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CHARACTERISTICS OF SOILS ALONG A TOPOSEQUENCE IN ISHIAGU, EASTERN NIGERIA AND ITS RELATION TO POTENTIAL AGRICULTURAL LANDUSE.

Nsor, M.E and Adesemuyi, E.A
Department of Soil Science and Meteorology,
Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State.

ABSTRACT

The soil along a toposequence in Isiagu, Eastern Nigeria was studied to establish its influence on soil properties and its relation to potential agricultural use. In order to characterize and classify the soil, three pedons were dug along the toposequence at the crest, middle slope and valley bottom. The soils were characterized in terms of their morphological, physical and chemical properties. The soils were generally medium to coarse textured. The distribution of clay content increased with soil depth for all pedons. The soils were strongly to moderately acid (pH 4.4 to 5.6). The highest concentration of organic carbon and organic matter occurred at the valley bottom and decreased with depth in all the pedons studied. Base saturation was low at the crest and middle slope and medium at the valley bottom. At the sub group level the soils at the crest were classified as Typic Hapludults (USDA) which correlated as Haplic Acrisols (FAO/UNESCO). The soils at the middle slope were classified as Typic Plinthudults (USDA) and Plinthic Acrisols (FAO/UNESCO). The valley bottom soils were classified as Histic Humaquepts (USDA) and Histic Cambisols (FAO/UNESCO). The soils at the middle slope and valley bottom were preferred for economic arable crop cultivation whereas the soils at the crest were most suited for forestry and wildlife. Strict measures to prevent soil erosion and replenish lost nutrients are required for enhanced productivity of these soils.

Key words: Characteristics, Toposequence, Potential Land use.

INTRODUCTION

Soil's topography plays a major role as one of the factors that influences pedogenesis and in the process that dictates the distribution and use of soils on the landscape (Esu *et al.,* 2008). Landscape position influences effective rainfall, drainage and erosion. Topography influences water velocity on a slope, variation in drainage conditions and deposition of minerals. This causes a series of changes in soil properties such as horizon differentiation, textural contrasts, changes in soil depth and chemical properties (Hall and Olson, 1991).

Lack of information on the soil resources of any region contributes to the problem of soil degradation and that of world food crisis, due to wrong use and poor management of land resources on different terrains. Inadequate information on the potentials of our soil resources is a major constraint limiting agricultural development in Nigeria. Land characteristic and soils information must be combined effectively to manage our soil for enhanced agricultural productivity. Upland soils deteriorate rapidly due to erosion and fertility depletion. There is thus the need to study soils on different terrains of a toposequence, classify them for proper identification and technological transfer. Proper understanding of the relationship between landscape and soil properties will enhance soil management. Studies on soil classification and soil landscape relationships in the extensive agricultural soils in Ishiagu, Eastern Nigeria are scarce. This however necessitates the present study with the specific objective of characterizing, classifying and recommending appropriate management measures aimed at enhancing their productivities.

MATERIALS AND METHODS

Site Description

This study was carried out on a toposequence located in Ishiagu, Ivo Local Government Area. Ishiagu lies around latitude 05^0 56^1 and 06^0 05^1 and longitude 07^0 31^1 and 07^0 48^1 E. The geology of the study area consists of shale and sandstones of the Asu River group (Obiora and Umeji, 1995).

The vegetation type in the area is the Derived Guinea Savannah. The climate of the area is the wet humid tropical type with distinct wet and dry seasons. The monthly temperature value is always around 27 ^{0}C, though with little variations. The annual rainfall ranges from 1750-2500 mm. The relative humidity in the study area varies from 50-60 % during the month of January, to about 60-70 % in July (FCAI, Meteorology Station, 2013).

SAMPLING TECHNIQUE

The stratified random sampling technique was adopted in this study. The identified toposequence was stratified into the valley bottom, middle slope and crest. Three (3) profile pits were excavated, one each representing the valley bottom, middle slope and crest of the toposequence.

