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Assessment of Selected Morphological, Physical and Chemical Characteristics of Upland Pedons in Eastern Kogi State, Nigeria

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ABSTRACT

This research aimed at assessing the morphological and physico-chemical characteristics of upland soils in Kogi State of Nigeria. The research adopted a free soil survey technique whereby four pedons (Okura-P, Egume-P, Acharu-P and Ankpa-P) represented by four (4) soil profile pits were used for the study. Soil samples were carefully collected from delineated soil horizons for laboratory physical and chemical analyses. The morphological descriptions of the soil profiles followed the standard of the United States Department of Agriculture (USDA). The results showed dominant dull reddish brown (2.5YR4/4, 5YR4/3) in the surface and reddish brown, (2.5YR4/6), a reddish brown (2.5YR 5/8, 5YR4/8) and red (10R4/8) in the subsurface soils, while the structure of the subsurface soils varied mainly between sub-angular and angular blocky structure. Sand fraction of the soils is mostly coarse with ranges of 500 to 670 g kg^{-1} at the surface and 330 to 660 g kg^{-1} in the sub-surface soils. The bulk density of the soils generally increased down the profiles with a mean sub-surface value of 1.82 g cm^{-3}, being higher than the surface mean value (1.74 g cm^{-3}). The pH value of the soils is higher at the surface soils with a mean value of 5.3 than in the sub-surface soils with a mean value of 4.9, while the percentage base saturation and aluminium saturation percentage had surface mean values of 30 and 4% and subsurface mean value of 35and 23% respectively. The test for coefficient of variation showed varying percentages across the pedons with saturated hydraulic conductivity scoring the highest (92%) in the subsurface soils. The fertility of these soils could be improved with addition of organic matter enrichment sources.

KEYWORDS: Upland, Pedon, Soil Structure, Soil texture, Base saturation, Cation exchange.

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INTRODUCTION

Upland soils are derived from a diversity of parent materials and influenced by various topo-positions. They are made up of chiefly the rock underlying the sites. These soils are very variable, and for each climatic type, there are both highly productive and very poor soils. However, on a general note, upland soils mean soils which are not designated as poorly drained, very poorly drained, alluvial, or flood plain by the National Cooperative Soils Survey, as may be amended, of the Natural Resources Conservation Service of the United States Department of Agriculture.

The concept of upland soils comprises of soils with characteristic sandy loam texture, but vary in organic matter content across landscape positions (Staniszewski *et al.* 2012*)*. However, Humberto Blanco-Canqui (2022) argued that upland soils are low in organic matter, low in soil fertility and vulnerable to water and nutrient losses through runoff and soil erosion. Crops in upland soils are grown under no-till management that generally improves soil physical properties as part of soil management due to poor fertility (ibid).

Uplands are portions of plain that are conditionally categorized by their elevation above the sea level. While lowlands are usually no higher than 200 m (660 ft) amsl, uplands are somewhere around 200 m (660 ft) to 500 m (1,600 ft) amsl, which are land areas lying above the elevation where flooding generally occurs (Wikipedia, 2023).

The productivity of upland soils is always affected by the marginal soil organic matter, low soil quality, vulnerability to water and nutrient losses (Bado et al., 2010). Now, most of the soils in the research area are under continuous cultivation, so they rapidly lose their fertility due to rapid decline in organic matter, leaching and crop uptake of basic cations and high rates of acidification

(Ukabiala, 2019). There are also large losses of organic matter as a result of land clearing and cultivation, especially with the breakdown of the traditional land use systems such as shifting cultivation and bush fallowing (Kowal and Kassam, 1978). There is therefore need for urgent and regular assessment of the status of the soil properties to ascertain levels of degradation and resilience which will assist in sound judgement and decision making on the use and sustained productivity of the soils. Thus, the main aim of the research was to assess selected morphological, physical and chemical characteristics of the upland pedons in eastern Kogi State, Nigeria.

MATERIALS AND METHODS

Study Area

The representative pedons were sited in Okura, Egume, Acharu and Ankpa, all within Dekina and Ankpa Local Government Areas in Eastern senatorial district of Kogi State, Nigeria (Figure 1). There are two distinct seasons in this region namely rainy season which lasts from April to October and the dry season observed between November and March (Ukabiala, 2019). A part of the dry season is very dusty and cold as a result of the north-easterly winds which bring about the harmattan. This zone has an annual rainfall ranging from 1100 to 1300 mm with a mean of 1200 mm per annum. The average monthly temperature varies between 17 and 36ºC (Amhakhian and Osemwota, 2012). The highest temperature (36ºC) has been recorded during the dry season (Ukabiala, 2012)). The mean relative humidity is lowest during the dry season and highest during the rainy season of the years, giving 15 and 67% respectively (Gideon and Fatoye, 2012). The percentage slopes ranged from 2 to 4%. The soils are well drained and intensively cultivated with cassava, maize and oil palm. The land-scape is characterized by elevation ranges of 280 - 426 m above mean sea level. The soils are mostly derived from shale parent materials and generally referred to as “Ochii” in the native language. The soils also support thick savannah vegetation in most parts of the year.

