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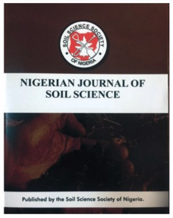

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Characterization, land capability and fertility classification of soils along Kpantinapu-Nukkai toposequence in Jalingo, Taraba State

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ABSTRACT

The objective of this study was to characterize the soils of the study area, determine some soil properties and classify the soils according to USDA Taxonomic System. Coordinates of the Pedons were obtained using hand held Geographic Positioning System (GIS) and one (1) profile pit was dug at the upper, middle and lower slope respectively. Some soil physical and chemical properties were determined using standard laboratory procedures. The results shows that the physical properties at the upper slope were dominated by sand with mean values ranging from 50 to 87%. Clay content increased with increase in profile depth and with decrease in slope along the toposequence (>35% clay). Soil pH were slightly acid to neutral across the slope and was statistically significant between the slopes. The soils had greater than 50% base saturation and were classified as Alfisols at the order level. The soils were classified as Typic Plinthustalfs, Typic Paleustalfs and Vertic Halpustalfs at the upper, middle and lower slope respectively. Capability class showed class C3(IIIse) at the upper slope while the lower slope was C3 (IIIws); and fertility class varied from moderately suitable (S2) to marginally suitable (S3). In order to attain food security and enhance agricultural productivity and quality of life in the study area, close attention should be given to upper slope position to control the damaging effects of erosion and integrated nutrient management should be employed to improve the soil fertility of the land.

1.0. Introduction

Soil is defined as a collection of natural bodies occupying parts of the earth's surface that is capable of supporting plant growth and living organism acting upon parent material as conditioned by topography over a period of time (Brady and Weil, 2007). Topography gives rise to toposequence of related soils from the same parent materials, about the same age and occupying under similar climatic conditions but have differences in their characteristics due to change in slope (Brady and Weil, 2007).

Local topography are called Toposequence as a general rule, soil profile on the convex upper slope in a toposequence are more shallow and have less distinct sub surface horizons than soils at lower slope. Soil's toposequence plays a major role as one of the factors that influence pedogenesis and in the process that dictates the distribution and use of soil on the landscape (Esu *et al.*, 2008). Landscape position influences effective rainfall, drainage and erosion. Toposequence influences water velocity on a slope, variation in drainage condition and deposition of minerals. This causes a series of change in soil properties such as horizon differentiation, textural contrasts, changes in soil depth and chemical properties (Hall and Olson, 1991).

There is an increasing demand for information on soils as a means to produce food (Fasina *et a*l., 2007). The basic information necessary to create functional soil classification schemes, and assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al*., 2004). The coupling of soil characterization, soil classification and soil mapping provides a powerful resource for the benefit of mankind especially in the area of food security and environmental sustainability. Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005).

Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of experience and technology from one place to another and helps to compare soil properties. According to Eswaram (1988), some different uses of soil characterization data include to aid in the correct classification of the soil and enable other scientists place the soils in their taxonomic or classification systems and to serve as a basis for more detailed evaluation of the soil as well as gather preliminary information on nutrient, physical or other limitations needed to produce a capability class.

Smart farmers need or require critical and useful soil information for objective soil fertility and farm management decisions on how best to grow their crops for optimum yield and sustainable use of the land. Characterizing soils and its classification gives different version of information to smart farmers on how to prepare the land for onward seeding and or cultivation and other agronomic practices at the appropriate time. More so, the necessary tools in land preparation and soil management can be predicted since the characteristics and nature of soils were determined and documented for the farmers use. Water management strategies and implementation could be improved with soil information from soil classification of soils by local farmers using cultural soil water management practices or techniques suitable for the soils characterized especially in rural areas in developing countries.

The need to provide information on the soil is more demanding now than ever before because of the problem arising from misuse of land resulting in land depletion and degradation. Increase in Nigeria population places increasing demand on land resources. Therefore, managing land resource requires knowledge of the soil characteristics. Farmers are now cultivating on difficult terrains owing to decrease in soil fertility after several years of cultivation and due to increase in demand for food crops, many locals venture into crop production hence more farming units put pressure on soil and land resources for agricultural production. The study area varies both laterally and horizontally and this presents various land degradation processes.

The soil resources of Kpantinapu-Nukkai Toposequence due to complex interaction of soil forming factors and processes, appears to be diverse in their nature. In addition, farmers have experience reduction in crop yield connected to continuous intensive cultivation for many years, leaching and soil fertility reduction especially at the upperslope in the study area. Also, soils on the upper slopes are being depleted due to erosion hazards. Therefore, it was important to study and characterize the soils of the study area. The objectives of this study were to: (1) evaluate morphological characteristics, (2) determine some physical and chemical properties of the soils, (3) classify the soils according to United States Department of Agriculture (USDA) Taxanomic System and (4) carryout land capability and suitability classification of soils in the study area.

2.0. Materials and Methods

2.1. Site Description

The study was conducted at Kpantinapu-Nukkai Toposequence in Jalingo, Taraba State Capital (Longitude $11^0$22.978E and Latitude 8^0 58.421N and Longitude 11^0 19.671E and Latitude 8^0 55.235N).

Climate of the area is typical of West African Savannah, with high temperature 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 35^0C and The rainfall of the area varies with time and space which affect the economic activities of the area particularly rainfed agriculture. The area receives an annual rainfall of between 700mm-1500mm which occurs (normally) from May to October ending with August and September as the highest rainfall experiencing months (Taraba State DRE, 2002). 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% (Taraba State DRE, 2002). Two trade winds are found in the area, viz: the North and East West trades respectively. The former originate 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).

The study area is predominated by the basement complex rocks with massive structure. The major groups of rocks are granite, gneiss and some basic rocks intruding in many parts of the upper slope. The rocks had medium to coarse texture, massive structure with a variety of white to gray colors. The parent materials can be said to be fairly resistant to weathering conditions as observed from some weatherable minerals visible in the profile.

