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SOILS DEVELOPMENT ON A TOPOSEQUENCE ON LOESSIAL DEPOSIT IN NORTHERN GUINEA SAVANNA, NIGERIA

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ABSTRACT

The morphological, physical and chemical properties of soils developed on loessial deposit in Funtua, Northern Guinea Savanna of Nigeria were examined and the influence of toposequence on their properties, pedogenesis and classification were evaluated. The study showed that landscape position, erosion and drainage significantly influenced variation in soil properties across the toposequence. Silt particle dominated particle size distribution, except on crest position (LS 1). Clay distribution significantly influenced variation in content of AWHC, exchangeable bases and CEC (r = 0.600**, 0.539** and 0.763**, respectively). Pedogenesis resulted in silt, clay, AWHC and CEC enrichment at lower slope positions (LS 4 and LS 5) and sand was highest in pedon LS 1. The soils were generally low to medium in exchangeable bases (Ca, Mg, K and Na) and low to high for CEC. All the soils were low in organic carbon, total nitrogen and available phosphorus. Toposequence affected variation of soil types with their classification as Kanhaplic Haplustalfs for soils on crest to lower slope and soil on bottom slope as Typic Haplustult according to USDA *Soil Taxonomy*. The soils were classified as Haplic Acrisols and Haplic Alisol, respectively according to World Reference Base 2006.

Keywords: soil classification, toposequence, loessial deposit, pedogenesis.

INTRODUCTION

Any variations in the geomorphic and hydrologic processes in soils as an integral part of land surface influence the pedogenic processes and soil properties through their effect on differential distribution of water, sediments and dissolve materials (Brunner *et al*., 2004; Young and Hammer, 2000; Ovalles and Collins, 1986). Soil properties on a toposequence differ due to degree of detachment, transportation and deposition of soil materials. Understanding soil properties and their variation is important for their sustainable utilization and proper management. The concept of toposequence, which involves processes that cause properties differentiation along hillslopes and among soil horizons have improved evaluating the interaction of pedogenic and geomorphic processes (Gessler *et al*., 2000; Esu *et al*., 1987; Ovalles and Collins, 1986; Daniel *et al*., 1971).

Loess soils are believed to develop from parent materials which before pedochemical weathering contain large amount of silt and about 10 - 20% clay (Buol *et al*., 1997). Typically, loess is a loose deposit of remarkably uniform physical composition mainly of silt texture (Buol *et al*., 1997). Soil genesis in loess causes distinct changes in morphological, physical and chemical properties. Morphological changes in soils developed in loess deposits include variation in color, solum thickness, degree of horizonation, depth of leaching and structural development (Young and Hammer, 2000; Schumacher *et al*., 1987).

Previous studies on loess soils in Northern Nigeria were mostly related to crust formation, fertility and survey (Adeoye, 1983; Malgwi, 1979; Lawes, 1962). At present, there is little or no work reporting loessial soil development and their properties on loess as influenced by toposequence in Northern Guinea savanna of Nigeria. The current study was carried out to examine the morphological, physical and chemical properties of soils developed on loess deposit and evaluate the influence of toposequence on their properties, pedogenesis, and classification and management implications.

METHODOLOGY

Study area

The study area is situated in northwestern part of Funtua town, Nigeria, between latitude 11^o 33^1 07.4” to 11^o 33^1 54.2” N and longitude 07^o 14^1 08.6” to 07^o 14^1 16.8” E. The site is underlain by undifferentiated basement complex of the pre-Cambrian to upper Cambrian era. Overlying it is superficial mantle of aeolian material referred to as Loess deposit (Sombroek and Zonneveld, 1971; Lawes, 1962). The land forms include a series of plains with scattered inselbergs (Mc Currry, 1973).

Funtua is located in the Northern Guinea Savanna zone close to Sudan Savanna region (Figure-1). The area has mean annual rainfall of about 1051 mm and last from May to October (Akintola, 1986; Bennett *et al*., 1979). From the rainfall distribution pattern, soil moisture regime is inferred to be ustic. The mean monthly temperature is high reaching 28.8^{o}C in April and 21.7^{o}C in December.

Land use of the area involves cultivation of cotton, millet, cowpea, soybean, groundnut, maize, and sorghum. The dry season (October to May) experience soil cultivation using irrigated agriculture to produce sugar cane, maize, tomato, onion, pepper, and vegetables (Maniyunda *et al*., 2007; Bennett *et al*., 1979).