FIELD WORK

The profile pits were dug at the most representative points of observation representing the various strata of the toposequence. The soil profiles were described according to the FAO (2006) guidelines. Soil samples were taken from the different horizons of the profile pits for routine chemical analysis, determination of soils physical parameters and other fertility indices.

LABORATORY ANALYSIS

Particle size analysis was determined by the pipette method (Gee and Bauder, 1986). Soils erodibility index was estimated by evaluating the ratio of sand and silt contents to clay content (Hudson, 1995). Evidence for argillic (Bt) horizon was obtained by determining the ratio of illuvial to eluvial clay.

Soil pH was determined in a 1:2.5, soil: water suspension (Thomas, 1996). Organic carbon was determined by the dichromate wet oxidation method (Nelson and Sommers, 1996). Total nitrogen was determined by the macro kjeldahl digestion procedure (Bremner, 1996). Exchangeable cations, extracted into IM ammonium acetate solution (AAS) were measured by versenate titration method (Ca^{2+} and Mg^{2+}) and by flame photometry (Na^+ and K^+). Exchangeable acidity (H^+ and Al^{3+}) was determined by the I M KCl extraction procedure (Juo, 1979). Available phosphorus in the soil was determined by the Bray 11 methods, using a solution of I M NH_4F and 0.5 M HCl in distilled water as the extractant (Kuo, 1996). The cation exchange activity class was determined by estimating the ratio of CEC by NH_4OAc at pH 7.0 to clay content.

RESULTS AND DISCUSSION

Morphological Characteristics

Under moist conditions, the soils at the crest were characterized with dark brown (7.5YR 3/2) surface soils over reddish brown (5YR 4/4) sub soils. The soils at the middle slope had dark reddish brown (5YR 3/3) epipedons over reddish brown (5YR 4/4) to reddish yellow (5YR 6/6) endopedons. The valley bottom soils were characterized by very dark greyish brown (10YR 3/2) surface soils over greyish brown (10YR 5/2) to gray (10YR 6/1) sub soils (Table 1). The sub soils of valley bottom were mottled throughout their entire depth with yellow brown (10YR 5/4) mottles due to seasonal fluctuation of the water table. However, the soils at the crest had reddish (2.5YR 4/6) sub soil mottles indicating the presence of weathering minerals (Table 1). Moberg and Esu (1991) and Akamigbo *et al.,* (2001) reported similar colours for soils of similar landscape positions. Weak to moderate, fine to medium crumb and granular structures characterized the soils at the crest and middle slope while sub soils at the valley bottom had moderate medium to coarse prismatic structures (Table 1). The dry consistence of these soils indicated soft surfaces over slightly hard sub soils at the crest and middle slope while at the valley bottom, hard surface soils occurred over very hard sub soils. Loose to very friable top soils over friable to firm sub soils characterized the moist consistence of the soils in the study area. Under wet conditions these soils had non-sticky, non-plastic or slightly-sticky, slightly plastic top soils over sticky-plastic sub soils (Table 1).

Physical Characteristics

The soils along a toposequence in Ishiagu Ivo LGA were characterized with sandy clay, loam, sandy loam and sandy clay. The medium to coarse texture of these soils is due to their granite origin which according to Webster and Wilson (1980) weathers into coarse textured soils. These soils had high soil erodibility index in the range 1.6 to 5.3 (Table 2). These values are higher than the critical limit of 1.0 suggested by Kinell (1981) for coarse textured soils thus making these soils vulnerable to sheet and gully erosion. The erosion severity is higher at the crest and middle slope to slope steepness. This finding corroborates that of Hudson (1995) who suggested that soils with high erodibility index are easily eroded. Total sand content dominated other soil separates in all the pedons studied with values ranging from 43-71 % (Table 2). There was a progressive increase in clay content with soil depth in all pedons studied with total sand content highest in top soils. This however indicates the presence of argillic or kandic sub-surface diagnostic horizons. Silt content was generally low (10-19 %) in all pedons. This observations also collaborates the work of Atofarati *et al.,* (2012) on two toposequence at Ile-Oluji, Ondo State, Nigeria.

