

PROFILE CHARACTERISTICS AND SOIL CLASSIFICATION, THEIR MANAGEMENT PRACTICES FOR CROP CULTIVATION IN JALINGO, TARABA STATE

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ABSTRACT

Soil profile management is key to sustainable crop production. Soil profile holds essential soil characteristics that are important for crop growth and development. This study was aimed at survey of the profile characteristics of soils, soil classification and management practices for crop cultivation in Jalingo, Taraba State. Three profile pits were dug from three physiographic units (upper, middle and lower slope); one for each. Soil morphological properties were described in situ, soil physical and chemical properties were determined in the laboratory using standard laboratory procedures. Results indicated that soils were sub angular blocky, coarse to fine, weak to moderate, loose, non- plastic when dry, moist and wet respectively at the upperslope while at the lowerslope; soils were very sticky, very plastic, firm when moist and hard when dry. Result for color showed soils were brown 7.5YR (4/3) when moist at the upperslope to yellowish brown 10YR (5/4) at surface 0-25cm and reddish yellow 7.5YR (6/6) when moist at 85-150cm depth of the lowerslope. Textural class indicated sand to sandy loam at the upperslope while the lowerslope were silt loam to sandy clay loam. Bulk density was high at the soil surface in both upper and middleslopes (1.78 g/cm³ and 1.82 g/cm³) but decreased to 1.46 g/cm³ at the surface for lowerslope. The soils were slightly acidic to neutral (6.1-6.5 to 6.6-7.3) regardless of the slope position, organic carbon were rated low to medium (<1 to 1.5%), total nitrogen ranged between 0.05% to 0.09%, and Mg²⁺ were rated medium (0.30-1.0cmol/kg) to high (>1.0cmol/kg) in the study area. The soils were classified as Typic Plinthustalfs, Plinthic Paleustalfs and Psammentic Paleustalfs across the land scape. Control of erosion, improving the exchangeable bases and use of organic and inorganic fertilizers will increase crop yield in the study area.

Key words: Slope; Pedon; Soil management; Horizon; Alfisols

INTRODUCTION

Temporal and spatial variations in the geomorphic and hydrologic processes in the soil as an integral part of land use types and slope positions influences the pedogenic processes and influence the distribution of water, sediments and organic materials in the soil (Young and Hammer, 2000; Brunner et al., 2004). The type of land use system applied in a given agro-ecology is an important factor in controlling the soil property levels since it affects the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization (Römkens et al., 1999). In addition, change in land use and management practices could be able to influence the physical, chemical as well as the biological properties of the soil (Yifru and Taye, 2011).

Land use can influence soil chemical, physical and biological properties because of

different anthropogenic activities, namely tillage, livestock trampling, harvesting, planting, application of fertilizer etc. On the other hand, land use could evolve or vanish in response to regional differences in soil properties, climate, population density, economic opportunities, cultural practices, and socio-economic factors (Getahun *et al.*, 2014; Ketema and Yimer, 2014).

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.

Soil profile management is key to sustainable crop production especially where farmers cultivate different crops year in year out. Soil profile holds essential soil characteristics that are important for crop growth and development. Soil profile management leads to the formation of different phenoforms. Common soil properties such as bulk density, porosity, moisture retention and hydraulic conductivity reflect the effects of short-range management. Tillage or soil traffic under wet conditions in a given year may lead to compaction, puddling and structure degradation which may not occur in the same soil where soil traffic is avoided. Therefore, for the purpose of long-range effects of management, it is important to focus on soil properties that are not significantly influenced by short-range management practices. For example, organic matter content shows long-range management effects in soils.

The productive potential of any soil depends on its morphological characteristics such as structure, texture, consistence etc which influence the fertility of soils. These properties determine the cation exchange capacity (CEC), water holding capacity, aeration, porosity and temperature of the soil. The objectives of this study were to identify the morphological characteristics of soils, determine the physical and chemical soil properties, classify the soils, evaluate their management for selected arable crop cultivation and highlight their inherent potentials for increased productivity.

MATERIALS AND METHOD

Study Area

The study was conducted in Jalingo, Taraba State Capital, Nigeria (Figures 1, 2 and 3). Three farming communities in the study area were selected; they are Kpantinapu, Kona and Nazo communities. The exact location of the profile pits in the three farming communities are given with the following coordinates; Kpantinapu- 08°58.421N;

011°22.968E, Kona- 08°57.796N; 011°20.609E, Nazo- 08°55.433N; 011°18.568E with elevation of 904 m, 209 m and 173 m above sea level, respectively.