Field Work

The topographical map of Kogi east (Figure 2) was used as base map for the study, following a free survey technique. The four pedons used for the investigation were denoted as Okura-P, Egume-P, Acharu-P and Ankpa-P. A soil profile pit representing each pedon was dug at the dimension, 200x150x200 (cm) for length, breadth and depth depending on the depth to impenetrable layers. The soil profile pits and their environs were described (field characterization) following USDA guidelines for description and sampling soils (Schoeneberger *et al*., 2012). Soil profile depths were rated using the critical limits established in Table 1. The site specific international coordinates of the pedons were georeferenced using a hand-held Etrex High Sensitivity Global Positioning System (GPS). Abney level equipment was used to determine the slope angles on the sites of the profile pits. Core samples were taken with core samplers of 99.6 cm^3 by volume from the pits at the surface and subsurface horizons which were used for the examination of some soil physical characteristics. Soil samples were collected from the pedogenic horizons starting from the base of the profiles to avoid contamination. The soil samples collected were preserved in well-labelled polyethylene bags and transported to a Soil Science Laboratory for physicochemical analyses.

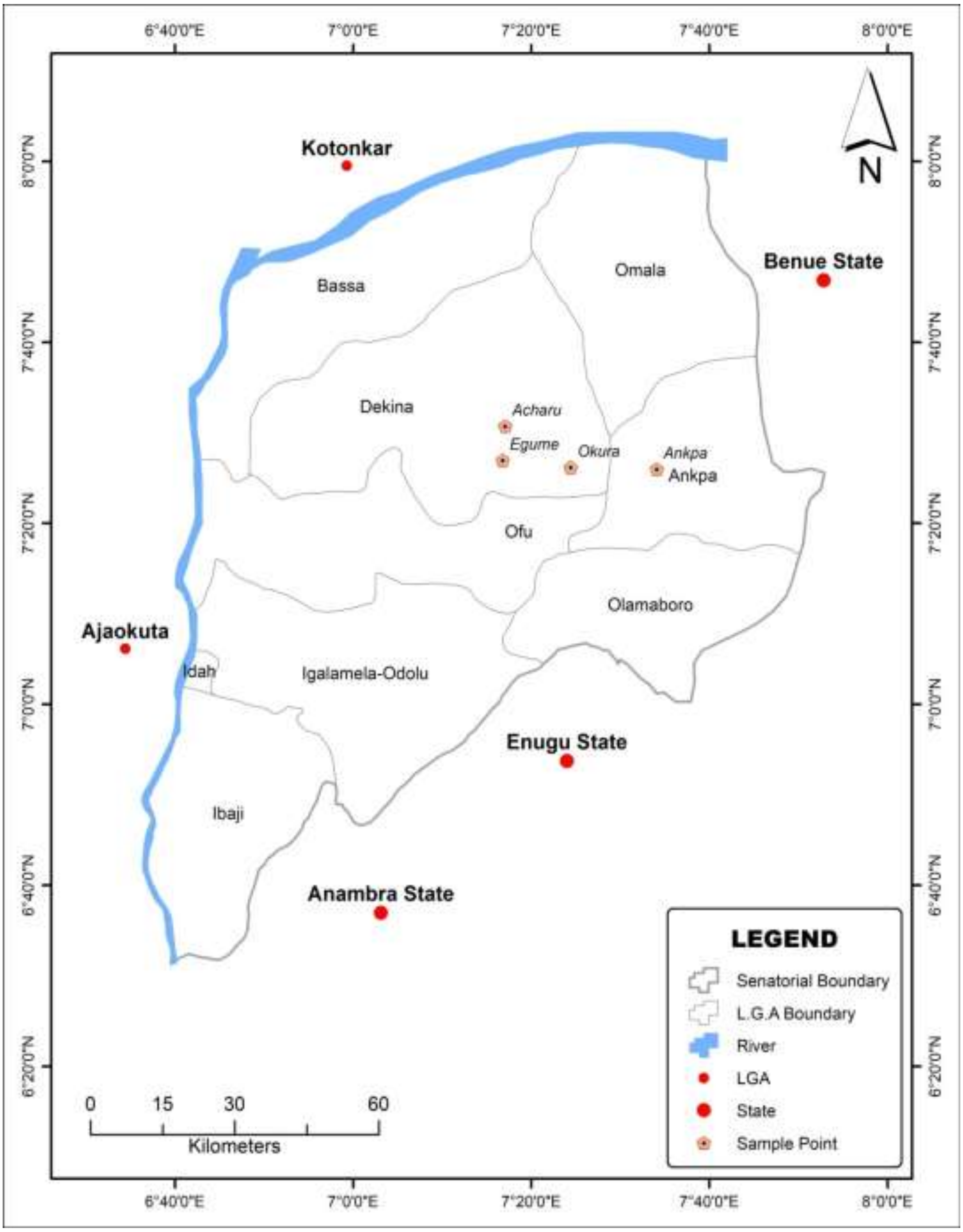

Figure 1: A map of Kogi East showing sample points

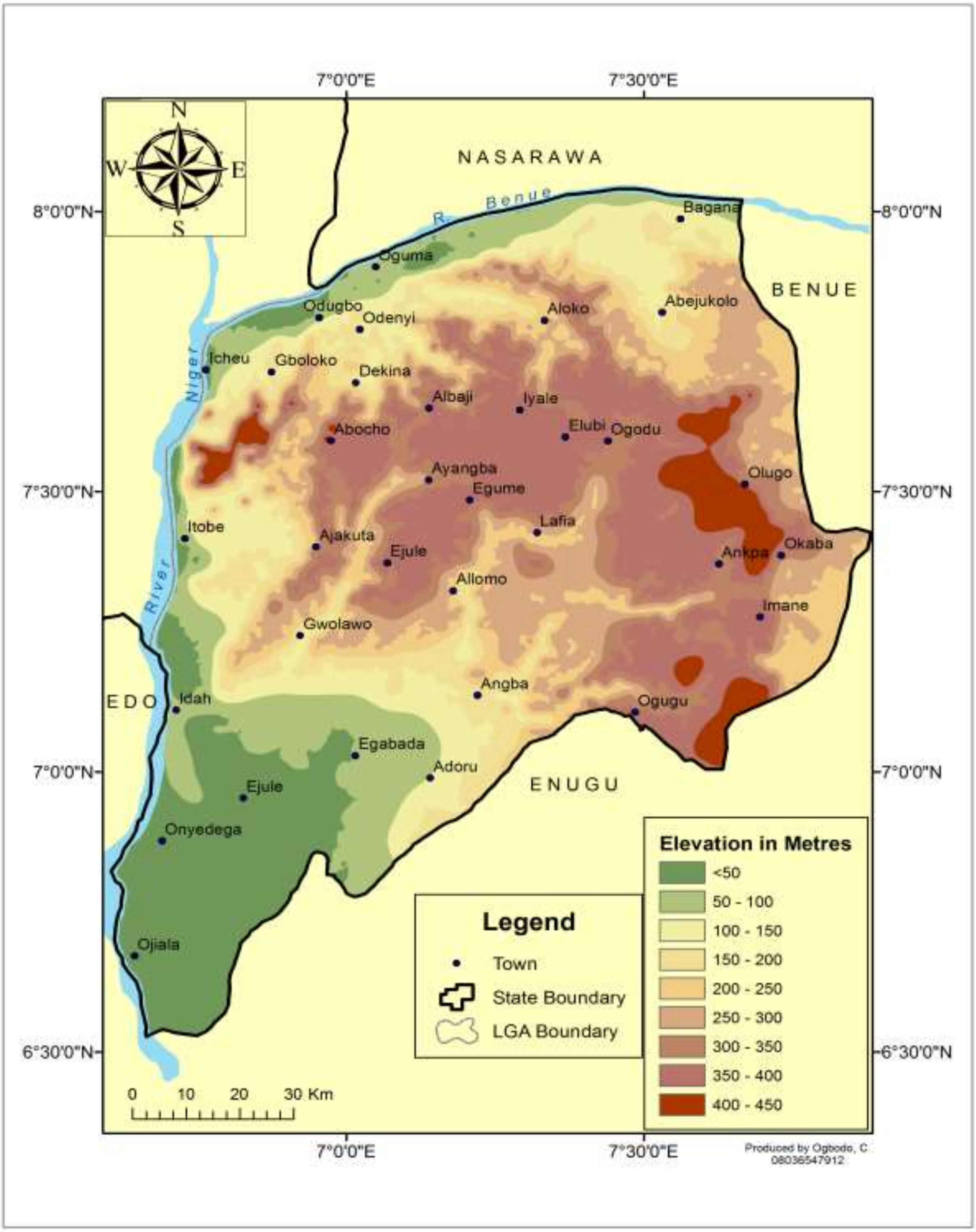

Figure 2: A topographical map of Kogi East
Source: Ukabiala (2019)

Table 1: Critical limits for interpreting soil depth

Soil depth (cm)	Interpretation
< 25	Very shallow
25 – 50	Shallow
50 – 100	Moderately deep
100 – 150	Deep
> 150	Very deep

Source: Soil Survey Staff (1999)

Laboratory Analyses

The various physical and chemical analyses through specific procedures in the laboratory were carried out. The soil samples collected from the field were air-dried and later sieved with a sieve of 2 mm mesh size before subjecting them to the analyses.

Soil physical characteristics

The particle size distribution (PSD) < 2 mm was determined using Bouyoucos (1962) Hydrometer method. Sodium hydroxide was used as dispersant. The textural classes were read out from the USDA soil textural triangle, while Bulk density was determined by the core method described by Landon (1981). The soil bulk density was calculated with the following formula;

Soil bulk density = oven dry weight of soil/volume of soil.