2.2 Field Work and Sampling

Three (3) profile pits were dug at the upper slope (5-7% Slope) with an elevation of 878m above sea level, middle slope (3-5% Slope) with elevation of 246m, and lower slopes (0-2% Slope) with elevation of 177m on the toposequence (Coordinates N08^{0}58.284', E011^{0}23.277'; N08^{0}58.446', E011^{0}20.556; N08^{0}55.164', E011^{0}19.062) respectively. Standard dimension of 2m deep, 1.5m long and 2m wide was used to dig the pits according to the USDA (2014) where there were no impediments and the pedons were represented by KNT3, KNT2 and KNT1 for upper, middle and lower slope respectively. Soil samples were collected according to the pedogenic horizons identified and soil morphological properties were described in-situ according to FAO (2006). The collected samples were well labeled and placed in clean polythene bags and transported to the laboratory for some soil physical and chemical determinations following standard laboratory procedures.

2.2.1 Soil sample preparation

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

2.3 Laboratory Analysis

2.3.1 Soil physical properties

Soil particle size distribution was determined by the Bouyoucos hydrometric method as described by Jaiswal (2004), 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^{0}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). Total porosity was calculated using the formula:

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

Where; F = Total porosity

Db = Bulk density

Dp = Particle density

Water holding capacity was determined using the gravimetric method. Soil samples were collected from field, weighed, dried to constant weight in an oven at 105^{o}C as described by Soil Survey Field and Laboratory Methods Manual (Burt, 2014).

2.3.2 Soil chemical properties

The pH of the soil was measured in a 1:2.5 soil to water suspension ratio using a glass rod and electrode pH meter (Jaiswal, 2004), using the same soil sample ratio from pH to determine EC, its measurement was carried out using the EC meter. The organic carbon (OC) 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 Nitrogen was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965). Available soil phosphorus was analyzed according to the standard procedure of Olsen *et al.* (1954) extraction method and the effective cation exchange capacity was measured by summing up the exchangeable bases and exchangeable acidity (H + Al). The exchangeable bases in the soil samples were determined by extracting with neutral ammonium acetate (NH_4OAc) (Black, 1965). The exchangeable potassium and sodium was determined via flame photometric method. Percentage base saturation was determined in the laboratory by using NH_4OA_C Ammonium (acetate) as described by Soil Survey Staff (2014). The following formula was used:

% BS= (A/B) x 100 ……………………………….. (2)

Where; A = NH_4 OA_C Extractable Bases (C_a + M_g) (cmol (+) kg^{-1}).

B = CEC – 7 (cmol (+) kg^{-1}).

2.4 Soil Classification

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

2.5 Data Analysis

Result from the laboratory analysis of some soil physical and chemical test were subjected to descriptive statistical analyses and One-way analysis of variance (ANOVA) was carried out using the Fishers Least Significance Difference (LSD) and the means were separated by using the pairwise comparison technique (comparison of two means) developed by Fisher (1935) to test for difference between the slope positions.

2.6 Land Capability Classification (LCC)

Land Capability Classification criteria used include land quality for rooting condition (s), soil workability (s), erosion hazard (e) and oxygen availability (w) respectively. The criteria was then used to develop classes of the factor ratings for the classification into Class I, Class II, Class III, Class IV and Class V respectively. Table 1 presents a summary of criteria used for land capability classification in this study. The criteria were used to rank land units based on the severity of land limitations for general agricultural cultivation. Table 9 shows land unit characteristics of the different soil units in the study area. The land unit characteristics were used to match the land characteristics with the initial ratings of land characteristics; this produced the land capability classification for the different soil units in the study area.

2.8 Soil Fertility Capability Classification

The study was carried out based on the principles of matching land use requirements with land qualities as described by Kparmwang et al. (1998) and FAO (1995) for land suitability classification of soils. The factor for rating

Table 1: Rating of Land Characteristics for Capability Classification

Land Quality			**Factor Rating**				
	Diagnostic factor	Unit	Class I	Class II	Class III	Class IV	Class V
Rooting condition (s)	Depth	Cm	150-200	100-150	75-100	50-75	>50
Soil workability (s)	Texture	Class	L,SCL,SiL	SL,SC	LS,C	S,SC	-
Erosion hazard (e)	Slope	%	0-2	2-4	4-7	7-12	12-18
Oxygen availability (w)	Drainage	Class	W. drained	Mod. Well drained	Poorly drained	V. poorly drained,excessively drained	

land requirements ranged from Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3) and Not Suitable (N). Table 2 shows the principles of matching land use requirements with land qualities as described by FAO (1995) and Nwaka and Kwari (1993). The data obtained for both land characteristics, qualities of land units and land use requirements were matched to give land suitability classes. The matching produced suitability classes for each quality. The extreme suitability class for the individual qualities combined gave the extent of limitation to productivity. The extent of combined limitations was used to produce the overall suitability class for each of the crop. The procedure was used to develop suitability classes for the major crops such as sorghum, maize, cowpea, ground nut and rice in the study area.