Field studies

Soil profile pits were dug to standard, described and sampled for laboratory analysis (Soil Survey Division Staff, 1993). Soil morphological properties were described in the field following the procedure described in the USDA Soil Survey Manual (Soil Survey Division Staff, 1993).

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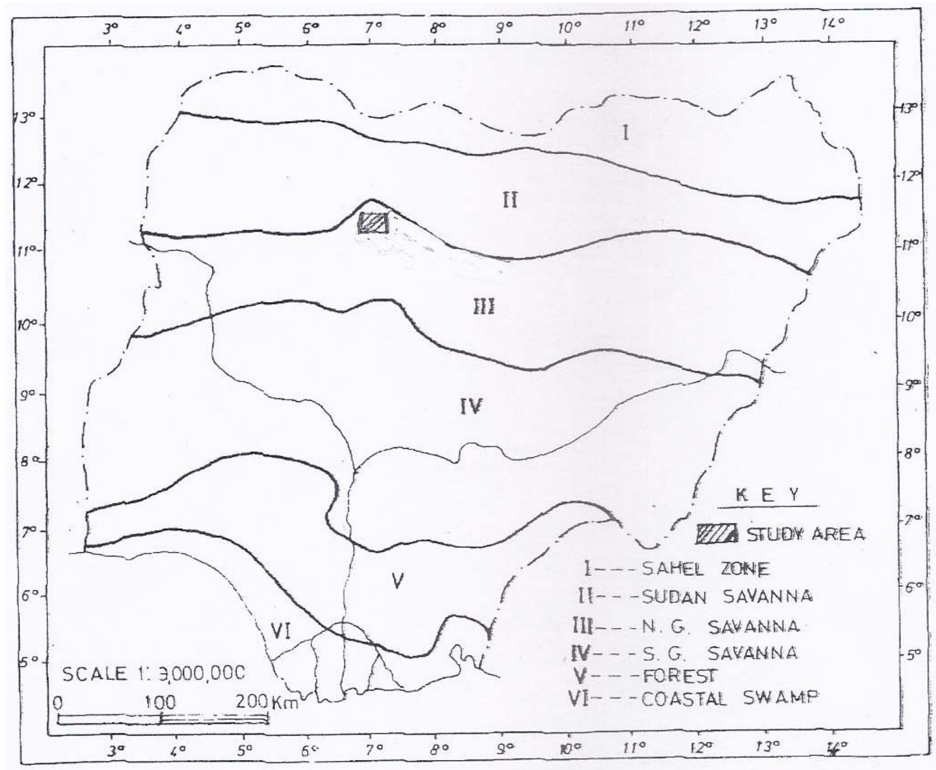

Figure-1. Map of ecological zones of Nigeria showing study area.

The following features were observed and described; soil depth, colour, mottling, structure, texture, consistence, horizon boundary, roots, concretions and pores.

Laboratory analysis

Soil samples collected from the profile pits were air-dried. Five hundred gramme of each sample was ground and sieved to remove materials greater than 2mm and its proportion was determined. Soil particles of less than 2mm fraction were used for the laboratory analyses. Particle size distribution was determined by hydrometer method (Gee and Bauder, 1986). Bulk density was determined by oven drying undisturbed samples collected on the field (Blake and Hartge, 1986). Available water holding capacity (AWHC) was determined by calculating the difference in moisture content at field capacity (33kPa) and permanent wilting point (1500kPa) (USDA, NRCS, 1995) as described by Klute (1986). Soil pH was determined in a 1:1 soil/water ratio and the saturation extract was also used to obtain electrical conductivity. Exchangeable bases (Ca, Mg, K, Na) were determined using NH_4OAc saturation method and exchange acidity was obtained by methods described by Thomas (1982). Cation exchange capacity (CEC) was determined by neutral (pH 7.0) NH_4OAc saturation method (Rhoades, 1982). Base saturation percentage (BSP) and exchangeable sodium percentage (ESP) estimated by calculation, using proportion of exchangeable bases and exchangeable Na respectively to CEC in percentage. Organic carbon was determined by Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982), total nitrogen (TN) micro-Kjeldahl technique as described by Bremner and Mulvaney (1982) and available phosphorus (AP) by methods described in IITA (1979) laboratory manual.