Soil porosity was calculated with the values of the bulk density using the method outlined by Vomicil (1965) and Brady and Weil (2002);

Soil total porosity (%) = 100 - (bulk density/Particle density x 100)

The Soil Saturated Hydraulic Conductivity (K_{sat}) was determined following the Klute and Dirksen (1986) method and calculated by using the transposed Darcy's equation for vertical flows of liquids;

$K_{sat} = (Q/At)/L/DH$,

where K_{sat} is the saturated hydraulic conductivity (cm h^{-1}), Q is steady-state volume of water outflow from the entire soil column (cm^3), A is the cross-section area (cm^2), t is the time interval (h), L is length of the sample (cm), and DH is the change in the hydraulic head (cm).

Soil chemical characteristics

Soil pH was determined in water and 1N KCl solution using a soil solution ratio of 1:2.5 with the aid of a glass electrode pH meter (McLean, 1982). Organic carbon was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982). Total nitrogen was estimated by the macro-kjeldahl digestion method (Bremmer and Mulvaney, 1982). Available phosphorus was obtained using Bray II bicarbonate extraction method (Olsen and Sommers, 1982), using 0.03 N ammonium fluoride with 0.1N HCl. The phosphorus in the extract was determined with a photo-electric colorimeter. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1N NH_4OAc (pH 7.0) using 1:10 soil solution ratio. The exchangeable potassium and sodium in the extract were determined with Flame Photometer while exchangeable calcium and magnesium were determined by atomic absorption spectrophotometry (Thomas, 1982). Exchangeable sodium percentage (ESP) was calculated using the standard of Soil Survey Staff (1999) formula;

$$ESP = \frac{\text{Exchangeable sodium}}{\text{Cation exchange capacity}} \times \frac{100}{1}$$

The titration method, as outlined in Selected Methods for soil and plant analysis (Thomas, 1982), was used in the determination of the exchangeable acidity. The samples were extracted with 1N KCl solution and the extract titrated with 0.05 NaOH to a permanent pink end point using phenophthalen indicator. Total exchangeable bases (TEB) were obtained by the summation of the exchangeable bases (Na, K, Ca and Mg) (Rhoades, 1982). The cation exchange capacity of the soils was determined with 1N NH_4OAc, pH 7.0 (Rhoades, 1982). The effective cation exchange capacity of the soil samples was estimated by the summation of the exchangeable bases and the exchangeable acidity (Rhoades, 1982);

$ECEC = Ca^{2+} + Mg^{2+} + K^+ + Na^+ + EA$, where EA is the exchangeable acidity.

