribed soil of Southern Cross River State exhibited dissimilar pedological trends in terms of soil colour, consistency, structure, drainage pattern etc. The physical and chemical properties of the soils are dissimilar in many respect. The soils could be made productive in terms of crop cultivation if proper management system is advocated.

12 Abiogba,

[1]

[1] A Comparative Analysis of Morphological and Physico-Chemical Characterization of Soils of Southern Cross River State -Nigeria

Figure 1:

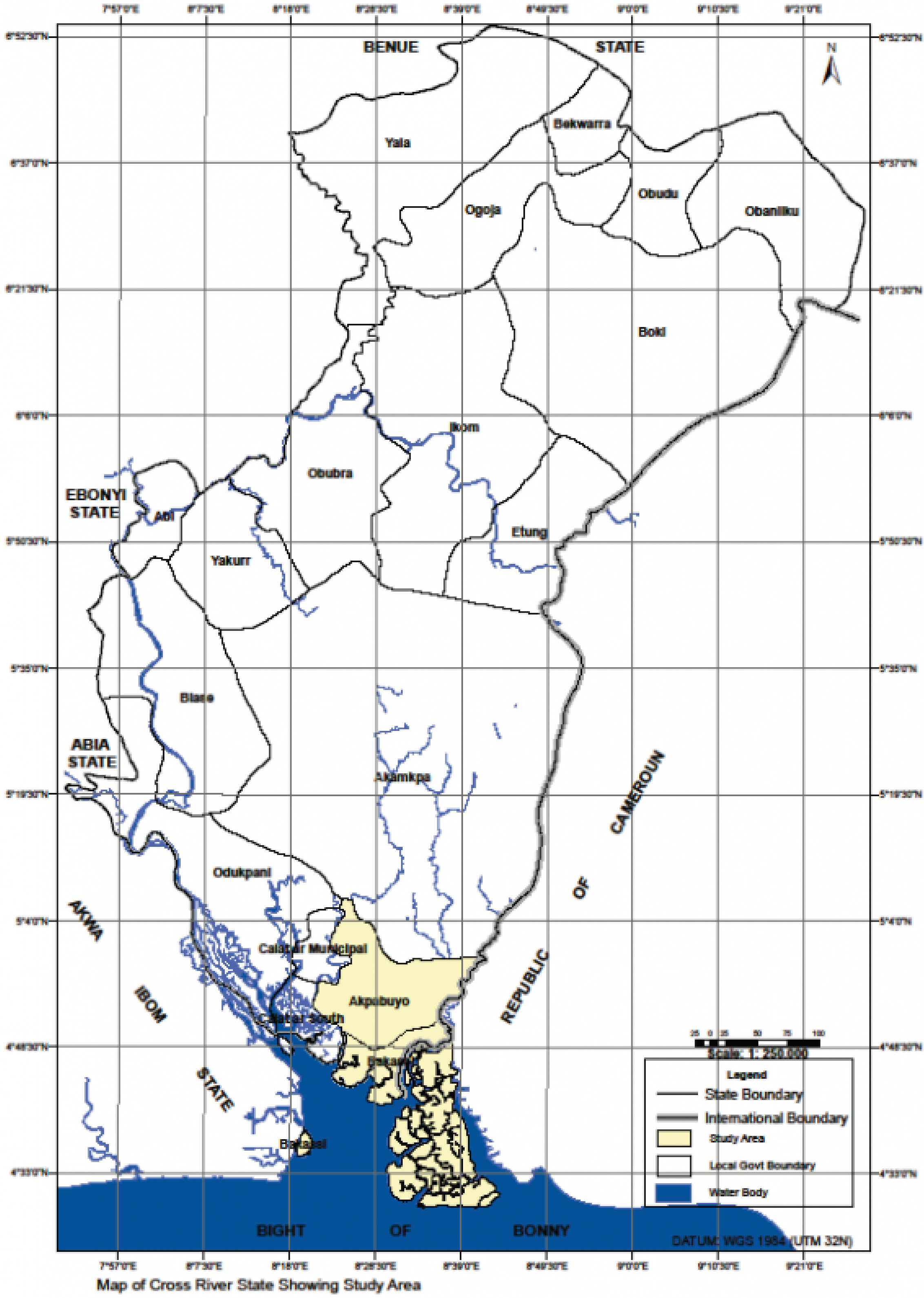
BENUE
STATE
Yala
Bekwarra
Ogoja
Obudu
Obanliku
Boki
Ikom
Obubra
EBONYI
STATE
Abi
Yakurr
Etung
Biase
ABIA
STATE
Akamkpa
CAMEROUN
OF
REPUBLIC
Odukpani
AKWA
IBOM
STATE
Calabar Municipal
Akpabuyo
Calabar South
Bakassi
BIGHT
OF
BONNY
Scale: 1: 250,000
Legend
State Boundary
International Boundary
Study Area
Local Govt Boundary
Water Body
DATUM: WGS 1984 (UTM 32N)
Map of Cross River State Showing Study Area