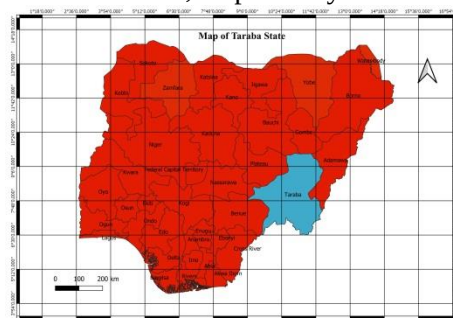


Figure 1: Map of Taraba State

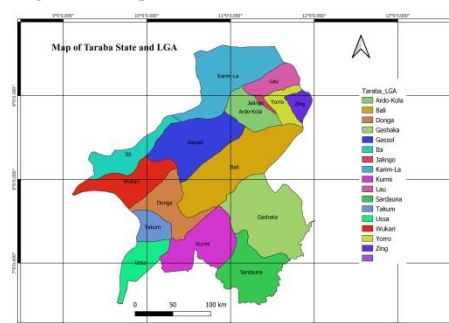


Figure 2: Map of Taraba State Local Government Areas

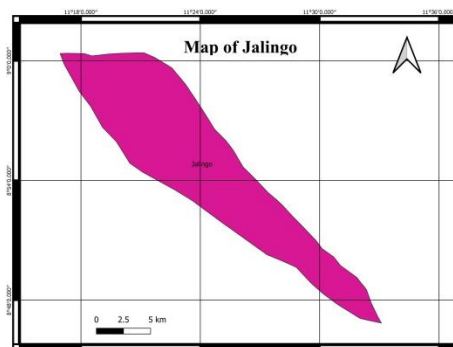


Figure 3: Map of Jalingo Local Government Area

Climate of the Area

The temperature of the study area is typical of West African Savannah, which means the temperature is high throughout the year due to high rate of solar radiation received as well as the distance away from the Ocean. Temperature increases between the period of January to April but normally drops at the onset of rainy season. A short period as temperature increased is also experienced between October and November before the onset of harmattan in December, where the temperature drops, and the temperature may be as high as 35°C and may be as low as 24°C.

The rainfall of the area varies with time and space which affect the economic

activities of the area particularly rain fed Agriculture. The area receives an annual rainfall of between 700mm-1500mm which occurs from May to October ending with August and September as the highest rainfall experiencing months. Relative Humidity is very low between January and March (20 – 30%). It starts increasing from April and reaches its peak in August and September with about 70%. Two trade winds are found in the area, viz: the North and East West trades respectively. The former originates from Desert, the latter originates from the Atlantic Ocean, and this implies that the former is associated with dry season while the latter is associated with rainy season (Adebayo, 1999).

Field Work and Sampling

Three (3) profile pits were dug from three (3) physiographic units (upper, middle and lower slopes); one for each and the most predominant land use is cultivation. The profile pits had varying depths due to the nature of the slope of the study area. The profile pits were dug using standard dimension of 2 x 1.5 x 2 m according to the USDA (2014). Soil samples were collected in each of the diagnostic horizons of the pits identified and soil morphological properties were described according to FAO (2006). Twelve (12) soil samples were collected, well labeled and placed in clean polythene bags as described by Soil Survey Field and Laboratory Methods Manual (2014).

Soil sample preparation

The collected soil samples from the fields were air-dried at room temperature in the laboratory until constant weights was obtained. The samples were grounded using pestle and mortar and sieved through a 2-mm stainless steel sieve. The soil samples were kept in dry and clean plastic bags for laboratory analyses.

Laboratory Analysis

Soil physical properties

Soil particle size distribution was determined by the Bouyoucos hydrometric method as described by Gee and Or (2002), after destroying organic matter (OM) using hydrogen peroxide (H_2O_2) and dispersing the soils with Sodium Hexametaphosphate ($NaPO_3$). Soil bulk density was determined by the undisturbed core sampler method after drying the soil samples in an oven at $105^{\circ}C$ to

constant weights as described by Jaiswal (2004). The mass of the oven-dried soil was divided by the total soil volume to obtain the bulk density (Black 1965). Also, Particle density was determined by using the pycnometer method (Blake and Hartge, 1986). Soil total porosity was determined using the following formula;

Total porosity was calculated using the formula:

$$F = 1 - (Db/Dp) \times 100$$

Where F = Total Porosity

Db = Bulk density

Dp = Particle density

Soil moisture content was determined using oven drying method which is depended on the oven drying temperature as described by Farley *et al.* (2004).

Soil chemical properties

The pH of the soils were measured in a 1:2 soil and water suspension ratio using a glass rod and electrode pH meter (Udo *et al.*, 2009). Electrical conductivity (EC) was determined using the same soil sample ratio from pH to determine EC, its measurement was carried out using the EC meter. The Organic Carbon was determined using Walkley and Black (1934) by oxidizing the organic matter (OM) in concentrated sulfuric acid solution (0.1N H_2SO_4) and percentage of soil organic matter was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. Total N was determined by the micro Kjeldahl digestion method by heating the samples at $360-410^{\circ}C$ with concentrated sulphuric acid (H_2SO_4), distilled with NaOH as described by Bremner (1996). Available soil phosphorus was determined according to the standard procedure of Olsen *et al.* (1954) extraction method. The effective cation exchange capacity was measured by summing up the exchangeable bases and exchangeable acidity ($H + Al$). Exchangeable bases (Ca^{2+} , Mg^{2+} , K^+ , Na^+) were determined by repeated extraction procedure with neutral 1M NH_4OAc (pH7) solution. The Ca^{2+} and Mg^{2+} in solution were read on an atomic absorption spectrophotometer while K^+ , Na^+ were read on the flame photometer (IITA, 1979). Percentage base saturation was determined in the laboratory by using NH_4OAc Ammonium (acetate) as described by Soil Survey Staff (2014). The following formula was used:

$$\% BS = (A/B) \times 100$$

Where: A = $\text{NH}_4 \text{ OAc}$ Extractable Bases (Ca+Mg) (cmol (+) kg^{-1}).

$$B = \text{CEC} - 7 \text{ (cmol (+) kg}^{-1}\text{)}.$$

Soil Classification

The soil morphological, physical and chemical properties were used for soil classification using the USDA Taxonomic System and Soil Survey Staff (2010).

Soil Management Practices

The soil management practices of the farmers were obtained extension workers and farmers themselves through interview of previous practices and observation of current practices by the farmers.

RESULTS AND DISCUSSIONS

Some Soil Morphological Properties of the Study Area

Table 1 presents the soil morphological properties of the study area. Pedon PD3 in Kpantinapu represents the upperslope (5-7%). The soils in Pedon consist of sub angular blocky, coarse to fine, weak to moderate and strong structure and depth of greater 135cm. The upper 0-13cm depth of the pedon was loose, non- plastic when dry, moist and wet respectively. The plasticity of the soils also increases with increase in depth. Similar trend was recorded where loose to very firm and loose to very hard when the soils were moist and dry respectively. These results might be due to the sandy nature of soils at the surface horizons as recorded in the work of Esu *et al.* (2008). However, the soils were sandy clay at the Bt and C horizons indicating illuviation of pedon materials down the profile over time.