The percentage base saturation was derived by dividing the total exchangeable bases (Ca, Mg, K and Na) by the CEC obtained and multiplying by 100 (Rhoades, 1982);

$$PBS = \frac{Ca^{2+} + Mg^{2+} + K^+ + Na^+}{CEC} \text{ X } \frac{100}{1}$$

Aluminium saturation percentage (ASP) was obtained by multiplying the ratio of aluminium concentration and ECEC with 100 (Soil Survey Staff, 1999);

ASP = Al / ECEC X 100

The results of the chemical analysis were compared with the critical limits in Tables 3 and 4.

Table 3: Critical limits for interpreting fertility levels of soil analytical parameters

Parameter	Very low	Low	Moderate	High	Very High
*Ca^{2+}(cmol kg^{-1})		< 2.0	2.1 – 5.0	> 5.0	
*Mg^{2+}(cmol kg^{-1})		< 0.30	0.31 – 1.0	> 1.0	
*K^+ (cmol kg^{-1})		< 0.15	0.16 – 0.3	> 0.3	
*Na^+(cmol kg^{-1})		< 0.10	0.11 – 0.3	> 0.3	
CEC (cmol kg^{-1})	<6.0	6.0 – 12.0	12.1 – 25.0	25.1 – 40.0	> 40.0
*ECEC (cmol kg^{-1})		< 6.0	6.1 – 12.0	> 12.0	

EA (cmol kg^{-1})		< 2.0	2.1 – 5	> 5	
Org. C (%)	< 0.4	0.4 – 1.0	1.1 – 1.4	1.5 – 2.0	
*Total N (%)	< 0.05	0.06 – 0.10	0.11 – 0.15	0.16 – 0.20	> 0.20
Avl. P (mg kg^{-1})	< 3.0	3.0 – 7.0	7.1 – 20.0	> 20.0	
BS (%)	< 20	20 – 40	41 – 60	60 – 80	80 – 100
ESP (%)	< 0.1	0.1 – 2.0	2.1 – 8.0	8.1 – 15.0	> 15.0
*B (mg kg^{-1})		< 0.2	0.21 – 2.0	> 2.0	
*Zn (mg kg^{-1})		< 0.8	0.81 – 2.0	> 2.0	
*Mn (mg kg^{-1})		< 1.0	1.1 – 5.0	> 5.0	
*Fe (mg kg^{-1})		< 2.5	2.51 – 5.0	> 5.0	

Source: *Shehu *et al.* (2015), Enwezor *et al.* (1989)

Table 4: Critical limits for interpreting soil pH

Soil reaction pH	Interpretation
< 4.5	Extremely acid
4.5 – 5.0	Very strongly acid
5.1 – 5.5	Strongly acid
5.6 – 6.0	Moderately acid
6.1 – 6.5	Slightly acid
6.6 – 7.3	Neutral
7.4 – 7.8	Slightly alkaline
7.9 – 8.4	Moderately alkaline
8.5 – 9.0	Strongly alkaline
> 9.0	Very strongly alkaline

Source: Soil Survey Staff (1999)

Statistical Analysis

The data generated from the laboratory analyses were subjected to descriptive statistics using Statistical Packages for Social Sciences (SPSS), version 20 for the interpretation of the results.

RESULTS

Morphological characteristics of soils of the study area

The morphological characteristics of the soils are shown in Table 5. All the pedons studied had depths greater than 190 cm and strong horizonation. The common distinctiveness and topography of boundaries between the horizons are clear smooth. The parent material and the well drained condition of the soil in this landscape showed soil moist colours of typic hue of 2.5YR and 5Y observed in the surface soil of Ankpa-P. The description of the colours showed dominant dull reddish brown (2.5YR4/4, 5YR4/3) in the surface and reddish brown (2.5YR4/6), a reddish brown (2.5YR 5/8, 5YR4/8) and red (10R4/8) in the subsurface soils.

The structure of the surface soils varied mainly between subangular and angular blocky structure. The surface soil was non-sticky and non-plastic (wet) and loose (moist), but sticky and plastic (wet), very friable to friable (moist) at the subsurface soils. All the profiles had root activities which were dominant at the A horizons. Few faint clay skins were observed in some subsurface soils. An artefact showing black earthen pot was observed at the depth of 190 cm in Ankpa-P.

Physical characteristics of soils of the study area

The physical characteristics of soils of the study area are presented in Tables 6 and 7. Sand fraction of the soils is mostly coarse with ranges of 500 to 670 g kg^{-1} at the surface and 330 to 660 g kg^{-1} at the subsurface soils. Silt was generally higher at the surface, having a mean value of 100 g kg^{-1} while the clay content was generally higher in the subsurface soils in all the profiles with a mean value of 199 g kg^{-1}. The value of the silt/clay ratio was 1.06 and 0.47 at the surface and subsurface soil, respectively. These textural characteristics gave rise to dominant loamy sand and sandy clay loam textural classes at the surface and subsurface soils. The coefficient of variation of the textural characteristics is comparatively higher in the subsurface than in the surface soils with ranges of 10 to 29 and 9 to 66 % respectively.