Chemical Characteristics

The pH of the soils in the study area ranged from 4.4 to 5.6, averaging 4.6 in the crest, 5.2 in the middle slope and 4.8 in valley bottom topographic position. These values are rated strongly to moderately acid. The strongly to moderately acid reaction of these soils may be caused by the high rainfall experienced in these localities and further complicated by the coarse textured nature of these soils permitting extensive leaching of basic cations.

Values of soil organic carbon ranged from 6.1 to 32.1 gkg^{-1}, averaging 12.7 gkg^{-1} for soils

Table 1: Morphological Characteristics of Soils along a Toposequence in Ishiagu, Ivo L.G.A

Horizon Designation	Horizon Thickness (cm)	Major Colour	Mottles	Texture	Structure	CONSISTENCE Dry	Moist	Wet	Roots	Pores	Horizon Boundary
Pedon A (Crest)											
Ap	0 – 20	7.5YR 3/2; Db		SCL	1F Crumb	S	l	ns – np	cm	Mc	cw
BC	20 – 46	2.5YR 3/4; Drb		SCL	1M Granular	Sh	vfr	ns – np	cf	cm	gw
BCt_1	46 – 82	5YR 4/4; Rb		SCL	1F Crumb	Sh	f	S – sp	mm	cm	cw
BCt_2	82 – 133	5YR 4/4; Rb		SC	1F Crumb	Sh	f	S – p	cc	cm	
Pedon B (Middle Slope)											
Ap	0 – 27	5YR 3/3; Drb		SL	1F Crumb	S	L	ns – sp	cm	fm	cw
BCt_1	27 – 43	7.5YR 4/4; B		SCL	2M Crumb	Sh	vfr	ss – sp	ff	fm	gw
BCt_2	43 – 88	5YR 4/4; Rb		SC	2C Granular	Sh	f	s – p	cf	cf	gw
Ct	88 – 151	5YR 6/6; Ry		SC	2C Granular	Sh	f	s – p	fc	cf	
Pedon C (Valley Bottom)											
Ap	0 – 20	10YR /3/2; VDgb	10YR 5/4; fff, Yb	SCL	2M Granular	h	vf	ss – np	cf	cc	as
Bt_1	20 45	10YR 5/2; Gb	10YR 5/4; ffd, Yb	SCL	2M Prismatic	vh	fr	ss – sp	fvf	ff	gw
Bt_2	45 – 71	10YR 6/1; G	10YR 5/4; cmd, Yb	SCL	2C Prismatic	vh	f	s – sp	fc	fvf	

Key:

1. Colour: Db = Dark brown, Drb = Dark reddish brown, Rb= Reddish brown, B = brown, Ry = Reddish yellow, VDgb= very Dark grayish brown, Gb = Grayish brown, G = Gray, R = Red, Yb = Yellowish brown.
2. Mottles: ffd = few fine distinct, cmd = common medium distinct.
3. Structure: 1 = weak, 2 = moderate, 3 = strong, f = fine, m = medium.
4. Texture: SCL = Sandy Clay Loam, SC = Sandy Clay, SL = Sandy Loam.
5. Consistence: S = Soft, Sh = Slightly hard, vh = very hard, h = hard , vfr = very friable, fr = friable, l = loose, f = firm, ns = non sticky, np = non-plastic, s = sticky, p = plastic, ss = slightly sticky, sp = slightly plastic.

at the crest, 11.6 gkg^{-1} at the middle slope and 24.1 gkg^{-1} for soils at the valley bottom (Table 3). These values were rated medium for soils at the crest and middle slope but high for soils in valley bottom locations. The high organic carbon in soils at the valley bottom may be due to increased organic matter deposition and subsequent mineralization. High organic carbon levels especially in top soils of middle slope may be due to the redistributive effect of slope (Esu *et al.,* 2008).