Results for colour for the pedon (PD3) showed soils were light brown 7.5YR (6/4) when dry and brown 7.5YR (4/3) when moist at 0-13cm depth. Brown color 7.5YR (4/4) when the soils were both moist and dry at 13-33cm depth of the pedon. These results indicated some organic matter presence in the soils which could support crop cultivation. Moberg and Esu (1991) reported similar results. The soils were yellowish red 5YR (4/6) at 33-65cm depth when moist and dry respectively. This could be attributed to the well-drained condition of the soils at the upper slope position; in addition to no mottles recorded in the pedon. The soils were red color 2.5YR (4/8 and 4/6) at depth of 65-135cm both when dry and moist. The red coloration characterized the iron (Fe_2^+) concentration and depleted organic carbon content typical of upperslope soils. This is in line with the report of Akamigbo *et al.* (2002) who reported similar colors for soils for similar landscape position.

Pedon PD2 represents the middle slope (3-4%) and is located in Kona. The pedon indicated the soils were sub angular blocky, weak structure, coarse and non-sticky and non-plastic at the surface horizon (0-27cm depth). The soils were moderate to strong structure at the subsequent horizons, with very sticky, very plastic, very firm and hard characteristics when wet, moist and dry respectively. These results might be due to increase in soils structure at the middle slope due to clay and other soil moving downslope from the crest. This activity increase soil structure and consistency downslope. Similar results were observed by Nsor and Adesemuyi (2016) on soils along slope in Isiagu, Eastern Nigeria.

Table 1: Some Morphological Characteristics of Soils of the Study Area

Pedon	HD	Depth (cm)	Colour		Mottles	Texture	Structure	Consistency	Roots
			(Dry)	(Moist)					
PD3	Ap	0-13	7.5YR 6/4	7.5YR4/3	n	SL	w,c,s.b.k	Wns,np,ml,dl	rff
	E	13-33	7.5YR 4/4	7.5YR4/4	n	SCL	m,c,s.b.k	Wsl,sp,mf,dh	rff
	Bt	33-65	5YR 4/4	5YR 4/6	n	SC	s,f,s.b.k	Wvs,vp,mvf,dvh	n
	C	65-135	2.5YR 4/8	2.5YR 4/6	n	SC	s,f,s.b.k	Wvs,vp,mvf,dv.h	n
PD2	Ap	0-27	7.5YR 5/3	7.5YR4/3	n	LS	w,c,s.b.k	Wns,np,ml,dl	rfm
	AB	27-57	7.5YR 6/6	7.5YR5/6	n	SCL	m,c,s.b.k	Wvs,vp,mf,dh	n
	Bt	57-92	7.5YR 6/8	7.5YR4/6	fmf	SC	s,c,s.b.k	Wvs,vp,mvf,dh	n
	C	92-130	7.5YR 7/4	7.5YR6/6	ccp	SC	s,c,s.b.k	Wss,sp,mf,dh	n
PD1	Ap	0-25	10YR 6/3	10YR 5/4	fff	SiCL	m,f,s.b.k	Wvs,vp,mf,dh	rff
	E	25-45	10YR 6/3	10YR 5/3	mcd	SiCL	m,f,s.b.k	Wvs,vp,mf,dh	rff
	Bt	45-85	10YR 5/3	10YR 3/2	mcp	C	s,f,s.b.k	Wvs,vp,mvf,vh	n
	C	85-150	7.5YR 7/4	7.5YR6/6	n	S	w,c,g	Wns,np,ml,dl	n

Key

HD: Horizon designation. **MOTTLES:** n= none, **Mottle Abundance:** f= few, c= common, m= many; **Mottle Size:** f= fine, m= medium, c= coarse; **Mottle Contrast:** f= faint, d= distinct, p= prominent. **TEXTURE:** S= sand, SL = Sandy loam, SCL = Sandy clay loam, SC = Sandy clay, LS= Loamy sand, SiL= Silt loam, Si= Silt, SiCL= Silty clay loam, CL= Clay loam, SiC= Silty clay, C= Clay, L= Loam. **STRUCTURE: Grade;** w= weak, m= moderate, s= strong. **Class:** f= fine, m= medium, c=coarse. **Type;** SBK = sub angular blocky. **CONSISTENCY: W=Wet;** ns= non sticky, np=non plastic, ss=slightly sticky, sp=slightly plastic, vs=very sticky, vp= very plastic, **M=Moist;** l=loose, vfr=very friable, f=firm, vf =very firm, **D=Dry;** l=loose, s=soft, h=hard, vh = very hard. **ROOTS (R); Abundance:** n= none, f=few, c=common, m=many; **Size:** f=fine, m=medium, c=coarse.

Pedon PD1 represents the lower slope (0-2%) and is located in Nazo. Results in the pedon revealed soils were sub angular, moderately fine structure to strong structure at 45-85cm depth. However, the soils at the C horizon were granular, weak structure and coarse. The pedon also recorded very sticky, very plastic, firm when moist and hard when dry characteristics except the last horizon was none sticky, none plastic and loose both when moist and dry. The result indicated that the soils were deep generally strongly structure and could be attributed to deposition of soil organic materials and clay downslope which generally improved the soil condition when compared with the previous pedons at the upperslopes. Esu *et al.* (2008) found soils on a toposequence were shallower and had less distinct sub surface horizons than soils at lower slopes. Nsor and Adesemuyi (2016) recorded similar findings were soils of Ishiagu, Eastern Nigeria had increase of soil materials downslope on a toposequence.