Table 5: Morphological characteristics of soils of the study area

Pedon/ Coordinate	Location	Horizon depth (cm)	Horizon designation	Colour Matrix	Mottles	Texture	Structure	Consistence Wet	Moist	Boundary	Pores	Roots	Others
Okura-P	Okura	0-15	Ap	10YR4/6	-	scl	14g	nsnp	l	cs	fme	fme	-
07º26’11.1”N		15-35	A	2.5YR4/6	-	scl	15c	sssp	fr	gs	ffi	ffi	-
007º24’25.0”E		35-75	AB	2.5YR3/6	-	cl	25sbk	sssp	vfr	ds	ffi	fvfi	-
		75-150	Bt1	2.5YR3/6	-	cl	25sbk	sssp	fr	ds	ffi	fvfi	Clay films on ped faces
		150-200	Bt2	10YR4/8	-	c	25sbk	sp	f	-	ffi	fvfi	Clay films on ped faces
Egume-P	Egume	0-22	Ap	2.5YR4/3	-	ls	15c	nsnp	l	as	ffi	mmeco	-
07º27’ 16.0”N		22-52	A	2.5YR4/4	-	ls	25c	nsnp	vfr	gs	fc	fco	-
007º16’47.7”E		52-87	B	2.5YR4/6	-	scl	25sbk	sssp	fr	ds	ffi	ffi	-
		87-130	Bt1	2.5YR4/8	-	sc	24sbk	sp	fr	ds	ffi	ffi	Few ants
		130-200	Bt2	2.5YR4/8	-	sc	25abk	sp	fr	-	fvfi	fvfi	Clay films on ped faces
Acharu-P	Acharu	0-24	Ap	2.5YR4/4	-	ls	24gc	nsnp	l	gw	mfi	mfi	-
07º29’59.9”N		24-57	AB	2.5YR5/4	-	lsl	25c	nsnp	vfr	cw	cme	mme	-
007º17’04.1”E		57-94	Bt1	2.5YR4/6	-	cl	245c	nsnp	vfr	ds	ffi	cmme	Clay films on ped faces
		94-140	Bt2	2.5YR5/8	-	sc	245abk	sssp	fr	ds	ffi	cfime	Clay films on ped faces
		140-200	Bt3	10R5/8	-	sc	25abk	sssp	fr	-	fvfi	fvfi	Clay films on ped faces
Ankpa-P	Ankpa	0-20	Ap1	5YR4/3	-	sl	245g	nsnp	l	aw	mfi	mfi	-
07º25’41.5”N		20-34	Ap2	5YR4/8	-	sl	25c	nsnp	vfr	gs	mme	mme	-
007º34’41.3”E		34-57	AB	2.5YR4/6	-	sl	25c	nsnp	vfr	dw	ffi	fco	Few black ants
		57-117	BA	2.5YR3/6	-	scl	35sbk	sssp	f	ds	fvfi	ffi	-
		117-167	Bts	2.5YR4/8	-	sc	25abk	sssp	fr	ds	ffi	ffi	Few black ants

	167-200	Btu	2.5YR4/8	-	sc	26sbk	sssp	fr	-	ffi	fvfi	Few medium black ants, pieces of black earthen pots, clay films on ped faces

Structure: 1=weak, 2= moderate, 3= strong, 4= fine, 5= medium, 6= coarse, c= crumb, g= granular, sbk= subangular, abk= angular blocky, s= single grain

Texture: l= loam, s= sand, c= clay, si= silt, cl= clay loam, sl= sandy loam, scl= sandy clay loam, sc= sandy clay, g= gravelly, v= very, e= extremely, st= stony

Consistency: sp= sticky and plastic, sssp= slightly sticky and slightly plastic, nsnp= non sticky and non plastic, l= loose, vfr= very friable, fr= friable, f= firm, v=very firm.

Pores and Roots: f= few, v= very, m= many, c=common, fi= fine, me= medium, co= coarse

Boundary: a= abrupt, c= clear, g= gradual, d= diffuse, s= smooth, w= wavy, i= irregular

The bulk density of the soils generally increased down the profiles with a mean value of 1.82 g cm^{-3}, being higher than the surface value (1.74 g cm^{-3}). The mean total porosity of the soils was higher at the surface soils, ranging from 27 to 7% with a mean value of 31%. Similarly, the saturated hydraulic conductivity was higher at the surface soils with mean value of 38.80 cm hr^{-1} than at the subsurface with a mean value of 32.05 cm hr^{-1}. The percentage CV for bulk density, total porosity and saturated hydraulic conductivity are 3, 6 and 27; 28, 6 and 92 for the surface and subsurface soils respectively.

Chemical characteristics of soils of the study area

The chemical characteristics of the soils are presented in Table 8. The pH value of the soils is higher at the surface soils with a mean value of 5.3 than in the subsurface soils with a mean value of 4.9. The mean of organic carbon (9.33 g kg^{-1}) and total nitrogen (1.20 g kg^{-1}) contents are higher at the surface soils when compared with those of the subsurface soils (4.70 g kg^{-1} and 0.70 g kg^{-1}, respectively). The carbon, nitrogen ratio (C:N) and the available phosphorus had mean values of 9 and 4.4 mg kg^{-1}, 7 and 1.95 mg kg^{-1} at the surface and subsurface soils, respectively. The exchangeable Ca, Mg, K and Na had respective mean value of 1.30, 1.27, 0.06 and 0.03 $cmol_c$ kg^{-1} at the surface and 2.10, 0.84, 0.07 and 0.02 $cmol_c$ kg^{-1} in the subsurface soils.