3.0. Results and Discussion

3.1 Some Morphological Properties of Soil of the Study Area

3.1.1 Soil Structure and consistency

Table 2: Rating of Land Use Requirement for Selected Crops

Land Quality	**Diagnostic Factor**	**Unit**	**Factor Rating**			
			S1	S2	S3	N
(a) Sorghum						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	5.5-7.5	4.8-5.5,7.5-8.0	4.5-7.8,8.0-8.3	<4, >8.3
Nutrient Retention cap (n)	Base saturation	%	>40	30-40	20-30	<20
Rooting condition (r)	Depth	Cm	>120	50-120	30-50	<30
Soil workability(w)	Texture	Class	SL, L	CL, SCL	SC, LS	S
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Structureless	-
Erosion Hazard (e)	Slope	%	0-4	4-8	8-12	>12
(b) Maize						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	6-7	5.5-6	5-5.5,7.5-8	<5.6, >8
Nutrient Retention cap (n)	Base saturation	%	>70	50-70	30-50	<30
Rooting condition (r)	Depth	Cm	>120	50-120	30-50	<30
Soil workability(w)	Texture	Class	SL, L	SCL, SiL	LS, CL, SCL	SC, SiL, C
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Weakly dev. Struc.	Structureless
Erosion Hazard (e)	Slope	%	0-2	2-4	4-6	>6
(c) Cowpea						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	6.0 – 7.0	5.5 – 8.0	4.5 – 8.5	< 4.5 > 8.5
Nutrient Retention cap (n)	Base saturation	%	> 60	40 – 60	10 – 40	< 10
Rooting condition (r)	Depth	Cm	> 100	50 – 90	25 – 50	< 25
Soil workability(w)	Texture	Class	LS, SL, CL	SC, SCL	SCL	S
Soil workability (k)	Structure	Class	Crumb	SBK	SBK	Columnar
Erosion Hazard (e)	Slope	%	0 – 4	4 – 6	6 – 8	>8
(d) Ground nut						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	5.8-6.2	5.5-5.8, 6.2-6.5	5-5.5, 6-6.7	<5, >7
Nutrient Retention cap (n)	Base saturation	%	>50	35-50	25-35	<25
Rooting condition (r)	Depth	Cm	>100	70-100	40-70	<40
Soil workability(w)	Texture	Class	SL, SiL	SiCL, CL	SiS, SC	<40
Soil workability (k)	Structure	Class	Mod. well. dev. Structure	Mod. dev. Structure	Structure less	C
Erosion Hazard (e)	Slope	%	0-2	2-5	5-8	>8
(e) Rice						
Oxygen availability (g)	Drainage	Class	Imperfectly drained	Moderately – well drained	Well drained; somewhat excessively drained	excessively drained
Nutrient avail. (a)	Reaction	pH	6.5-6.0, 6.5-7.0	5.5-5.0, 7.5-7.9	5.0-4.5, 7.9-8.2	<4.5, >8.2
Nutrient Retention cap (n)	Base saturation	%	>50	35-20	<20	-
Rooting condition (r)	Depth	Cm	>75	51-75	25-50	<25
Soil workability(w)	Texture	Class	SiC, C, SiCL,CL, Si, SiL	Fine C, SCL, SL, Loamy fine sand	LS, L coarse sand, fine sand	S, Coarse sand
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Structureless	-
Erosion Hazard (e)	Slope	%	0-3	3-8	8-15	>15

Key: < = Less than, > = Greater than, Mod.= Moderately, SL = Sandy Loam, L = Loam, SiL= Silty Loam, SiCL = Silty Clay Loam, LS = Loamy sand , SBK = Subangular blocky Dev. = Develop, S1=suitable, S2=moderately suitable, S3=marginally suitable, N=not suitable

Table 3 presents the morphological properties of soils in the study area. Pedon KTN3 pt2 in Takemobile represents the upperslope (5-7%). The soils were weak, coarse and sub angular blocky structure at all depths except at 55-118cm depth which had coarse and moderate structure. Similar trend was observed where the soils were non-sticky, non-plastic, loose when wet, moist and dry except at that last horizon which were slightly-sticky and hard when dry. The soils were characterized by few fine roots at the surface horizons of the pedon, while the last two horizons were devoid of any inclusions. These results could be due to the coarse and sandy nature of upper slope soils as observed by Atofarati et al. (2012) on two toposequence in Ile-Olluji, Ondo State, Nigeria.

Pedon KNT 2 represents the middle slope (3-4%) and is located in Gulum. The pedon had a sub-angular blocky, moderate to medium structure at the surface horizon (0-25cm); strong to medium structure (25-50cm) and coarse to strong structure at 50-125cm depth respectively. The soils were slightly sticky, slightly plastic, firm when moist and loose when dry at the same depth. Soil consistency increased down the profile to very sticky, very plastic, firm and hard characteristics. This increase at the middle slope position could be attributed to clay and other soil materials deposited at the middle slope as they are transported from the upperslope. This activity increase soil structure and consistency downslope. This result is supported by Nsor and Adesemuyi (2016) on soils along toposequence in Isiagu, Eastern Nigeria. The pedon had roots ranging from few to many, and fine to medium characteristics at the surface and subsurface horizons. This result suggested that root penetration and activity of the soils inclusions might promote or decrease root movement. Similar results were discussed by Bengough et al. (2001) who reported that root penetration resistance depends on many factors, but stones or gravel and water content of the soil are important especially.

Pedon KNT 1 represents the lower slope (0-2%) and is located in Nukkai. Investigation revealed that the soils were sub angular blocky, slightly sticky, slightly plastic, very friable and soft at the surface horizon (0-35cm). The consistency increased through the profile with; very sticky, very plastic, very firm and very hard characteristics. The result indicated that the soils were deep, generally strong structured and very plastic consistency. Esu et al. (2008) found soils on a toposequence; at the upper slopes were shallower and had less distinct sub surface horizons than soils at lower slopes. The presences of fine and coarse roots ranging from common to many were observed in the horizons of the pedon. These results might be attributed to the action of erosion at the upper slopes which detach clayey materials and transport them downslope leaving coarser materials at the upper slope. Similar result was reported by Nsor and Adesemuyi (2016) on soils of a toposequence.