Results for soil colour for the pedon showed soils were pale brown 10YR (6/3) and yellowish brown 10YR (5/4) at surface 0-25cm depth when dry and moist respectively. This result might be due to materials detached, transported and deposited at the lowerslope by the action of surface runoff water. Similar soil surface colour on a slope position was reported by Musa and Gisilanbe (2017) and attributed to movement of soil materials downslope. At the depth of 25-45cm, the soils were pale brown 10YR (6/3) when dry and brown 10YR (5/3) when moist with many coarse and distinct mottles present; indicating that the soils were seasonally flooded. The soils were pink colour 7.5YR (7/4) and reddish yellow 7.5YR (6/6) when dry and moist respectively at 85-150cm depth. This colour change at the lower horizon could be attributed to the coarse, granular quartz parent materials of the soils at the C horizon, very distinct from the surface soil colour which indicated some soil nutrients present.

Some Physical Properties of Soils in the Study Area

Table 2 presents the results for some physical properties of soils of the study area. Pedon PD3 showed the surface horizon (0-13 cm) had 87% sand content while Bt horizon

increased to 28% (33-65 cm) clay content and the C horizon (65-135 cm) had 36% clay. This result indicated a decreasing trend with increase in depth of the profile for sand while; clay content increased with profile depth upslope. This result indicates that leaching and illuviation of soil minerals and clay down the profile increased coarse materials on the soil surface due to increase rainfall, hence the high sand fractions at the surface soils. This result is in line with the findings of Nsor and Adesemuyi (2016) who reported progressive increase in clay content with soil depth in all pedons studied with total sand content highest in top soils. Additionally, surface soils might have been further exposed to ploughing for cultivation purpose and erosion hazard; these could have led to mineral soil particles washed by moving water at the surface. The soils vary from sand, sandy loam, sandy clay loam to sandy clay as the depth increased. Ewulo *et al.* (2002) investigated soils with similar trends. Soil texture is an important fertility indicator for potentials capacity and productivity. Loide (2004), found that as the percentage of clay particles and colloids contained in the soils increase, the content of plant nutrients bound by these particles and colloids increase as well.

Sand dominated the soil fraction in pedon PD2 and PD1 especially at the soil surface. The lowerslope had an increase in silt and clay contents and the Bt horizon recorded 30% clay contents for both middle and lowerslopes respectively. Udoh *et al.* (2008) and Chikezie *et al.* (2009) reported increase in clay content with horizon depth in their separate reports. These results showed that materials were moved downslope over time where they were deposited thereby increasing the clay content. This result is supported by the observation Noma (2012) were moisture content increase with decrease in slope. Bulk density was high at the soil surface in both upper and middleslopes (1.78 g/cm³ and 1.82 g/cm³) but decreased to 1.46 g/cm³ at the surface soil of the lowerslope. Total porosity mostly increased at the Bt horizons while the water holding capacity was increased downslope likewise the field capacity. Similar findings were recorded by Atofarati *et al.* (2012) on two toposequence in Ondo State, Nigeria.

Table 2: Some Physical Properties of Soils of the Study Area

Pedon	HD	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Classes	B.D (g/cm ³)	T. Porosity (%)	WHC (%)	Field Capacity cm ³ water/cm ³ soil
PD3	Ap	0 – 13	87	10	3	Sand	1.78	33	8.50	0.13
	E	13 – 33	65	20	15	Sandy loam	1.50	43	10.50	0.21
	Bt	33 – 65	48	24	28	Sandy clay loam	1.37	48	11.00	0.28
	C	65 - 135	50	14	36	Sandy Clay	1.34	49	10.50	0.30
		Mean	62.50	17.00	20.50		1.50	43.25	10.13	0.23
PD2	Ap	0 -27	88	10	2	Sandy	1.84	31	8.00	0.12
	AB	27 – 57	48	19	33	Sandy Clay Loam	1.35	49	11.00	0.29
	Bt	57 – 92	50	20	30	Sandy Clay Loam	1.37	48	12.30	0.28
	C	92 - 130	58	24	18	Sandy loam	1.46	45	13.00	0.23
		Mean	61.00	18.25	20.75		1.51	43.25	11.08	0.23
PD1	Ap	0 – 25	65	19	16	Sandy loam	1.46	45	10.00	0.21
	E	25 – 45	38	52	10	Silty loam	1.51	43	16.00	0.25
	Bt	45 – 85	47	23	30	Sandy Clay loam	1.36	49	11.00	0.28
	C	85 - 150	87	10	3	Sand	1.78	33	8.00	0.33
		Mean	59.25	26.00	14.75		1.53	42.50	11.25	0.27

Key: HD= Horizon designation, B.D = Bulk Density, T = Total, WHC = Water Holding Capacity

Some Chemical Properties of Soils in the Study Area

The results of chemical properties of soils in the study area are presented in Table 3. The result for pH showed that the soils were slightly acidic to neutral (6.1-6.5 to 6.6-7.3) regardless of the slope position according to soil ratings by Usman (2005). Pedon PD3 indicated that pH was 6.70 (Neutral) at 0-13cm depth surface soils but decreased with depth between 6.31 to 6.41 (Slightly acidic). Pedon PD2 at middle slope recorded similar trend for soil pH while the lowerslope recorded a slightly acidic (6.3) pH on the soil surface. These results agree with report of Noma (2012). The EC values were non-saline (<0.40 dS/m) across the slopes and in all depths of the pedons.