The exchangeable acidity, comprising of exchangeable H and Al recorded lower mean value of 2.63 $cmol_c$ kg^{-1} than the surface soils with mean value of 1.37 $cmol_c$ kg^{-1}. The ECEC ranged from 2.86 to 5.34 $cmol_c$ kg^{-1} at the surface and 3.01 to 9.66 $cmol_c$ kg^{-1} in the subsurface soils. The percentage base saturation and aluminium saturation percentage had surface mean values of 30 and 4% and subsurface mean value of 35and 23% respectively. The range of the exchangeable sodium parentage values at the surface and subsurface were 0.29 to 0.45% and 0.11 to 0.30%, with respective mean of 0.37 and 0.20%.

The CV of the chemical properties ranges from 4 to 52% in the surface soils, and from 1 to 48% in the subsurface soils. The highest variation occurred in the surface soils' total nitrogen (52%), and very slight variation (1%) in C:N of the subsurface soils.

Table 6: Textural characteristics of soils of the study area

Pedon	Location	Depth (cm)	Horizon designation	Coarse sand	Fine sand	Silt	Clay	Silt:Clay	Texture
				($g\ kg^{-1}$)					
Okura -P	Okura	0-15	Ap	560	220	110	110	1.00	sl
07º26'11.1"N		15-35	A	450	290	50	210	0.24	scl
007º24'25.0"E		35-75	AB	470	210	70	250	0.28	scl
		75-150	Bt1	410	250	90	250	0.36	scl
		150-200	Bt2	330	270	130	270	0.48	scl
Egume-P	Egume	0-22	Ap	500	320	90	90	1.00	ls
07º27' 16.0"N		22-52	A	460	380	50	110	0.45	ls
007º16'47.7"E		52-87	B	430	290	50	230	0.22	scl
		87-130	Bt1	380	380	30	210	0.14	scl
		130-200	Bt2	410	310	50	230	0.22	scl
Acharu-P	Acharu	0-24	Ap	550	250	110	90	1.22	ls
07º29'59.9"N		24-57	AB	490	350	50	110	0.45	ls
007º17'04.1"E		57-94	Bt1	420	260	70	250	0.28	scl
		94-140	Bt2	420	280	50	250	0.20	scl
		140-200	Bt3	400	300	70	250	0.28	scl
Ankpa-P	Ankpa	0-20	Ap1	670	150	90	90	1.00	ls
07º25'41.5"N		20-34	Ap2	660	200	50	90	0.56	ls
007º34'41.3"E		34-57	AB	600	220	70	110	0.64	ls
		57-117	BA	350	310	230	110	2.09	sl
		117-167	Bts	470	150	130	250	0.52	scl
		167-200	Btu	460	160	130	250	0.52	scl
Surface range				**500-670**	**150-320**	**90-110**	**90-110**	**1.00-1.22**	**ls**
Subsurface range				**330-660**	**150-380**	**30-230**	**90-270**	**0.14-0.56**	**ls-scl**
Surface mean				**575**	**235**	**100**	**97**	**1.06**	**ls**
Subsurface mean				**453**	**275**	**86**	**199**	**0.47**	**Scl**
Surface CV (%)				**10**	**29**	**11**	**11**	**10**	**-**
Subsurface CV (%)				**9**	**20**	**43**	**17**	**66**	**-**

sl= sandy loam, scl= sandy clay loam, ls=loamy sand, CV = Coefficient of Variability

Table 7: Physical characteristics of soils of the study area

Pedon/Coordinate	Location	Depth (cm)	Bulk density ($g\ cm^{-3}$)	Total porosity (%)	K_{sat} ($cm\ hr^{-1}$)
Okura -P	Okura	0-25	1.80	32.08	55.66
07º26’11.1”N		25-50	1.92	27.55	1.42
007º24’25.0”E		50-75	1.83	30.94	10.12
Egume-P	Egume	0-25	1.74	34.34	32.38
07º27’ 16.0”N		25-50	1.87	29.43	31.37
007º16’47.7”E		50-75	1.74	34.34	75.89
Acharu-P	Acharu	0-25	1.66	37.36	65.78
07º29’59.9”N		25-50	1.73	34.72	62.74
007º17’04.1”E		50-75	1.78	32.83	60.72
Ankpa-P	Ankpa	0-25	1.74	34.34	55.66
07º25’41.5”N		25-50	1.85	30.19	4.05
007º34’41.3”E		50-75	1.83	30.94	10.12
Surface range			**1.66-1.92**	**27.55-7.36**	**1.42-75.89**
Subsurface range			**1.73-1.92**	**27.55-34.34**	**1.42-75.89**
Surface mean			**1.74**	**32.42**	**38.80**
Subsurface mean			**1.82**	**31.37**	**32.05**
Surface CV (%)			**3**	**6**	**27**
Subsurface CV (%)			**28**	**6**	**92**