Figure 2:

1

O. A. (2011): Spotio-temporal variation of
soil nutrients and the effect on cassava cultivation in
Alfisol and Ultisol zones in South-Western Nigeria.
Ph.D. Thesis, Department of Geography, University
of Ibadan
2. Abua, M. A. and Edet, E. O. (2007): Morphological
and Physico-Chemical Characteristics of Coastal
Plain Soils of Southern Cross River State -Nigeria.
Nigeria Geographical Journal, Vol. 5, No. 1, pp. 109-
114
3. Akamigbo, F. O. R. (2001): Survey, Classification
and Landuse of Wetland Soils in Nigeria. Invited
paper presented at 27th Annual Conference of the

Figure 3: Table 1 :

2

Horizon depth (cm)	Pedon	Munsell colour (wet condition)	Texture	Structure	Consistence	In
Level or nearly level: 0-2% (1): Reference point, AP0 (N04 0 56.648; E 008 0 24.193)						
0-14	P1	10YR3/2;vdg	sl	1, 4, sbk	wns, wnp, mf	cc
14-40		2.5Y5/4;lob	scl	2, 4, sbk	wss, wsp, mf, dsh	ffr
40-82		10YR5/4;yb	sl	3, 4, sbk	wss, wsp, mf, dl	ffr
82-122		10YR5/6;yb	scl	3, 4, sbk	wss, wsp, mf, dh	ffr a
122-200		10YR6/8;yb	scl	3, 2, sbk	wss, wsp, mf, dh	ffr
Moderately to strong sloping: 4-7% (3); North transect, APNT 1-1 (N 04 0 56.794; E008 0 xxxx)						
0-22	P2	5Y 2.5/2;drb	s	1, 4, sbk	wns, wnp, mf, dl	mo mr
22-41		10YR 4/4;dyb	sl	1, 2, sbk	wns, wnp, mf, dl	mo mr
41-122		10YR 6/8;by	scl	1, 4, sbk	wns, wnp, mf, dl	mr mr
122-151		2.5Y 5/6;lob	sl	1, 4, sbk	wns, wnp, mf, dl	mr mr
151-200		2.5Y 4/2; dgb	ls	1, 4, sbk	wns, wnp, mf, dl	mr
Moderately to strong sloping: 4-7% (3); North transect, APNT 2-2 (N 04 0 56.906; Exxxxxxxxxx)						
0-28	P3	10YR 3/1; vdg	sl	1, 2, sbk	wns, wnp, mf, dl	mr tm
27-65		10YR 5/6; yb	scl	1, 2, sbk	wns, wnp, mf, dl	mr
65-105		10YR 5/4; yb	scl	3, 2, sbk	wss, wsp, mf, dsh	ffr mr
105-155		10YR 6/6; by	sc	3, 2, sbk	wvs, wsp, mf, dsh	ffr
152-200		10YR 5/8; yb	sc	4, 3, sbk	wvs, wsp, mf, dsh	
Level						

Figure 4: Table 2 :