The organic carbon content of the soils in all pedons were rated low to medium (<1 to 1.5%) according to critical soil ratings by Babalola (1998). All the surface horizons of the upper and middleslopes recorded low (0.86 and 0.99%) organic carbon contents respectively; however, the lower slope recorded medium (1.06%) organic carbon content. This result might be due to the ability of the lowerslope pedon to hold more clay and moisture as a result of deposition and subsequent mineralization which supports crop growth and organic carbon addition in the soils. Similar results were reported by Nsor and Adesemuyi (2016). Generally, there was increase in organic carbon with decrease in slope in the study area and this could be attributed to redistributive effect of the slope in the study area. Esu *et al.* (2008), found high organic carbon in the lower slope and linked it to redistributive effect of slope. Organic matter was rated low (<2%) for all slopes in the study area and particularly, followed the trend for organic carbon.

Total nitrogen ranged between 0.05% to 0.09% and were rated low across the landscape. This result could be due to continuous cultivation of the arable land by farmers over the years which resulted to crop removal of the nitrogen and leaching effect. The available phosphorus were rated low (<8.0 mg/kg) to medium (8.0-20.0 mg/kg) for all pedons on the slopes according to soil ratings by Aduayi *et al.* (2002). The low available phosphorus in the study area might be due to high phosphorus adsorption capacity of the soils and phosphorus fixation which is not radially available for crop's use. Idigbor *et al.* (2008) reported high phosphorus adsorption capacity and

fixation as reasons for low phosphorus in their study. The calcium content increased with decrease in slope and were rated medium (2-5 cmol/kg) to high (>5 cmol/kg) across all slopes. The upper slope had a mean value of 3.72 for calcium, 5.28 for middleslope and 9.34 for the lowerslope respectively. This result showed an increasing trend downslope. This result might be attributed to the nature of parent materials and less leaching activity at the lower slope. At the upper and middle slope, the surface horizon recorded 5.76 cmol/kg but was reduced due to leaching activity down the profile; reducing the calcium content of the soils. Similar findings were made by Ogunwale *et al.* (2002).

Results for magnesium (Mg^{2+}) was in an irregular pattern from the surface soils down the profile and were rated medium (0.30-1.0 cmol/kg) to high (>1.0 cmol/kg) across all the pedon. This result might be due to the magnesium bearing parent materials that were weathered and became part of the soils. Nsor and Adesemuyi (2016) reported medium to high Mg for soils on toposequence in Umudike, Abia State. Result for sodium (Na^+) indicated similar pattern to results for magnesium where sodium were medium (0.1-0.3 cmol/kg) to high (>0.3 cmol/kg) and potassium (K^+) had similar pattern in all the pedons of the study area.

The mean values for total exchangeable bases (10.16>6.94>5.92) and total exchangeable acidity (2.05>1.81>1.47) followed a pattern of lowerslope>middleslope>upperslope respectively. Also, higher base saturation for the three positions were recorded at the surface Ap horizons (6.67, 6.73, 13.29) than the epipedon and this might be as a result of nutrient biocycling. Ogunwale *et al.* (2002) reported higher soil mineral nutrients (exchangeable bases) and likened it to nutrient biocycling in East Nigeria. Results for the effective cation exchange capacity (ECEC) and percentage base saturation (PBS) were rated medium to high (4-10, >10 and 50-80%, >80%) respectively. The results also recorded higher mean values at the lower slope while the upper slope had lower values. These results might be attributed to downward movement of soil minerals downslope as a result of detachment of soil materials, transportation and deposition at the lower slope. These results support report of Atofarati *et al.* (2012) carried out in Ile-Oluji, Ondo State.

Table 3: Soil Chemical Properties of the Study Area

Pedon	HD	Depth (cm)	pH (1:2)	EC (dS/m)	Org.C (%)	Org.M (%)	TN (%)	Av-P (mg/kg)	Ca	Mg	Na	K cmol/kg	TEB	TEA	ECEC	PBS
PD3	Ap	0 – 13	6.70	0.02	0.86	1.48	0.07	11.37	5.76	0.48	0.04	0.38	6.67	1.40	8.07	82.65
	E	13 – 33	6.31	0.03	1.03	1.77	0.09	9.22	2.40	2.03	0.04	0.36	4.84	1.48	6.32	76.57
	Bt	33 – 65	6.40	0.03	1.05	1.81	0.09	8.74	2.88	3.32	0.04	0.31	6.55	1.40	7.95	82.38
	C	65 – 135	6.41	0.02	0.95	1.63	0.08	9.22	3.84	1.16	0.09	0.51	5.60	1.60	7.20	77.79
		Mean	6.46	0.03	0.97	1.67	0.08	9.64	3.72	1.75	0.05	0.39	5.92	1.47	7.39	79.85
PD2	Ap	0 -27	6.60	0.04	0.99	1.70	0.08	8.98	5.76	0.87	0.04	0.05	6.73	2.02	8.75	76.91
	AB	27 – 57	6.30	0.03	0.73	1.26	0.06	8.74	2.88	1.74	0.13	0.23	4.99	1.40	6.39	78.07
	Bt	57 – 92	6.10	0.03	1.02	1.75	0.08	8.74	4.32	1.31	0.48	0.13	6.23	2.80	9.03	69.01
	C	92 – 130	6.50	0.02	0.64	1.10	0.05	4.92	8.16	1.16	0.39	0.10	9.82	1.00	10.82	90.75
		Mean	6.38	0.03	0.85	1.45	0.07	7.85	5.28	1.27	0.26	0.13	6.94	1.81	8.75	78.69
PD1	Ap	0-25	6.30	0.04	1.06	1.82	0.09	8.50	10.56	1.60	0.13	1.00	13.29	1.60	14.89	89.25
	E	25 – 45	7.30	0.06	0.98	1.69	0.08	12.09	4.80	1.02	0.35	0.13	6.29	4.00	10.29	61.14
	Bt	45 – 85	6.24	0.03	1.10	1.89	0.09	8.98	10.08	1.45	0.13	0.23	11.89	1.60	13.49	88.14
	C	85 – 150	6.85	0.03	0.87	1.50	0.07	7.79	7.20	1.02	0.04	0.92	9.18	1.00	10.18	90.18
		Mean	6.67	0.04	1.00	1.73	0.08	9.34	8.16	1.27	0.16	0.57	10.16	2.05	12.21	82.18