K_{sat} = Saturated hydraulic conductivity, CV = Coefficient of Variation

Table 8: Chemical characteristics of soils of the study area

Pedon/ Coordinate	Location	Depth	Horizon designation	pH		OC	TN	C:N	Av. P	Exchangeable cations					
										Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}	Al^{3+}
		(cm)		(H_2O)	(KCl)	(g kg^{-1})			(mg kg^{-1})	(cmol$_c$ kg^{-1})					
Okura-P	Okura	0-15	Ap1	5.6	4.7	15.50	1.90	8	6..53	2.00	2.00	0.09	0.05	0.80	0.40
07º26'11.1"N		15-35	A	4.5	3.6	6.30	0.90	7	1.87	5.60	0.40	0.04	0.02	2.00	1.60
007º24'25.0"E		35-75	AB	4.5	3.5	5.50	1.10	5	1.87	3.00	1.60	0.03	0.02	2.40	1.60
		75-150	Bt1	4.7	3.5	5.50	0.60	9	1.87	1.40	0.80	0.03	0.02	2.00	2.00
		150-200	Bt2	4.6	3.6	5.00	0.70	7	2.80	0.40	1.60	0.03	0.02	1.20	2.00
Egume-P	Egume	0-22	Ap	4.8	4.1	8.80	0.70	13	5.60	1.00	1.20	0.05	0.03	1.60	0.40
07º27' 16.0"N		22-52	A	4.9	3.8	6.70	0.90	7	1.87	0.60	0.80	0.04	0.02	0.80	2.00
007º16'47.7"E		52-87	B	5.2	4.3	5.00	0.60	8	1.87	1.00	0.80	0.03	0.02	1.00	1.40
		87-130	Bt1	4.9	4.1	2.90	0.40	7	1.87	0.60	1.00	0.20	0.01	1.20	1.20
		130-200	Bt2	4.9	3.9	2.50	0.40	6	0.93	0.40	0.80	0.20	0.01	1.20	1.20
Acharu-P	Acharu	0-24	Ap	5.3	4.2	7.12	0.90	8	5.60	1.20	0.80	0.04	0.02	0.80	-
07º29'59.9"N		24-57	AB	4.9	3.7	7.10	0.70	10	0.93	3.60	0.80	0.04	0.02	2.80	-
007º17'04.1"E		57-94	Bt1	4.8	3.6	5.90	0.70	8	0.93	0.80	0.80	0.03	0.02	2.00	0.80
		94-140	Bt2	5.0	4.0	3.80	0.70	5	0.93	4.40	0.80	0.03	0.01	1.40	0.60
		140-200	Bt3	4.9	3.8	3.40	0.60	6	1.57	0.40	0.80	0.02	0.01	2.00	0.40
Ankpa-P	Ankpa	0-20	Ap1	5.7	4.6	5.90	0.80	7	2.80	0.80	0.80	0.03	0.02	1.40	-
07º25'41.5"N		20-34	Ap2	5.5	4.0	5.90	0.40	15	4.66	1.20	1.20	0.03	0.02	0.80	0.40
007º34'41.3"E		34-57	AB	5.4	4.1	2.10	0.70	3	1.87	1.00	0.60	0.20	0.01	0.80	0.40
		57-117	BA	4.7	3.6	5.00	0.80	6	1.87	4.80	0.40	0.03	0.02	0.80	1.60
		117-167	Bts	4.5	3.6	4.60	0.60	8	1.87	1.00	0.80	0.03	0.02	0.80	1.60
		167-200	Btu	4.9	3.7	3.40	0.90	4	1.87	3.80	0.20	0.02	0.01	1.60	1.20
Surface range				**4.8-5.7**	**4.1-4.7**	**5.50-15.5**	**0.7-1.9**	**7-13**	**2.8-5.6**	**0.80-2.00**	**0.80-2.00**	**0.03-0.09**	**0.02-0.05**	**0.80-1.60**	**0.40-0.40**
Subsurface range				**4.5-5.5**	**3.5-4.3**	**2.10-7.10**	**0.40-1.10**	**3-15**	**0.93-4.66**	**0.40-5.60**	**0.20-1.60**	**0.02-0.20**	**0.01-0.02**	**0.80-2.80**	**0.40-2.00**

Surface mean	**5.3**	**4.4**	**9.33**	**1.20**	**9**	**4.48**	**1.30**	**1.27**	**0.06**	**0.03**	**1.17**	**0.40**
Subsurface mean	**4.9**	**3.8**	**4.70**	**0.70**	**7**	**1.95**	**2.10**	**0.84**	**0.07**	**0.02**	**1.49**	**1.24**
Surface CV (%)	**7**	**7**	**46**	**52**	**30**	**30**	**42**	**48**	**4**	**33**	**36**	**0**
Subsurface CV (%)	**40**	**5**	**14**	**14**	**1**	**32**	**45**	**22**	**67**	**12**	**38**	**43**

OC= Organic carbon, TN= Total Nitrogen, Av. P= Available Phosphorus, Ca^{2+}= Exchangeable Calcium, Mg^{2+}= Exchangeable Magnesium, K^{+}= Exchangeable Potassium, Na^{+}= Exchangeable Sodium, Al^{3+}= Exchangeable Aluminium, -= No significant value, CV = Coefficient of Variation