3.1.2 Soil colour

Soils of pedon KNT3 showed brown colour 7.5YR (5/2 and 4/2) when dry and moist at 0-14cm depth, gray 7.5YR (6/1) when dry and dark brown 7.5YR (3/2) when moist at 14-37cm depth respectively. These results support similar trends observed by Bengoughet al. (2001). The soils were reddish brown 5YR (5/6) when dry at the depth of 55-118cm and this might be due to well drained condition of the soils and the reddish to yellowish colour could be indicative of absence of organic carbon and high presence of iron (Fe2+); and the presence of hematite are likely. This is in line with the report of Akamigbo et al. (2001) who reported similar colors for soils for similar landscape position. Pedon KNT2 indicated that the soils had brown colour 7.5YR (5/2) when dry and dark brown 7.5YR (3/2) when moist at the surface horizon. The colour developed to yellowish red 5YR (4/6) when dry and reddish brown 5YR (4/4) when moist at 25-50cm depth, yellowish red colour 5YR (4/6) and yellowish red 5YR (4/4) at 50-77cm depth when dry and moist respectively. This suggested that the soils were perfectly drained and had high presence of Fe2+ with low organic matter.

Pedon KNT 1 showed a varying trend from the previous pedons. The soils were pale brown 10YR (6/3) when dry and brown colour 10YR (4/3) when moist with few, fine, faint mottles at the surface horizon (0-35cm), indicating that the soils were imperfectly drained. The soils had a highly mottled subsurface, brown colour of 10YR (4/3) when dry and very dark greyish brown colour 10YR (3/2) when moist. Water-logged condition might have resulted to gleization which could have been the reason for the greyish coloration. The red colour mottles observed could be attributed to Fe2+ and Fe3+ reversible changes in the soils. Similar trend of results were reported by Abagyeh et al. (2017). These results might also be due to increase in organic matter content and other soil materials detached, transported and deposited downslope by action of water. Also, the increase in organic materials downslope might have accounted for reddish colorations which indicated decay of root materials in the profile. Gisilanbe et al. (2017) reported similar findings on soils of a toposequence.

3.2 Some Physical Properties of Soils in the Study Area

Table 4 presents the physical properties of soils in the study area. Result for particle size distribution indicated that pedon KNT3 recorded sandy loam across all horizons except the surface horizon (0-14cm) which showed highest percentage of sand with the value of 86% and low clay content (3%). This result might be attributed to the clay content detached and transported downslope leaving coarse sand fraction at the upper slope. However, clay content increased with increased in horizon depth from 3% (0-14cm) to 17.5% at the B-horizon. This result might be due to leaching activity over time and clay materials washed down the profile, leaving coarse material at the surface horizon. Similar trend of particle size was reported by Ogbaji (2010) who characterized soils in Onwu River Floodplain. Silt significantly varied in all the slopes while pedon KNT 3 varied with both KNT 2 and 1 in clay content (Table 5). Clay content increased at the lower slope with 45% clay content at the subsurface horizon indicating that clay materials were deposited downslope due to action of moving water from the upper slope.

Result of soil textural classes indicated that the soils were predominantly sand to sandy loam at the upper slope, sandy clay to sandy clay loam at the middle slope and clay to silty clay at the lower slope.

This distribution of soil texture might be linked to toposequencial arrangement and distribution of the soils due to action of erosion, transportation of soil materials and deposition. Bulk density decreased with increase in profile depth from 1.84g/cm3 at the surface horizon to 1.45g/cm3 at the C-horizon at the upper slope and from 1.48g/cm3 to 1.31g/cm3 at the lower slope. This trend might be due to sand-clay contents responsible for increase in bulk density where sand content increased and vise vasa.

Table 3: Some Morphological Characteristics of Soils of the Study Area

Pedon	**HD**	**Depth (cm)**	**Colour**		**Mottles**	**Texture**	**Structure**	**Consistency**	**Inclusions**
			Dry	Moist					
KNT 3	Ap	0-14	7.5YR 5/2	7.5YR4/2	n	SL	w,c,s.b.k	Wns,np,ml,dl	rmm
	E	14-37	7.5YR 6/1	7.5YR3/2	n	S	w,c,s.b.k	Wns,np,ml,dl	rmc
	B	37-55	7.5YR 5/4	7.5YR5/4	n	S	w,c,s.b.k	Wns,np,ml,dl	rcc
	C	55-118	5YR 5/6	5YR 5/6	n	SC	m,c,s.b.k	Wss,sp,mvf,dh	rfc
KNT 2	Ap	0-25	7.5YR 5/2	7.5YR3/2	n	LS	m,m,s.b.k	Wss,sp,mf,dl	rmm
	Bt1	25-50	5YR 5/6	5YR 4/4	n	SCL	s,m,s.b.k	Wvs,vp,mf,dh	rff
	Bt2	50-77	5YR 4/6	5YR 4/4	n	SC	s,c,s.b.k	Wvs,vp,mvf,dvh	n
	C	77-125	5YR 5/6	5YR 4/6	n	SC	s,c,s.b.k	Wvs.vp,mvf,dvh	n
KNT 1	Ap	0-35	10YR 6/3	10YR 4/3	Fff	SiL	m,f,s.b.k	Wss,sp,mvf,ds	rcc
	Bt1	35-65	10YR 4/3	10YR 3/2	Cmd	C	s,f,s.b.k	Wvs,vp,mvf,dvh	rmc
	Bt2	65-95	10YR 5/4	10YR 4/3	Ffd	C	s,f,s.b.k	Wvs,vp,mvf,dvh	rcc
	Bt3	95-153	10YR 6/4	10YR 5/4	Fcp	C	s,f,s.b.k	Wvs.vp,mvf,dvh	rfc

Key

HD: Horizon designation, **Mottles:** n= none, F= few, f= fine, f= faint, C= common, m= moderate, d= distinct, p= prominent. **Texture:** S= sand, SL= Sandy loam, SCL= Sandy clay loam, SC= Sandy clay, LS= Loamy sand, C= Clay, SiL= Silt loam. **Structure:** ***Grade***; w= weak, m= moderate, s= strong. ***Class***; f= fine, m= medium, c= coarse. ***Type***; sbk= sub angular blocky. **Consistency:** ***Wet***; ns= non sticky, np= non plastic, sl= slightly sticky, sp= slightly plastic, vs= very sticky, vp= very plastic, ***Moist***; l= loose, vf= very friable, f= firm, vf= very firm, ***Dry***; l= loose, s= soft, h= hard, vh= very hard. **Inclusion:** r= root; ***Abundance***: f= few, c= common, m= many; ***Size***: f= fine, m= medium, c= coarse, n= none.