Key

EC =Electrical conductivity, O.C = Organic Carbon, TN=Total Nitrogen, AV-P= Available Phosphorus, Ca= Calcium, Mg= Magnesium, Na= Sodium, K = Potassium, TEB= Total Exchangeable Bases,

TEA =Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity, PBS, Percentage Base Saturation

Soil Classification

Table 3 shows summary of the soil classification of the study area. All the soils of the mapping unit were classified as Alfisols with formative element 'alf' at the order level due to their %BS >50 and argillic epipedon. The soils were developed under Ustic soil moisture regime and classified as Ustalfs at the suborder level (USDA Soil Taxonomy). Similar results were documented by Lawal *et al.* (2012) where they reported the soils of Minna in the study area were Alfisols and developed under Ustic soil moisture regime. These findings are supported by the findings of Maniyunda and Gwari (2014). The soils were further classified as Plinthusterts at the great group level due to the presence of plinthites distributed in the profile, visible at >50cm depth of the lower horizons. At the subgroup level, the soils were classified as Typic Plinthustalfs due the presence of high Base saturation (>50). The soils were classified Typic Plinthustalfs due sandy, coarse texture and the nature of soils which were susceptible to erosion.

Pedon PD2 soils studied had a surface Ap-horizon and this might be due to the cultural practices of the farmers in the study area were

the soils were ploughed. The soils were classified as Alfisols at the order level due to high base saturation calculated from NH_4OAc Extractable Bases 1N (>50%). The soils were formed under Ustic soil moisture regime and classified as Ustalfs at the sub-order level, (USDA Soil Taxonomy). According to the Soil Survey Staff (2010), these soils were further classified as Plinthic Paleustalfs based on the heavy presence of plinthites in more than one of the lower horizons of the pedon.

The soils of pedon PD1 were classified as Alfisols (alf) at the order level due to their %BS >50 and mollic surface. The soils shrink when wet and had when dry and had an argillic epipedon. The soils had wedge-shaped aggregates in >15cm thick with the upper boundary within 125cm of the mineral soil surface. The soils were formed under Ustic soil moisture regime and classified as Ustalfs at the sub-order level (USDA Soil Taxonomy). According to the Soil Survey Staff (2010), these soils were further classified as Psammentics due to the sandy particle-size class throughout the upper 75cm of the argillic horizon at the great group level and Psammentic Paleustalfs at the Subgroup level.

Table 4: Summary of Soil Classification of the Study Area

Pedons	Location	Classification (USDA)			
		Order	Sub-order	Great group	Sub group
PD3	Kpantinapu	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs
PD2	Kona	Alfisols	Ustalfs	Plinthustalfs	Plinthic Paleustalfs
PD1	Nazo	Alfisols	Ustalfs	Psammentic	Psammentic Paleustalfs

Management Practices by Farmers and Recommendations

The management practices of farmers and their recommendations are presented in Table 5. All the lands in the study area were cultivated lands. From the upperslope to the lowerslope, due to the nature of topography and soil types, different crops were cultivated by

farmers in their attempt to best manage the soils for optimum yields. However, best soil sustainable practices might be best suited for the soils and manage the scares resources of the farmers.

Table 5: Soil Management Practices for Arable Crops and Recommendations in the Study Area

Slope	Location	Land Use	Crops	Soil Management Practice	Comments
Upperlope	Kpantinapu- N08°58.421; E011°22.968 Elv. 904m	Cultivation & Grazing of Cattle	Maize & Guinea corn	Continuous cultivation was practiced by the farmers with majority of the farmers not using chemical fertilizers. Farmers cultivate on ridges made to accommodate the crops and for moisture retention. Large gully erosion sites were observed in many parts of the fields with outcrop of many granite parent materials all over the field. The read is hilly and farmers cultivate on marginal lands. Many tress were also visible on the plot. Animals graze the fields.	Soil erosion is a serious threat to the land and farmers should incorporate organic materials to the soils in other to improve the soil texture and structure. Informed chemical fertilizers application will improve the soil minerals and make it less prone to erosion. Inter cropping with nitrogen fixing leguminous crops should be adopted; this will improve soil particles binding forces through cohesion and adhesion as a result of nitrogen fixation and improved microbial activities in the soils. Therefore, erodability factor of the soils will be reduced which is a very serious threat to the soils. Economic trees should be planted at strategic positions. Farmers should form cooperatives and solicit for local and state government assistance in dealing with soil erosion hazards. Government should assist farmers with inorganic fertilizers at subsidized rates. Crop rotation should be adopted to replace use of high feeder crops on the same plot at the same time.
Middleslope	Kona- N08°57.796; E011°20.609 Elv. 209m	Cultivation	Maize, Guinea corn & Ground nut	Continuous cultivation of farm land yearly. Each crop is cultivated as a mono-crop. Some farmers apply small quantity of fertilizers (NPK) indiscriminately without soil testing. Dumping plant parts into rill erosion sites. Grazing of cattle adds organic materials to the soils.	Rill erosion sites should be controlled before it develops to a gully by incorporating organic materials with the soils and leveling the land. In addition, channels for free water movement could be created to avert destruction of larger poisons of the fields. Addition of organic materials to the soils should be adopted more significantly to improve soil fertility. Use of inorganic fertilizers after soil testing and recommendation should be done; this will improve soil fertility losses from continuous cultivation and improve crop yields. Animal droppings should be incorporated to the soils for decomposition and mineral release for plant uptake.
Lowerslope	Nazo- N08°55.433; E011°18.568 Elv. 173m	Cultivation & Grazing	Mango Tress, Ground nut, Cow pea, Maize, Sugar cane & Vegetables	Grazing of farm animals like cattle on the field due to presence of nearby river is practiced. Cultivation of some garden crops like tomatoes and amarantus near the river in fragmented small quantities by the farmers. Addition of NPK fertilizers without soil testing and usually by broadcasting method. Some farmers collect cow dung for use on their fields and most times; just throw them on the fields. This is done in small quantity and inconsistently. Some Farmers, due to the nature of the fadama soils, practice dry season farming (Irrigation). Sand deposits observed.	After harvest, animals should graze on the cultivated fields so that their droppings will be added to the soils. The field should be ploughed using mould plough so that the animal droppings will be mixed with the soil and decomposition processes will be enhanced and the organic matter release sequence optimized. Water from nearby river can be channeled to the field for dry land farming more effectively and efficiently by the use of pump machines. Inorganic fertilizers should be used to improve soil fertility losses after soil testing and recommendations. Increasing sand deposits observed should be control by creating a barrier to reduce overflow from the river.