Total nitrogen ranged from 0.4 to 4.1 gkg^{-1}, averaging 0.9, 1.3 and 3.7 gkg^{-1} for soils at the crest, middle slope and valley bottom respectively (Table 3). These values are rated low for soils at the crest, medium for soils at the middle slope and high for valley bottom soils. The high total nitrogen level at the valley bottom may be due to its high organic carbon content which according to Konnovora (1966) accounts for about 90 to 98% of total nitrogen.

Amongst the exchangeable cations, sodium ranged from 0.04 to 0.06 $cmolkg^{-1}$, averaging 0.05 $cmolkg^{-1}$ for soils at the crest and 0.06 $cmolkg^{-1}$ for soils at the middle slope and valley bottom (Table 3). These values are rated low in the entire study area. Exchangeable potassium ranged from 0.05 to 1.20 cmolkg-1, averaging 0.08 $cmolkg^{-1}$ for soils at crest, 0.09 $cmolkg^{-1}$ for soils at the middle slope and 1.04 $cmolkg^{-1}$ for valley bottom soils. These values are rated high for valley bottom soils but low for crest and middle slope soils. Exchangeable calcium in the study area ranged from 0.6 to 3.6 $cmolkg^{-1}$, averaging 0.8, 1.3 and 3.1$cmolkg^{-1}$ for soils at the crest, middle slope and valley bottom respectively. These values are rate medium for valley bottom soils but low for crest and middle slope soils. Exchangeable magnesium ranged from 0.6 to 4.3 $cmolkg^{-1}$, averaging 1.2, 1.3 and 4.0 $cmolkg^{-1}$ for soils at crest, middle slope and valley bottom respectively. These values are rated medium for valley bottom soils but low for crest and middle slope soils.

Table 2: Physical Characteristics and Soil Erodibility Index of Soils along a Toposquencie in Ishiagu, Ivo L.G.A.

Horizon Designation	Horizon Depth (cm)	Coarse Sand %	Fine Sand %	Total Sand%	Silt %	Clay %	Textural Class	Soil Erodibility Index
				Pedon A (Crest)				
Ap	0 – 20	46	19	65	14	21	SCL	3.8
BC	20 – 46	42	15	57	17	26	SCL	2.8
BCt_1	46 – 82	37	14	51	19	30	SCL	2.3
BCt_2	82 – 133	31	43	43	19	38	SC	1.6
				Pedon B (Middle Slope)				
Ap	0 – 27	40	31	71	13	16	SL	5.3
BCt_1	27 – 43	38	17	55	15	30	SCL	2.3
BCt_2	43 – 88	46	5	51	13	36	SC	1.8
Ct	88 – 151	36	14	50	18	32	SC	2,1
				Pedon C (Valley Botton)				
Ap	0 – 20	46	20	66	10	24	SCL	3.2
Bt_1	20 – 45	42	19	61	12	27	SCL	2.7
Bt_2	45 – 71	36	18	54	14	32	SCL	2.1

Key:
SCL = Sandy Clay Loam, SC = Sandy Clay, SL = Sandy Loam

Amongst the exchangeable cations calcium and magnesium dominated over potassium and sodium. This finding collaborates that of Enwezor (1981). High soil mineral nutrient (exchangeable bases) observed in top soil horizons are probably due to nutrient biocycling (Ogunwale *et al.,* 2002). The medium to high levels of exchangeable cations observed in soils of valley bottom locations may be due to erosional deposition of sedimens containing solutions of these cations.

The result of the cation exchange capacity (CEC) of soils in the study area indicated medium level (8.23 cmolkg^{-1}) for soils at the valley bottom but low for soils at the crest (2.08 cmolkg^{-1}) and middle slope (2.85 cmolkg^{-1}).