0-27	P4	2.5YR 2.5/0; bl	sl	1, 2, sbk	wns, wnp, mf, dl	mcr, ai, w, sn, tm, mmp	gd
27-56		5YR 3/2; drb	sl	1, 2, sbk	wns, wnp, mf, dl	mfr, ai, w, sn, mmp	gd
56-115		5YR 3/2; drb	cl	3, 2, sbk	wns, wnp, mf, dl	fcr, ai, w, c, mmp	gd
115-152		7.5YR 4/4; b	sl	3, 2, sbk	wss, wsp, mf, dsh	fcr, ai, c, mmp	gd
152-200		10YR5/8; yb	sc	3, 2, sbk	wss, wsp, mf, dl	ffr, ai, c, mmp	gd
Level							

Figure 5: or nearly level: 0-2% (1); West transect, APNT 1-1 (N 04 0 56.760; E 08 0 24. xxxx)

0-27	P5	5YR 2.5/1; bl	sl	1, 2, sbk	wns, wnp, mf, dl	mrc, ai, c, mmp	cs
27-56		7.5YR 3/2; db	sl	3, 2, sbk	wns, wnp, mf, dl	mfr, c, mmp	cs
56-103		5YR 2.5/1; bl	sl	3, 2, sbk	wns, wnp, mf, dl	ffr, c, mmp	gd
152-200		10YR 4/3; b	scl	3, 2, sbk	wss, wsp, mf, dh	ffr, c, ai, mmp	cs
Moderately							

Figure 6: or nearly level: 0-2% (1): West transect, APNT 2-2 (N 04 0 56.910;E008 0 xxxx)

0-32	P6	2.5YR 5/6	sl	1, 4, skb	wns, wnp, mf, dl	mfr, ai, c, mmp	cs
32-61		10YR 3/2	sl	1, 2, cr	wns, wnp, mf, dl	ffr, ai, c, mmp	cs
61-117		7.5YR 3/2	sl	1, 2, sbk	wns, wnp, mf, dl	ffr, ai, mmp	cs
117-200		5YR 3/2	ls	3, 2, sbk	wss, wsp, mf, dh	ffr, ai, mmp	cs
	Steepy						

Figure 7: to strong sloping: 4-7% (3);East transect T, APNT 1-1 (N 04 0 56.603; E008 0 xxxxxxx)

0-21	P7	10YR 3/5	ls	3, 2, sbk	wns, wnp, mf, dsh	ccr, ai	gd
21-27		2.5YR 5/4	scl	3, 2, sbk	wss, wsp, mf, dh	mcr, st, c, ai	gd
57-200		10YR 6/8	sc, gr	3, 2, sbk	wns, wnp, mf, dvh	fcr, gr	cs
	Level						

Figure 8: sloping and hilly: 12-18% (5); East transect, APNT2-2 (N 04 0 56.521; E008 0 xxxxxxxxxx)

0-22	P8	5YR 3/4	ls	1, 5, sbk	wns, wnp, mf, dl	mfr, wm, ai, mmp	gd
22-56		10YR 3/6	scl	3, 5, sbk	wns, wnp, mf, dl	mfr, wm, c, mmp	gd
56-110		7.5YR 4/2	sl	3, 5, g	wns, wnp, mf, dl	ffr, c, mmp	cs
110-200		10YR 5/8	sc	3, 5, g	wns, wnp, mf, dsh	ffr, ai, mmp	cs
Level							

Figure 9: or nearly level: 0-2% (1); South transect, APNT1-1 (N 04 0 56.370; E008 0 xxxxxxxx)

0-14	P9	10YR 4/6	sl	1, 2, sbk	wns, wnp, mf, dl
14-46 46-89 89-200		2.5Y 5/6 7.5YR 4/4 10YR 5/7	scl scl scl	3, 5, sbk 3, 5, g 3, 5, g	wss, wsp, mf, dsh wss, wsp, mf, dl wss, wsp, mf, dh

Legends : vdg = very dark gray; yb= yellowish brown; b = brown; db = dark brown; bl= black; dgb=dark gray brown; drb= dark reddish brown