Table 4: Some Physical Properties of Soils in 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**
KNT 3	Ap	0 -14	86	11	3	S	1.84	31	9.2	0.12
	E	14 – 37	62	20	18	SL	1.48	44	10.2	0.22
	B	37 – 55	63	19.5	17.5	SL	1.47	44	10.5	0.22
	C	55 – 118	59	22	19	SL	1.45	45	11.6	0.23
		Mean	67.50	18.13	14.38		1.56	41.00	10.38	0.20
KNT 2	Ap	0 – 25	90	8	2	S	1.84	31	7	0.11
	Bt1	25 – 50	47	12	41	SC	1.32	50	10	0.33
	Bt2	50 – 77	47	20	33	SCL	1.35	49	12.2	0.3
	C	77 – 125	50	20	30	SCL	1.37	48	11	0.28
		Mean	58.50	15.00	26.50		1.47	44.50	10.05	0.26
KNT 1	Ap	0 – 35	63	20	17	SL	1.48	44	10	0.22
	Bt1	35 – 65	42	13	45	C	1.29	51	11	0.35
	Bt2	65 – 95	17	42	41	SiC	1.26	53	16	0.39
	Bt3	95 – 153	48	10	42	SC	1.31	50	10	0.33
		Mean	42.50	21.25	36.25		1.34	49.50	11.75	0.32

Key: Textural class: S=Sand, SL=Sandy loam, SC=Sandy clay, SCL=Sandy clay laom, SiC=Silty clay, T =total, B.D =Bulk Density, WHC =Water Holding Capacity

Table 5: ANOVA Analysis for Some Soil Physical Properties

Pedon	**Sand (%)**	**Silt (%)**	**Clay (%)**	**B.D (g/ cm^3)**	**T. Porosity (%)**	**WHC (%)**	**Field Capacity cm^3 water/cm^3 soil**
KNT 3	67.50^a	18.13^a	14.38^a	1.56^a	41.00^a	10.38^a	0.20^a
KNT 2	58.50^a	15.00^b	26.50^b	1.47^a	44.50^a	10.05^a	0.26^a
KNT 1	42.50^a	21.25^c	36.25^b	1.34^a	49.50^a	11.75^a	0.32^a
LSD (5%)	37.03	0.00	21.75	0.84	14.17	9.70	0.13

Means with same alphabets within a column are not statistically significant at 5% level.

Soil total porosity did not vary significantly at 5% level however, values increased with increase in profile depth at the upper and lower slopes (31 to 45% and 44 to 53%). Water holding capacity and field capacity followed similar trend and increased with decrease in slope. This could be due to moisture and other soil materials moving down the profile by action of leaching. Water holding capacity and field capacity were higher a lower slope due to clay fractions increase downslope. Maniyunda and Gwari (2014) indicated that silt and clay soil fractional contents increased while sand decreased along the toposequence along with moisture and other soil materials. Furthermore, soil moisture and other soil nutrients are eroded at the upper slope especially during the peak of the rainy season and transported downslope where they were deposited. This result was also observed by Noma (2012) were moisture content increase with decrease in slope.

3.3 Some Chemical Properties of Soils in the Study Area

The result of chemical properties is presented in Table 6. The result for pH showed that KNT 1 significantly varied with KNT 3 and KNT 2 however, the two did not significantly vary at 5% level (Table 7). The soils were slightly acidic (6.1-6.5) at the upper slope, slightly acidic to moderately acidic (6.1-6.5 to 5.6-6.0) at the middle slope and slightly acidic to neutral (6.1-6.5 to 6.6-7.3) at the lower slope (Usman, 2005). These results agree with report of Noma (2012). Electrical conductivity revealed that KNT 3 significantly varied with KNT 2 and KNT 1 with range between 0.02ds/m to 0.07ds/m. This result is supported by Adediran (2004).

The organic carbon content of the soils were generally rated low (<1%) according to ratings by Babalola et al. (1998). This result might be due to continues cultivation and crop removal across the slope. Farmers cultivate the land yearly with little effort to ameliorate lost nutrient coarse materials with low organic carbon. Furthermore, increase in erosion activity at the upper slope might have accounted for the low organic carbon in the area (Ogunwale et al., 2002). Organic matter were rated low (<2%) and result from analysis showed that the upper slope significantly varied with the mid and lower slopes. This result might be attributed to attempts farmers made by using organic materials and other cultural activities to reduce the effect of erosion at the upper slope which slightly increased the organic matter content. Total nitrogen were also generally low (0-0.15%) across the slope. This could be linked to erosion effect at the upper slope and crop removal at the lower slope which reduced the total nitrogen in the area. This result is supported by Hawando (1997).

The available phosphorus all varied across the slopes and were low to medium (<8 to 8-20mg/kg) in the study area. The values for available phosphorus increased from surface to subsurface horizons in KNT 3 (9.70 to 10.18) and in KNT 1 (7.79 to 10.89). These results might be attributed to leaching down the profile and the slightly acidic nature of soils which supported P-availability in the area. This result agrees with the findings of Yacob et al. (2014).