The exchangeable acidity in the study area ranged from 2.6 to 9.0 cmolkg^{-1}. The exchangeable acidity was due majorly to exchangeable H^+ however with trace levels of exchangeable Al^{3+} (Table 3).

Values of available phosphorus in the study area ranged from 3.0 to 10.1 mgkg^{-1}, averaging 3.5, 6.0 and 7.4 mgkg^{-1} for soils at the crest, middle slope and valley bottom respectively. These values were all rated low. The low available phosphorus level encountered in the study area collaborate the finding of Eshett (1987) who remarked that most Nigerian soils have low phosphate reserves due to high phosphorus fixation.

Base saturation in the study area ranged from 20.0 to 58.1%, averaging 23.8 % for soils on crest, 30.5 % for soils of middle slope positions and 53.1% for soils valley bottom. These values of base saturation were rated low for soils of crest and middle slope but high for soils of valley bottom locations.

Taxonomic Classification of Soils in the Study Area

The soils in the study area are classified using the USDA soil taxonomy (Soil survey staff, 2010) and correlated with the FAO/UNESCO legend of World Reference base (FAO/UNESCO, 1988).

Soils of crest and middle slope have translocated clay in B-horizon (Bt) as evidenced by clay skins and ratios of illuvial: elluvial clay greater than 1.5. This signified the presence of argillic horizon. These soils also had low supply of basic cations and base saturation less than 35 % by ammonium acetate method. They are therefore classified as Ultisols (Soil Survey Staff, 2010). These soils are further classified as Udults due to their occurrence under Udic soil moisture regime, at the sub order level. The soils at the crest were further classified as Hapludults at the great group level and as Typic Hapludults at the subgroup level which correlated approximately as Haplic Acrisols (FAO/UNESCO).

The soils at the middle slope were classified Plinthudults at the great group level due to presence of Plinthites in their sub soils and as Typic Plinthudults at the sub order level. The FAO/UNESCO equivalent of Typic Plinthudults is Plinthic Acrisols.

The valley bottom soils were characterized by histic epipedons and a cambic endopedon. These soils also had medium levels of base saturation with poorly developed horizons. These properties qualified the placement of these soils under the Inceptisol soil order (Soil Survey Staff, 2010). These soils occurred under Aquic conditions and were thus classified Aquepts at the sub order level. At the great group level, they were classified Humaquepts due to their possessesion of histic epipedons. These soils were further classified as Histic Humaquepts at the sub group level and correlated approximately as Humic Cambisols (FAO/UNESCO).

Table 3: Chemical Properties of Soils along a Toposequence in Ishiagu, Ivo LG.A.