SUMMARY AND CONCLUSION

Due to land fragmentation and urbanization, farmers are increasingly becoming more desperate for cultivable lands. The land cultivated by farmers are cultivated continually with little or nothing done to reduce erosion, leaching and crop removal of essential nutrients responsible for growth and development of crops. This has resulted in lower yields experienced by the farmers in recent times. Where it is used, fertilizer application is done indiscriminately without soil testing. This further compounds on the fragile soils and leads to the soils being eroded; especially at the upperslopes where surface runoff is more prevalent due to aspect. Regardless of farming activities, clay, soil organic carbon and other soil exchangeable bases are detached, transported and deposited at the lowerslope in the study area. This has resulted in improved soil texture and structure, higher soil moisture content and water holding capacity for crop's growth and development. Therefore, higher yields are recorded downslope. Slope affects the morphological, physical and chemical properties of soils and should be managed properly for optimum crop yields.

REFERENCES

- Adebayo, A.A. (1999). Climate I; Sunshine Temperature, Evaporation and relative humidity in Adamawa state in map. Pracet publisher and Department of geography Federal University of Technology Yola Nigeria, pp. 3-5.
- Adayi, et al. (2002). Rating for fertility classes, fertilizer use and management practices for crops in Nigeria. P 28.
- Akamigbo, F.O.R., Ezedinma, F.O.C and Igwe, C.A. (2002). Properties and classification of some Fadama soils of Bauchi State, Nigeria. Proceedings of the 24th Annual Conference of the Soil Science Society of Nigeria. Pp. 45-51.
- Atofarati, S.O., Ewulo, B.S. and Ojeniyi, S.O. (2012). Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria.
- Babalola, O., Babaji, G.A. and Mustapha, S. (1998). Soil Management for Sustainable Agriculture and Environmental Harmony. Proceedings of the 24th Annual Conference of the Soil Science Society of Nigeria held at the Abubakar Tafawa Balewa University, Bauchi, 7-11th December.
- Black, C.A. (1965). Methods of Analysis. Agronomy No. 9 part 2, Amer. Soc. Agronomy, Madison, Wisconsin.
- Blake, G.R. and Hartge K.H. (1986). Bulk density. In methods of Soil Analysis. Klute A. (Ed). Part 1.2nded. Agron. 9. ASA and SSA, Madison, WI. P.363-375
- Bremner, J.M. (1996). Total Nitrogen In: Sperk, D.L (Ed.) *Methods of Soil Analysis, Part 3*. Chemical Methods. No.5, ASA and SSSA, Madison, Wisconsin, Pp. 1085-1121.
- Brunner, I., Zimmermann, S., Zingg, A. and Blaser, P. (2004). Wood-ash recycling affects forest soil and tree fine-root chemistry and reverses soil acidification. *Plant and Soil* 267 (1-2), 61-71.
- Chikezei, A., Eswaran, H., Asawalam, D.O. and Ano, A.O. (2009). Characterization of the benchmark soils of contrasting parent materials in Abia State, Southeastern Nigeria. *Global J. of Pure and Applied Sciences*. 16(1): 23-29.
- Ekwueme, B. Nyong, E.E. and Petters, S.W. (1995). Geological Excursion Guide environments in the Cretaceous of the Calabar Flank, SE. Nigeria. *Journal of Africa Earth Science*, 3 (4): 455-460.
- Esu, I.E., Akpan-Idiok, A.U. and Eyong, M.O. (2008). Characterization and classification of soils along a typical hill slope in Afikpo Area of Ebonyi State, Nigeria. *Nigerian Journal of Soil and Environment*, Vol. 8. Pp. 1-6.
- Ewulo, B.S. Ojanuga, A.G. and Ojeniyi, S.O. (2002). Nature and properties of soils with kandic horizon in humid Southwest Nigeria. *Bioscience Research Communications*. 14(6): 693-700.
- Farley, K.A. Kelly, E.F. and Hofstede, R.G.M. (2004). Soil Organic Carbon and Water Retention after Conversion of Grasslands to Pine Plantations in the Ecuadorian Andes. *Ecosystems* 7: 729-739.