Table 8 continued

Pedon/ Coordinate	**Location**	**Depth**	**Horizon Designation**	**EA**	**CEC**	**ECEC**	**TEB**	**PBS**	**ESP**	**ASP**
		(cm)		**(cmol$_c$ kg^{-1})**				**(%)**		
Okura-P	Okura	0-15	Ap	1.20	11.20	5.34	4.14	37	0.45	7
07º26'11.1"N		15-35	A	3.60	9.20	9.66	6.06	65	0.22	17
007º24'25.0"E		35-75	AB	4.00	8.00	8.65	4.65	58	0.25	18
		75-150	Bt1	4.00	9.60	6.25	2.25	23	0.21	32
		150-200	Bt2	3.20	7.40	5.25	2.05	27	0.27	38
Egume-P	Egume	0-22	Ap	2.00	7.40	4.28	2.28	31	0.41	9
07º27' 16.0"N		22-52	A	2.80	7.40	4.26	1.46	19	0.27	47
007º16'47.7"E		52-87	B	2.40	7.80	4.25	1.85	24	0.26	33
		87-130	Bt1	2.40	7.60	4.21	1.81	27	0.13	29
		130-200	Bt2	2.40	6.60	3.81	1.41	20	0.15	31
Acharu-P	Acharu	0-24	Ap	0.80	7.00	2.86	2.06	26	0.29	0
07º29'59.9"N		24-57	AB	2.80	7.80	7.26	4.46	54	0.26	0
007º17'04.1"E		57-94	Bt1	2.80	8.20	4.45	1.65	18	0.24	18
		94-140	Bt2	2.00	9.00	7.24	5.24	64	0.11	8
		140-200	Bt3	2.40	8.60	3.63	1.23	14	0.12	11
Ankpa-P	Ankpa	0-20	Ap1	1.40	6.60	3.05	1.65	25	0.30	0
07º25'41.5"N		20-34	Ap2	1.20	6.60	3.65	2.45	37	0.30	11
007º34'41.3"E		34-57	AB	1.20	6.60	3.01	1.81	27	0.15	13
		57-117	BA	2.40	8.80	7.65	5.25	60	0.23	21
		117-167	Bts	2.40	8.60	4.25	1.85	22	0.23	38

	167-200	Btu	2.80	7.80	6.83	4.03	51	0.13	18
Surface range			**0.80-2.00**	**6.60-11.2**	**2.86-5.34**	**1.65-4.14**	**25-37**	**0.29-0.45**	**0-7**
Subsurface range			**1.20-4.00**	**6.60-9.60**	**3.01-9.66**	**1.23-6.06**	**14-65**	**0.11-0.30**	**0-47**
Surface mean			**1.37**	**8.33**	**3.96**	**2.65**	**30**	**0.37**	**4**
Subsurface mean			**2.63**	**7.99**	**5.63**	**2.99**	**35**	**0.20**	**23**
Surface CV (%)			**37**	**26**	**30**	**43**	**19**	**22**	**17**
Subsurface CV (%)			**27**	**7**	**25**	**31**	**25**	**11**	**48**

- = No significant value EA= Exchangeable acidity, CEC= Cation exchange capacity, ECEC= Effective Cation Exchange Capacity, TEB= Total Exchangeable Bases, PBS= Percentage Base Saturation, ESP= Exchangeable Sodium Percentage, ASP= Aluminium Saturation Percentage, CV = Coefficient of Variation

DISCUSSION

The soils are well drained soils occurring on landscape with deep water. Also the absence of mottles in any of the horizons proofs the established drainage condition. The brown to reddish brown colours of the soils indicated the oxidized state of iron (Brady and Weil, 2002). The moderate to high subsurface bulk density resulted in low porosity of those layers. The higher bulk densities of the soils may be attributed to the soil texture and organic matter. According to Brady and Weil (2002), soils with higher proportion of sand generally have higher bulk densities than the finer-textured soils. The bulk density results of this research area are contrary to the bulk densities of the coastal plain soils of the southern Nigeria (with lower elevation) which had average value of 1.45 g cm^{-3} (Ogban and Ekerette, 2001). This dissimilarity could be because the finer texture of the soils of the southern part of Nigeria studied which were organized in porous granules and the pores exist both between and within the granules which ensured high total pore space and a lower bulk density (Kolay, 2000). However, the surface soils of the soils have lower mean bulk density and higher total porosity than the subsurface soils. This is related to the fact that the organic carbon contents are higher at the surface than in the subsurface. It may also be attributed to the weight of overlying soil layers on the subsurface soils.

The organic carbon contents of the soils of this mapping unit are generally low with an exception of moderate value in the surface soil of Okura-P which may have been as a result of long accumulated organic matter on the surface due to long period of fallow (Akamigbo, 2005). The general low content of organic carbon could be attributed to rapid mineralization and humification of the organic matter in the environment with ustic moisture regime (Akamigbo, 1999). This rapid rate of mineralization has manifested in not so high C:N ratios for the soils. According to Ahn (1979), C:N ratio of 12 indicates advanced stage of mineralization. The slightly higher C:N ratios in Egume-P and Ankpa-P soils as shown in Table 8, may be attributed to leaching of nitrates and denitrification losses.

The nitrogen and exchangeable bases in these soils were low, following the same trend of the organic carbon. Ahn (1979) noted that most of the soil nitrogen reserves in West Africa are in the soil organic matter. The available phosphorus levels in the pedons of the soils are low to moderate. According to Sanchez (1976), phosphorus deficiencies are very common in highly weathered *Oxisols*, *Alfisols* and *Ultisols*. He further stated that many tropical soils have extremely high capacities to immobilize phosphorus and that total phosphorus in the surface soil decreases with increasing weathering intensity. The levels of available phosphorus in the soils agrees with Olson and Engheslad (1972) who stated that there is greater areal extent of highly weathered soils in the tropics.

CONCLUSION

The investigation of the upland soils of within eastern part of Kogi State revealed that the soils are well drained with reddish colour depicting presence of oxides of iron, with low to moderate levels of cation exchange capacity and percentage base saturation which are part of the major soil indicators. These values reflect the capacity of the soils to retain cations, as well as their degree of weathering. Efforts in improving the fertility and productivity of the soils will not be complete without considering management options that will ameliorate the acidity problem through proper liming and enrichment of soils' organic matter. This as well will make available the immobilized phosphorus in the soil for crop uptake. Addition of inorganic fertilizers that will readily supply nitrogen, phosphorus and potassium will also yield positive results.

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