Results for Ca, Mg, Na and K analysis in the study area indicated that they did not significantly vary at 5% level of significance. Exchangeable calcium were rated medium to high (2-5 to >5cmol/kg) across the pedons and particularly increased from 1.44 to 5.28cmol/kg at the subsurface horizon of the lower slope. This result might be due to eluviation calcium materials giving rise to the increase. Magnesium were rated high (>1 cmol/kg) and this could be due

Table 6: Soil Chemical Properties of Soils in 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**	**TEB**	**TEA**	**ECEC**	**PBS**
										←		**cmol/kg**				→
KTN3	Ap	0 -14	6.10	0.03	0.88	1.51	0.07	9.70	3.36	1.45	0.04	1.00	5.86	1.60	7.46	78.54
	E	14 – 37	6.50	0.02	1.20	2.06	0.10	10.18	4.80	1.60	0.22	0.44	7.05	2.20	9.25	76.22
	B	37 – 55	6.40	0.03	0.85	1.46	0.07	7.07	5.28	0.87	0.09	0.33	6.57	2.12	8.69	75.61
	C	55 – 118	6.03	0.02	0.93	1.60	0.08	9.22	4.80	1.31	0.13	0.05	6.29	1.40	7.69	81.79
		Mean	6.26	0.03	0.97	1.66	0.08	9.04	4.56	1.31	0.12	0.46	6.44	1.83	8.27	78.04
KTN2	Ap	0 – 25	6.03	0.03	0.85	1.47	0.07	8.58	2.88	1.50	0.13	0.23	4.74	2.60	7.34	64.96
	Bt1	25 – 50	6.33	0.02	0.74	1.27	0.06	9.22	2.88	1.60	0.13	0.13	4.74	2.80	7.54	62.85
	Bt2	50 – 77	5.96	0.02	0.84	1.44	0.07	7.31	3.36	1.74	0.13	0.36	5.59	3.20	8.79	63.61
	C	77 – 125	5.80	0.07	0.99	1.70	0.08	9.22	2.40	1.16	0.13	0.21	3.90	1.80	5.70	68.41
		Mean	6.03	0.04	0.86	1.47	0.07	8.58	2.88	1.50	0.13	0.23	4.74	2.60	7.34	64.96
KTN1	Ap	0 – 35	6.50	0.04	0.67	1.15	0.06	7.79	1.44	1.74	0.13	0.15	3.47	2.20	5.67	61.19
	Bt1	35 – 65	6.60	0.07	1.03	1.77	0.09	10.89	5.28	1.16	0.17	0.10	6.72	1.40	8.12	82.76
	Bt2	65 – 95	6.93	0.02	0.81	1.39	0.07	10.41	5.28	1.74	0.48	0.08	7.58	1.60	9.18	82.57
	Bt3	95 – 153	6.50	0.02	0.96	1.65	0.08	8.02	4.80	1.60	0.22	0.08	6.69	1.90	8.59	77.89
		Mean	6.63	0.04	0.87	1.49	0.08	9.28	4.20	1.56	0.25	0.10	6.12	1.78	7.89	76.10

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

Table 7: ANOVA Analysis for some Soil Chemical Properties

Pedon	**pH (1:2)**	**EC (dS/m)**	**Org.C (%)**	**Org.M (%)**	**TN (%)**	**Av-P (mg/kg)**	**Ca**	**Mg**	**Na**	**K**	**TEB**	**TEA**	**ECEC**	**PBS**
							←			**cmol/kg**			→	
KTN3	6.26^a	0.03^a	0.97^a	1.66^a	0.08^a	9.04^a	4.56^a	1.31^a	0.12^a	0.46^a	6.44^a	1.83^a	8.27^a	78.04^a
KTN2	6.03^a	0.04^b	0.86^a	1.47^b	0.07^a	8.58^b	2.88^a	1.50^a	0.13^a	0.23^a	4.74^a	2.60^b	7.34^a	64.96^a
KTN1	6.63^b	0.04^b	0.87^a	1.49^a	0.08^a	9.28^c	4.20^a	1.56^a	0.25^a	0.10^a	6.12^a	1.78^a	7.89^a	76.10^a
LSD (5%)	0.29	0.00	0.64	1.10	0.04	0.00	2.47	1.25	0.21	0.49	2.39	0.69	5.58	8.95

Means with same alphabets within a column are not statistically significant at 5% level.

to magnesium bearing mineral which are predominant in the study area and part of weathered materials during soil development. This result is similar to the findings of Sheleme (2011) and supported by Ojanuga (2006). Values for sodium were low (0 to 0.15cmol/kg) at the upper and midslopes but increased downslope to high (>0.3cmol/kg) at the Bt-horizon at 65-95cm depth. This could be attributed to eluviation from the surface horizon and subsequent illuviation at the Bt-horizon. The slight increase downslope might be as a result of movement of materials from the upper slope and deposition at the lower slope position. Fasina (2005) discussed similar findings. Total exchangeable bases and effective cation exchange capacity did not significantly vary across the slope while the middle slope varied with both the upper and lower slopes for total exchangeable acidity and percentage base saturation. The base saturation were medium to high (50-80 to >80%) and this result is supported by report of Anikwe et al. (2005).

3.4 Soil Classification

Table 8 shows summary of the soil classification of the study area. All the soils of the area were classified as Alfisols at the order level due to their %BS >50 calculated from NH4OAc Extractable Bases 1N and possession of an argillic epipedon. The soils were formed under Ustic soil moisture regime and classified as Ustalfs at the suborder level across the slope. At the great group level, KNT 3 was classified as Plinthustalfs due to the presence of plinthites, iron-rich, humus-poor mixture of clay with quartz and other minerals. Also, there were some dark-red redox concentrations that formed platy and polygonal patterns or gravels distributed and very visible at >50cm depth of lower horizons of the pedon. Pedon KNT 2 was classified as Paleustalfs at the great group level due to >5% plinthite in more than one horizon of the mineral soil surface. Pedon KNT 1 mostly had >30% clay and developed slickenside and the thickness of all horizons were greater than 25cm with cracking properties. The soils were very sticky when wet and very hard when dry. The soils had wedge-shaped aggregates in >15cm thick with the upper boundary within 125cm of the mineral soil surface. They therefore qualify as Vertic soils and classified as Halpustalfs at the great group level. Due to cracks within 125cm depth of the mineral soil surface which were >5mm wide through a thickness of 30cm. The soils were further classified as Typic Plinthustalfs, Typic Paleustalfs and Vertic Halpustalfs at the sub group level.