- Food and Agriculture Organization (2006). Guidelines for Soil Description (4th Ed.) Food and Agriculture Organization of the United Nations, Rome. 97 pp.
- Gee, G.W. and Or, D. (2002). Particle size analysis. In: J.H. Dane and G.C. Topp (eds). *Method of soil analysis, part 4-Physical methods*. Soil Science Society of America. Book series. No. 5 ASA and SSA Madison, WI, pp 255-293.
- Getahun, H., Mulugeta, L., Fisseha, I., Feyera, S. (2014). Impacts of land uses changes on soil fertility, carbon and nitrogen stock under smallholder farmers in central highlands of Ethiopia: implication for sustainable agricultural landscape management around Butajira area. *N. Y. Sci. J.* 2014, 7(2).
- Idigbor, C.M., Asawalam, D.O. and Agbede, O.O. (2008). Phosphorus forms and P sorption Capacity of Fauna modified soils of South-Eastern Nigeria. *Journal of Agricultural Production and Technology*. 4 (2): 195-210.
- International Institute for Tropical Africa. (1979). *Methods of Soil and Plant Analysis*. International Institute for Tropical Africa Publications.
- Jaiswal, P.C. (2004). Soil plant and water analysis. John Wiley and Sons, inc., New York.
- Ketema, H., Yimer, F. (2014). Soil property variation under agroforestry-based conservation tillage and maize based conventional tillage in Southern Ethiopia. *Soil Tillage Res.* 141, 25–31.
- Lawal, B.A., Adeboye, M.K.A., Tsado, P.A., Elebiyo, M.G. and Nwajoku, C.R. (2012). "Properties, classification and agricultural potentials of lateritic soils of Minna in sub-humid agroecological zone, Nigeria". *Internat. J. of Develop. and Sustain.* 1(3) pp. 903-911.
- Loide, V. (2004). About the effect of the contents and ratios of soils available Ca, K and Mg in liming of acid soils. *Agricultural Research Center, Teaduse 4/6. Agronomy Research 2* (1), 71-82.
- Maniyunda, L.M. and Gwari, M.G. (2014). Soils Development on a Toposequence on Loessial Deposit in Northern Guinea Savanna, Nigeria. Department of Agricultural Engineering, College of Engineering, Kaduna Polytechnic, Kaduna, Nigeria E-Mail: lemuelmusa@gmail.com *ARPN Journal of Agricultural and Biological Science*. Asian Research Publishing Network (ARPN). ISSN 1990-6145 VOL. 9, NO. 3.
- Moberg, J.P. and Esu, I.E. (1991). Characteristics and composition of Nigerian Savannah soils. *Geoderma*, 48, 113-129.
- Musa, H. and Gisilanbe, S.A. (2017). Differences in Physical and Chemical Properties of Soils on Yelwa-Dabora Toposequence in Ganye Local Government Area, Adamawa State, Nigeria. *Sky journal of soil science and environmental management* vol. 6(1), pp.011-018.
- Noma, S.S., Tanko, I.I., Yakubu, M., Dikko, A.U., Abdullahi, A.A., Audu, M. (2012). Chrono Toposequence Studies of Soils of Dundaye District, Sokoto State, Nigeria. A Paper Presented at the 35th Annual Conference of the Soil Sci. Soci. of Nigeria held at FUT, Minna.
- Nsor, M.E. and Adesemuyi, E.A. (2016). Characteristics of soils along a toposequence in Ishiagu, Eastern Nigeria and its relation to potential agricultural land use. *Nigerian Journal of Soil Science*. Vol. 26 (1). Pp. 78-86.
- Nyong, E.E. and Ramanatham, R.M., (1985). A record of oxygen – deficient paleo-Ogunwale, J.A., OLaiyan, I.O. and Aduloju, M.O. (2002). Morphological, physico-chemical and clay mineralogical properties of soils overlying basement complex rocks in Ilorin East, Nigeria. *Moor journal of Agricultural Research*, 3(21):147-164.
- Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939. 1-19 Paris. 50 pp. Perspective, De-Rio Press Nigeria Limited, Calabar.

- Petters, S.W. (1995). South-Eastern Benue Trough and Ikom-Mamfe Embayment, In: Geological Excursion Guide Book (26-36), Dec-Ford Publishers Limited, Calabar.
- Römkens, P.F.M., Van Der Plicht, J., Hassink, J. (1999). Soil organic matter dynamics after the conversion of arable land to pasture. *Biol. Fertil. Soils* 28, 277–284.
- Russell, E.W. (1973). Soil Conditions and Plant Growth. English Language Book Society
- Schoenholtz S. H., Miegroeth, H.V. and Burger J.A., (2000) A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. Department of Forestry, Mississippi State University, USA.
- Soil Survey Field and Laboratory Method Manual (2014). Soil survey Investigations Report NO. 51 Version 2. United State Department of Agriculture, Natural Resources Conservation Service National Survey Center, Kellogg Soil Survey Laboratory.
- Soil Survey Staff (2010). Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. 2nd Edition. agric. Handbook. No. 436. US. Gov. print, office. Washington, DC, U.S.A. p 346.
- Udo, E.J., Ibia, T.O., Ogunwale, J.O., Ano, A.O., Esu, I. (2009). *Manual of soil, plant and water analysis*. 183pp., Sibon Books Ltd. Lagos.
- Udoh, B.T., Ibia, T.O., Udo, B.U. and Edem, S.O. (2008). Assessment of micronutrients status of inland depression and floodplain (wetland) soils in Akwa Ibom State, Southeastern Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*. 7(2): 156-161.
- Usman, B.H. (2005). The soils of Adamawa State, North-Eastern Nigeria. Agriculture in Adamawa State. Pp.62-75.
- Walkley, A. and Black, C.A. (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*, 37:29-38.
- Yifru, A. and Taye, B. (2011). Effect of land use on soil organic carbon and nitrogen in soils of Bale, Southeastern Ethiopia. *Trop. Subtrop. Agroecosystem*. 14 (2011), 229–235.
- Young, F.J. and Hammer, R.D. (2000). Defining Geographic Soil Bodies by Landscape Position, Soil Taxonomy, and Cluster Analysis. *Soil Sci. Soc. Am. J.* Vol. 64(1). Pp. 989-998.