Horizon Designation	Horizon Depth (cm)	pH ($H_2$0)	Org. C	Org. M. gkg^{-1}	Total N	Na^+	K^+	Ca^{2+}	Mg^{2+} $cmolkg^{-1}$	CEC	ECEC	Al^{3+}	H^+	EA	Avail. P. $mgkg^{-1}$	BS %	CEC: Clay	Activity Class
Pedon A (Crest)																		
Ap	0 – 20	4.8	17.9	30.9	1.4	0.05	0.12	1.3	1.6	3.07	10.57	Trace	7.5	7.5	4.4	29.0	0.1	
BC	20 – 46	4.6	16.1	27.8	1.1	0.06	0.08	0.7	1.2	2.04	2.04	Trace	5.6	5.6	3.3	26.7	0.1	
BCt_1	46 – 82	4.4	9.9	17.1	0.6	0.04	0.06	0.6	1.0	1.70	1.70	Trace	7.1	7.1	3.1	19.3	0.1	
BCt_2	82 - 133	4.6	6.7	11.6	0.4	0.04	0.06	0.6	0.8	1.50	1.50	Trace	6.0	6.0	3.0	20.0	0.03	
$\bar{X}$			12.7	21.9	0.9	0.05	0.08	0.8	1.2	2.08	8.63	Trace	6.6	6.6	3.5	23.8	0.1	SA
Pedon B (Middle Slope)																		
Ap	0 – 27	5.6	19.2	33.1	2.3	0.06	0.16	2.1	2.6	4.92	13.92	Trace	9.0	9.0	10.1	35.3	0.3	
BCt_1	27 – 43	5.5	11.4	19.7	1.6	0.06	0.10	1.1	1.2	2.46	6.66	Trace	4.2	4.2	5.2	36.9	0.1	
BCt_2	43 – 88	5.0	9.7	16.7	0.9	0.05	0.05	1.0	0.6	1.70	7.30	Trace	5.6	5.6	4.8	23.3	0.04	
Ct	88 - 151	4.6	6.1	10.5	0.5	0.05	0.05	1.0	0.8	2.30	8.70	Trace	6.4	6.4	3.9	26.4	0.1	
$\bar{X}$		5.2	11.6	20.0	1.3	0.06	0.09	1.3	1.3	2.85	9.15	Trace	6.3	6.3	6.0	30.5	0.2	SA
Pedon C (Valley Bottom)																		
Ap	0 – 20	4.6	32.1	55.3	4.1	0.06	1.20	3.6	4.3	9.16	15.76	Trace	6.6	6.6	9.6	58.1	0.4	
BCt_1	20 – 45	4.6	23.8	39.8	3.6	0.06	1.11	3.2	4.0	8.37	17.87	Trace	9.5	9.5	7.0	46.8	0.3	
BCt_2	45 – 71	5.1	16.3	28.1	3.4	0.06	0.80	2.6	3.7	7.16	13.16	Trace	6.0	6.0	5.5	54.4	0.2	
$\bar{X}$		4.8	24.1	41.1	3.7	0.06	1.04	3.1	4.0	8.23	15.60	Trace	7.4	7.4	7.4	53.1	0.3	A

Key
SA = Sub-Active; A = Active

Potential Agricultural Landuse of Soils in the Study Area

Soil erosion and low pH (high acidity) are the two most important factors limiting potential agricultural land use in the study area for extensive food crop production. Specific remarks are made for the three strata of the toposequence representing the land terrain types.

Land Type A (Crest)

The soils of the crest have slope varying 14 - 17 %. These soils are moderately deep with gravelly sandy clay sub soils and sandy clay loam surface soils. Present land uses are mainly bush fallow or shifting cultivation of food crops mainly cassava and other arable crops. Due to the inherent low soil fertility status, steep slope and erosion hazard, most soils belonging to this land type are unsuitable for intensive food, crop production, particularly large scale mechanized farming. These soils can be used for forestry and wild life.

Land Type B (Middle Slope)

The soils on middle slope have slope varying 7-14%. These soils also posses sandy loam over sandy clay textures, becoming gravelling in the sub soil from about 40 cm depth downward with plinthites. Soils of this land type have slightly better quality for food crop cultivation primarily because of better overall fertility status and moderate slope steepness. These soils are probably more suited for arable crops and economic tree crops or forest trees.

Land Type C (Valley Bottom)

Soils of this land type occurred on 0-3% slope. These soils are poorly drained, greyish, shallow and sandy clay loam textured. Potential rice cultivation in these small hydromorphic valleys is high. However, the temporary water logging of these soils may limit growth of upland crops such as yam, cassava and maize. The valley bottom soils may also be used as grazing land with planted pasture species such as *Stylosanthes* (legume) and *Andropogon* (grass) which tolerates soil acidity and low soil fertility status.

CONCLUSION

Soils vary considerably on a toposequence and influence their agricultural potentials. Soils at the crest of the toposequence studied were generally considered unsuitable for extensive food crop cultivation. The soils on middle slope and valley bottom are probably more suited for economic arable crop cultivation. Strict measures to prevent soil erosion and replenish lost soil nutrients are required for enhanced productivity of soils in the study area.

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