3.5 Land Capability Classification

Table 10 presents the land capability classification of the study area. The study indicated that KNT3 was classified as C3 (IIIse) with limitation in slope (e) and texture (s). The upper slope is characterized by erosion due to aspect and many of the soils were usually eroded during the rainy season. Land Unit II (KNT2) overall classification showed that the class was C4 (IVsew) with limitation in soil workability and slope (e). Land Unit I (KNT1) was classified as C3 (IIIws) with limitation in drainage (w) and texture (s). This result might be due to increase in moisture content downslope and consequently; reducing the oxygen availability of the soils.

Table 8: Summary of USDA Soil Classification of the Study Area

Pedons	Location	Classification (USDA)			
		Order	Sub-order	Great group	Sub-group
KNT3	Takemobile	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs
KNT2	Gulum	Alfisols	Ustalfs	Plinthustalfs	Plinthic Paleustalfs
KNT1	Nukkai	Alfisols	Ustalfs	Halpustalfs	Vertic Halpustalfs

3.6 Soil Fertility Capability Classification

The result for fertility capability classification for selected crops is presented in Table 11. The result indicated that Pedon KNT3 was classified as moderately suitable (S2rke) for sorghum, marginally suitable (S3ke) with limitation in soil workability (k) and erosion hazard (e) for maize, cowpea and groundnut, and not suitable (N) for rice cultivation. This result might be due to coarse, sandy loose nature

Table 9: Land Unit Characteristics for the Land Units in the Study Area

Land quality	Diagnostic factor	Unit	Land Unit III (KNT3)	Land Unit II (KNT2)	Land Unit I (KNT1)
Rooting condition (s)	Depth	Cm	118	125	153
Soil workability (s)	Texture	Class	S-SL	S,SC,SCL	SL,C,SC
Erosion hazard (e)	Slope	%	5-7	3-5	0-2
Oxygen availability (w)	Drainage	Class	W. drained	Mod. Well drained	Poorly drained

Table 10: Land Capability Classification of the Study Area

Land Quality	Diagnostic Factor	Land Units KNT 3	KNT2	KNT1
Rooting condition	Depth (s)	C2	C2	C1
Soil workability	Texture (s)	C2	C4	C2
Erosion hazard	Slope (e)	C3	C3	C1
Oxygen availability	Drainage (w)	C1	C2	C3
Overall Capability		C3(IIIse)	C4(IVsew)	C3(IIIws)

of soils at the upper slope that are not particularly suitable for rice production; which require reasonable amount of water in its life circle. Pedon KNT2 had overall suitability class of marginally suitable for sorghum (S3ak), maize (S3en) and groundnut (S3wa) with limitation in soil reaction, erosion hazards and texture respectively. Furthermore, the classification also showed moderate suitability for cowpea (S2wg) and rice (S2gw) cultivation for the pedon (KNT2). Pedon KNT1 revealed marginal suitability class for sorghum and maize (S3g) with limitation in oxygen availability. Cowpea (S3gk) and ground (S3ga) were also marginally suitable with limitations in oxygen availability (g), soil workability (k) and nutrient availability (a) respectively. However, the pedon was classified as suitable (S1) for rice cultivation. This might be connected to accumulation of basic cation, clay and moisture down slope which supports rice cultivation.

4.0. Conclusion

The findings from this study showed that on a toposequence, soil morphological, physical and chemical properties vary. Some of the factors responsible for the variation were slope position and cultural practices of farmers in the study area. Slope position had a significant effect on depth, colour, silt and clay properties. Also, slope had an effect of some chemical properties which include; while soil pH, electrical conductivity, organic matter, available phosphorus, total exchangeable acidity and percentage base saturation. Generally, the soils had sandy coarse soil surface and the upper slopes were heavily eroded due to the sandy lose nature of the soils. The lower slope had more silt and clay contents which indicated more potentials and nutrient content for agricultural production than the upper slope however; continues cultivation must be done in such a way that lost nutrients should be augmented using organic and inorganic fertilizers.

Land use requirement / Land quality	**Suitability Ratings of Sampling Units**														
	Sorghum			Maize			Cow pea			Ground nut			Rice		
	KNT3	KNT2	KNT1	KNT3	KNT2	KNT1	KNT3	KNT2	KNT1	KNT3	KNT2	KNT1	KNT3	KNT2	KNT1
Oxygen availability (g)	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S3	S2	S1
Nutrient availability (a)	S1	S3	S1	S1	S2	S1	S1	S2	S1	S2	S1	S3	S1	S1	S1
Nutrient retention (n)	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Rooting condition (r)	S2	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Soil wrk (texture) (w)	S1	S2	S1	S1	S2	S1	S1	S2	S1	S1	S3	S2	N	S2	S1
Soil wrk structure (k)	S2	S2	S1	S3	S2	S1	S2	S1	S2	S2	S2	S2	S2	S2	S1
Erosion hazard (e)	S2	S2	S1	S3	S3	S1	S3	S2	S1	S3	S2	S1	S2	S2	S1
Overall suitability	S2rke	S3ak	S3g	S3ke	S3en	S3g	S3ek	S2wg	S3gk	S3ea	S3wa	S3ga	N	S2gw	S1

Key: wrk=workability, S1=suitable, S2=moderately suitable, S3=marginally suitable, N=not suitable

References

Abageh, S.O.I., Wuese, S.T. and Ezenwa, M.I.S. (2017). Characterization, classification and management of intergrated landscape in the Benue Valley of Benue State. Nigerian Journal of Soil Science. Vol. 27(1) 267-281.