Statistical analysis

Correlation analysis was conducted to determine the relationship between the soil properties. The data were analyzed using Statgraphic Centurion XV soft-ware package to determine the relationships between the various soil properties (Stat Point, 2005).

Soil classification

Soil classification was carried out according to the USDA system-*Soil Taxonomy* (Soil Survey Staff, 2010) and correlated with World Reference Base (WRB) for Soil Resources 2006 (FAO, 2006).

RESULTS AND DISCUSSIONS

Morphological properties

Soil properties generally varied more within morphological and physical properties than in chemical properties. The soil was moderately deep at upper slope position (68 cm depth) and deep at crest (LS 1) and middle slope (LS 3). Soil depth further increased to very deep (150 -152 cm) at lower slope (LS 4) and bottom slope (LS 5). This indicated that soil depth tend to increase across the toposequence, from upper arm to lower slope arm. Soil depth restriction in pedon LS 2 was due to underlying basement complex rock encountered at a depth of 68 cm. This may also be attributed to increase in slope gradient on upper slope position resulting in surface wash of soils than on the crest position that was nearly level (0 - 2 % slope). The very deep soils encountered in pedons LS 4 and LS 5 at lower and bottom slope respectively were attributed to transportation of eroded loessial material from upper slope position to depression areas (LS 4 and LS 5). Soils were dominantly silt loam texture in the surface horizon and clay loam in subsoil horizons, thus reflecting aeolian deposition of silts in the surface soils of the study area. Dominance of clay loam in subsurface horizons was attributed to illuviation of clay into the subsoils giving rise to pronounced argillic horizons which characterize most Nigerian Guinea savanna soils that have undergone some extent of development (Esu, 1982). Blocky structure dominated in the soils across the toposequence and structural development increased along the slope from crest to bottom slope, except for massive structure observed in BC horizon in the midslope where there was lithologic discontinuity attributed to the presence of underlying basement complex parent material. Soil drainage condition was poor in Pedons LS 4 and LS 5, but improved from midslope to crest position being moderate to well drain respectively. The variation in drainage condition was attributed to the influence of topography and increase in clay content down the slope. The poorly drained status in soils on lower and bottom slopes may be improved by incorporation of organic matter and ridge cultivation. Horizonation was observed to be more pronounced between surface horizons and subsurface horizons than within subsoil (B horizons) due to melanization in the surface (Ap) horizon and was less pronounced in the bottom slope (Pedon LS 5) compared to other pedons in the slope due to continuous addition of material to the bottom slope.

Physical properties

Soil physical properties are presented in Table-1. Silt dominated the particle size fraction of the fine earth (<2mm) portion of the soils, except in crest slope soils (Pedons LS 1) where sand dominated and was attributed to surface wash of medium to fine particles from the crest slope position and moved down the slope. Silt content varied between 22 and 65%, with highest value in the surface horizon of each pedon, indicating its aeolian means of transportation from its origin (Soil Survey Division Staff, 1993). The high silt content in these soils is in agreement with the fact that loess material is predominantly of silt size (Amusan *et al*., 1995; Soil Survey Division Staff, 1993; Schumacher *et al*., 1987). Silt content increased down the slope in both surface and subsurface horizons, whereas sand content decreased in the same direction. Clay illuviation was more pronounced in Pedons LS 2 and LS 3 (upper and middle slopes respectively), and it was attributed to slope angle and drainage which facilitated erosion, translocation and illuviation of clay. Clay content of surface horizon increased from crest to bottom slope and was attributed to alluvial deposition process. Silt/clay ratio ranged between 0.88 and 6.25 with higher values in surface horizons compared to subsurface horizons. The higher values in the surface horizons (3.26 to 6.25) were rated extremely high (Sombroek and Zonneveld, 1971). The surface values indicated recent aeolian deposition of silt (loessial material) that had less weathering compared to subsurface horizons and it was due to annual enrichment of surface horizons from harmattan dusts. Bulk density of the soils ranged between 1.26 and 1.67 Mgm^{-3} with higher values in surface soils than in the subsurface horizons and may be attributed to crust formation as also reported by other researchers in Guinea Savanna of Nigeria and Central Louisiana in United State of America (Switzer and Pettry, 1992; Schumacher *et al*., 1987; Kowal and Knabe, 1972; Lawes, 1962). This influenced the pattern of total porosity being low in surface soils. Available water holding capacity ranged between 6.30 and 18.30% and was considered to be adequate to support most plant growth, except for the surface horizons of Pedons LS 1, LS 2 and LS 3 (Crest to middle slope) which were less than the critical value of 9.00% (USDA, NRCS, 1995; FAO, 1979). The mean AWHC increased from crest to bottom slope and may be due to increase in clay content in the same direction, as clay particle increase micro-porosity and moisture retention. This was buttressed by the significant correlation between clay and AWHC (r = 0.600**). The low soil moisture retention capacity found in surface horizons of Pedon LS 1 and LS 2 could be improved through construction of bonded contour ridges which will reduce loss of water and soils through surface run off erosion (Odunze, 2006).