Colours : lob= light olive brown; vdg=very dark gray brown; by= brownish yellow; dyb=dark yellowish bro cr=crumb

Structure : 1=weak; 2=medium; 3=moderate; 4=coarse; 5=fine; sbk=subangular blocky; g=granular

dh=dry, hard; dvh=dry, very hard; wvs= wet, very sti

Texture : sl=sandy loamy; scl=sandy clay loamy; sc=sandy clay;ls=loamy sand; gr=gravelly; s=sand

Inclusion : mcr= many coarse root; ai=ants, insects; mfr=many fine roots; c=charcoal; mmp=many micro and macro pores, ffr=few fine roots; fcr=few coarse roots;

[Note: w=worms; sn=snails; tm=termites; ccr=common coarse roots; a=ants; ck=crickets; 5=Class E (Steepy sloping and hilly)

Figure 10: or nearly level: 0-2% (1): SOUTH TRANSECT APNT2-2 (N 04 0 56.210;E0 xxxxxx)

3

Figure 11: Table 3 :

[November] , November . Calabar, Nigeria.

[Walkey and Black ()] *An Examination of the Digestive Method for Determining Soil Organic Matter and Proposed Modification of the Chronic Acid Tillage Method*, A Walkey , I A Black . 1934. p. .

[Arkcerson et al. ()] T K Arkcerson , D L Rourke , A J Vessel . *Soil of the World (map) U.S.A., Government Printing Offices*, (Washington D.C) 1998.

[Esu ()] I E Esu . *Fundamental of Pedology. Stirling-Horden Publishers (Nig.) Ltd*, (Lagos, Ibadan, Benin City, Jattu Uzairue) 1999. p. 136.

[Food and Agricultural Organisation (FAO/UNESCO) (1998): Soil Map of the World Legend] *Food and Agricultural Organisation (FAO/UNESCO) (1998): Soil Map of the World Legend*, Paris FAO/UNESCO.

[Keys of Soil Management Support Services 5th Monograph Soil Survey Staff ()] 'Keys of Soil Management Support Services 5th Monograph'. *Soil Survey Staff* 1992. (19) .

[Keys to Soil Taxonomy ()] *Keys to Soil Taxonomy*, (Washington DC) 2006. (Soil Survey Staff)

[Gibbons ()] 'Limitations to the Usefulness of Soil Classification'. F R Gibbons . *Trans-International Congress son Soil Science* 1965. 4 p. .

[Gbadegesin and Nwagwu ()] 'On the suitability assessment of the forest and savanna ecological zones of southwestern Nigeria for maize production'. A S Gbadegesin , U Nwagwu . *Nigeria. Journal of Tropical Agriculture* 1990. 1986. Elsevier Science Publishers B.V. 31 (3) p. . (Agric Ecosystems Environ.)

[Kang et al. ()] 'Phosphorus Forms and Fixation Capacity of Representative Soils in Akwa Ibom State of Nigeria'. B T Kang , O A Osiname , E J Ndo , T O Ibia . *Geodarma* 1972. 1993. 58 p. . (Proceedings of the Ford/IITA/RAT International Seminar on Tropical Soil Research)

[Production Yearbook: FAOSTAT Database ()] *Production Yearbook: FAOSTAT Database*, 2003. (FAO)

[Juo ()] 'Selected methods for soils and plants analysis. International Institute of Tropical Agriculture (IITA), Manual Series No. 1 in Method of Making Mechanical Analysis of Soils'. A S R Juo . *Soil Science Society of Nigeria* 1979. 68 p. .

[Akpan-Idiok and Antigha ()] 'Soil Survey Irrigation/Drainage and Flood Control Project'. A K Akpan-Idiok , N R B Antigha . *Nsecal Engineering Services* 2006.

[Soul Science Society of Nigeria] *Soul Science Society of Nigeria*, p. .

[USDA Soil Conservation Services Soil Survey Staff ()] 'USDA Soil Conservation Services'. *Soil Survey Staff* 1998. (Key to Soil Taxonomy. 8th edition)