Adebayo, A.A. (1999). Climate I; Sunshine Temperature,Evaporation and relative humidity in Adamawa state in map. Adebayo A.A. and A.H.Tukur (Eds) pradet publisher and Department ofgeographyFederal University Of Technology Yola Nigeria pp 3-5.

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 27th Annual conference of 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 International Journal of AgriScience Vol. 2(7): 642-650.

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, G.R. (1965). Bulkdensity. In: C.A. Black (ed.).Methods of Analysis. Agronomy part I,

Blake, G.R. and Hartge, K.H. (1986). Bulk density.InmethodsofSoilAnalysis.Klute A. (Ed).Part 1.2nded.Agron. 9. ASA and SSA, Madison, W1. P.363-375.

Boyoucos. (1965). Hydrometer methods improved for making particle size analysis of soils. Soil Sci. Soc. Am. Proc. 26: 464- 465.

Brady, .N.C. and Weil (2007). TheNatureandProperties of Soils.13thedition.Pearson Education. India.

Burt, R. (2014). Soil Survey Staff. Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 51, Version 2.0. Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Esu, I.E. (2005). Soil characterization and mappingforfoodsecurity. A Keynote Address.

Eswaran, H., Kinble, J. and Cook, T. (1988). Classification, management and use potential of swell shrinkage soils. Transaction of the international workshop on swell -shrinkage soils. Oct 24-28, 1988. National Bureau of soil survey and landuse planning. Nagpur, India. Pp. 1-12.

FAO. (1995). Guidelines: Land evaluation for rain fed agriculture. Soil Resources Management and Conservation Services, Land and Water Development Division, Rome. Food and Agricultural Organization, FAO Soil Bulletin 52. 237pp.

FAO. (2006). World Base Reference for Soil Resources, Rome: FAO-ISRIC-IUSS,.

Fasina, A.S., Omolayo, F.A., Ajayi, SO., and Falodun, A.A. (2007). Influence of Land Use on Soil Properties in Three Mapping Units inSouthwestern Nigeria-Implications for SustainableSoil Management. In Uyovbisere, E.O, Raji, B.A,Yusuf, A.A, Ogunwale, J.O, Aliyu, L. and Ojeniyi,S.O (Eds). Soil and water management for poverty alleviation and sustainable EnvironmentProceedings of the 31st annual conf. of SSSN/ABUZaria Nig. Nov.13th to 17th, 2006.

Gisilanbe, S.A., Musa, S.A., Lebbiso, I.J., Bilayabu, S.S. and Dahiru, H.A. (2017). Soil Morphological Properties, Classification, Suitability and Capability Classification on Dabora-Yelwa Toposequence, Adamawa State, Northeastern Nigeria. International Journal of Plant & Soil Science 17(4): 1-10, 2017; Article no.IJPSS.32045 ISSN: 2320-7035.

Hawando, T. (1997). Desertification in Ethiopian Highlands, RALA Report No 200, Norwegian Church AID, Addis Ababa. www.rala.is/rade/ralareport/Hawando.pdf.

Jaiswal (2004). Soil plant and water analysis Kalyani publisher Ludhiana New Delhi.

Kparmwang. T., Abubakar, A.S., Chude, V.O., Raji, B.A. and Malgwi, W.B. (1998). Suitability Assessment of the microtopograhical land features of the River Galma Fadama at Zaria using the principles of limited condition and Arithmetic modelling In: proc. Of the 24th Annual Conference soil Sci. Soc. Of Nigeria held at the Abubakar Tafawa Balewa University, Bauchi 7th – 11th Dec. 1988.

Lekwa, M.U., Anene, B.O. and Lekwa, G. (2004). Chemical and Morphological Soil Characteristicsin Drainage Toposequence in SoutheasternNigeria. In Ojeniyi, S.O., Ano, A.O., Awasalam,D.O. and Chukwu, G.O. (Ed) Land Degradation,Agricultural Productivity and rural poverty, environmental implications proceedings of the 28thAnnual Conference of the Soil Science Society of Nigeria.

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.

Noma, S.S., Tanko, I.I., Yakubu, M., Dikko, A.U., Abdullahi, A.A. and 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 Science Society of Nigeria held at FUT, Minna, March 7 – 11, 2011.

Nwaka, G.I.C. and Kwari, J.D. (1993). Mapping and land evaluation studies of soils of Jere Bowl (unpublished).

Ogunkunle, A.O. (2005). Soil Survey and Sustainable Land Management. Proceedings of the 29thAnnual Conference of the Soil Science Society of Nigeria.

Olsen, S.R., Cole, C.V., Watanabe F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction withsodium bicarbonate. USDA Circular 939. 1-19 Paris. 50 pp.Perspective, De-Rio Press Nigeria Limited, Calabar.

Schoenholtza, S.H., Miegroetb, 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.

Sehgal, J.L. (1996). Pedology: Concepts and Applications, Kalyani Publishers, New Delhi.

Sheleme, B. (2011). Characterization of soils along a Toposequence in Gununo area, southern Ethiopia. J. Sci. Dev. 1(1):31-41.

Soil Survey Staff (2010). Soil Taxonomiy. A basic system of soil classification for making and interpreting soil surveys. 2ndEdition.agric.Handbook.No. 436.US. Gov. print, office. Washington,DC,U.S.A. p 346.

Soil Survey Staff (2014). in press. R. Burt and Soil Survey Staff (eds.). Kellogg soil survey laboratory methods manual. Soil survey investigations report No. 42. Version 5.0. USDA–NRCS. GPO, Washington, DC.

Usman, B.H. (2005). The soils of Adamawa State, North-Estern 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 titrati.3on method. Soil Science, 37:29-38.

Yacob, A., Heluf, G. and Sheleme, B. (2014). Pedological characteristics and classification of soils along landscapes at Abobo, southwestern lowlands of Ethiopia. Soil and Water Research Section, Gambella Agricultural Research Center, P. O. Box 62, Gambella, Ethiopia. Journal of soil science and environmental management.