Chemical properties

The chemical properties of all the soils are presented in Table-2. Soil pH ranged between 4.9 and 5.8 and was rated as moderately to very strongly acid. Exchangeable bases and CEC were rated low to medium and low to high respectively based on the rating of Nigerian savanna soils by Enwezor *et al*. (1989) and Esu (1991). Cation exchangeable capacity increased from crest down the slope and was attributed to increase in clay content also with movement along the slope downward. (r = 0.763**). Exchangeable calcium, magnesium, potassium and sodium were all low to medium (Enwezor *et al*., 1989; Esu, 1991). Exchangeable bases occurred in the order Ca > Mg > K > Na. Cation exchange capacity increased from crest to bottom slope and was related to pattern of increase in clay (r = 0.763**). However, base saturation decreased along the slope downward, and was rated moderate for soils on lower slope to crest and low for soil on bottom slope. It may be attributed to leaching of bases due to impeded drainage in the lower slope positions in the loess soils (Pedons LS 4 and LS 5).

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Table-1. Morphological and physical properties of pedons of the study area.

Horizon	Depth (cm)	Munsell Colour (Moist)	Texture	Structure	Gravel (gkg^{-1})	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Si/C ratio	Bulk Density Mgm^{-3}	AWHC %
Profile - LS 1	**Crest slope**		**(Kanhaplic Haplustalf, fine loamy, mixed, subactive,isohyperthermic)**								
Ap	0-14	10YR 4/4	Gravelly SandyLoam	2csbk	20	53	36	11	3.27	1.67	8.90
Bt	14-35	10YR 5/6	Gravelly Loam	2csbk	25	43	36	21	1.71	1.49	10.30
BC1	35-67	10YR 5/6	Grav.Sandy Clay Loam	0m	26	49	26	25	1.04	1.48	9.60
BC2	67-113	10YR 5/8	Grav.Sandy Clay Loam	0m	25	53	22	25	0.88	1.62	15.20
Profile - LS 2	**Upper slope**		**(Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic)**								
Ap	0-15	10YR 4/4	Silt Loam	1csbk	0	41	50	8	6.25	1.56	6.40
Bt	15-37	10YR 5/6	Clay Loam	1csbk	0	27	42	31	1.35	1.48	9.10
Bt2	37-68	10YR 5/6	Clay Loam	1csbk	0	25	38	37	1.02	1.41	15.90
Profile - LS 3	**Middle slope**		**(Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic)**								
Ap	0-11	10YR 5/6	Silt Loam	2csbk	5	37	51	12	4.25	1.51	6.30
Bt1	11-25	10YR 5/8	Clay Loam	2csbk	0	31	38	31	1.23	1.46	11.10
Bt2	25-48	10YR 5/6	Clay Loam	2csbk	3	25	36	39	0.92	1.26	9.40
2BC1	48-76	10YR 5/8	Grav.Clay Loam	0m	40	35	32	33	0.96	1.31	9.90
2BC2	76-93	10YR 6/6	Clay Loam	0m	10	35	32	33	0.96	1.54	9.60
2BC3	93-125	10YR 6/4	Clay Loam	0m	16	37	32	31	1.03	1.55	14.50
Profile - LS 4	**Lower slope**		**(Kanhaplic Haplustalf, fine silty, mixed, semiactive, isohyperthermic)**								
Ap	0-13	10YR 3/3	Silt Loam	1csbk	0	35	50	15	3.33	1.48	13.80
Bt1	13-29	10YR 3/4	Loam	2csbk	5	31	42	27	1.56	1.46	12.20
Bt2	29-43	10YR 5/6	Clay Loam	2csbk	0	21	40	39	1.03	1.40	12.50
Bt3	43-71	10YR 5/6	Silt Clay	0m	0	15	42	43	0.97	1.33	17.20
2BC1	71-97	10YR 5/4	Grav.Clay Loam	0m	30	27	36	37	0.97	1.52	15.60
2BC2	97-150	10YR 5/4	Clay Loam	0m	2	41	22	31	0.71	1.53	15.10
Profile - LS 5	**Bottom slope**		**(Typic Haplustult, fine silty, mixed, semiactive, isohyperthermic)**								
Ap	0-23	10YR 4/4	Silt Loam	2csbk	0	17	65	18	3.61	1.40	14.30
Bt1	23-52	10YR 5/6	Silt Clay Loam	1csbk	0	11	58	31	1.87	1.40	10.30
Bt2	52-83	10YR 5/4	Silt Clay	2csbk	0	7	50	43	1.16	1.42	18.30
Bt3	83-152	10YR 6/2	Silt Clay	2csbk	0	7	50	43	1.16	1.49	16.80

Table-2. Chemical properties of soils of the study area.

Horizon	Depth (cm)	pH H_20	Exchangeable Bases Ca	Mg	K	Na	TEB	TEA	CEC	CEC (Clay)	BS	ESP	EC	OC	TN	AP
			(-------------------			cmol(+)kg^{-1}				---------)	(-----%-------)		dSm^{-1}	(---gKg^{-1}	---)	(mgKg^{-1})
Profile - LS 1	**Crest slope**		**(Kanhaplic Haplustalf, fine loamy, mixed, subactive, isohyperthermic)**													
Ap	0-14	5.6	1.58	0.21	0.18	0.07	2.04	0.30	4.9	18.5	42	1.40	0.045	8.18	0.70	15.6
Bt	14-35	5.7	2.18	0.44	0.14	0.07	2.83	0.40	4.8	13.9	59	1.50	0.036	5.39	0.88	1.6
BC1	35-67	5.7	2.18	0.44	0.50	0.15	3.27	0.65	6.9	22.9	47	2.20	0.033	3.39	0.35	2.7
BC2	67-113	5.1	2.70	0.56	0.14	0.08	3.48	1.15	7.7	28.3	45	1.10	0.037	1.80	0.70	0.5
Profile - LS 2	**Upper slope**		**(Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic**													
Ap	0-15	5.8	1.16	0.31	0.16	0.07	1.70	0.45	3.7	14.8	46	1.90	0.060	7.18	0.35	2.7
Bt	15-37	5.0	2.18	0.40	0.10	0.07	2.75	0.70	6.8	17.2	40	1.00	0.016	4.19	0.35	0.5
Bt2	37-68	4.9	2.40	0.52	0.12	0.11	3.15	1.20	8.8	21.1	36	1.30	0.018	2.79	0.53	1.6
Profile - LS 3	**Middle slope**		**(Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic)**													
Ap	0-11	5.5	1.05	0.19	0.12	0.05	1.41	0.40	6.9	20.8	20	0.70	0.050	5.79	1.23	9.6
Bt1	11-25	5.5	2.40	0.31	0.09	0.07	2.87	0.20	6.9	15.5	42	1.00	0.025	5.99	0.35	2.7
Bt2	25-48	5.2	3.04	0.48	0.09	0.07	3.68	0.25	8.8	17.5	42	8.00	0.025	5.59	0.88	1.6
2BC1	48-76	5.2	2.18	0.34	0.10	0.07	2.69	0.70	7.4	18.0	36	1.00	0.025	4.19	0.88	1.6
2BC2	76-93	5.3	1.73	0.68	0.09	0.06	2.56	0.30	8.6	23.7	30	0.70	0.030	2.19	0.35	2.1
2BC3	93-125	5.5	1.88	0.56	0.16	0.09	2.69	0.45	6.5	18.5	41	1.40	0.006	2.19	0.53	1.1
Profile - LS 4	**Lower slope**		**(Kanhaplic Haplustalf, fine silty, mixed, semiactive, isohyperthermic)**													
Ap	0-13	5.6	2.70	0.56	0.16	0.07	3.49	0.40	7.2	21.0	48	1.00	0.060	11.57	0.88	8.4
Bt1	13-29	5.4	2.70	0.56	0.11	0.06	3.43	0.25	8.4	21.0	41	0.70	0.024	7.78	0.70	2.7
Bt2	29-43	5.4	2.40	0.63	0.12	0.06	3.21	0.40	8.7	16.2	37	0.70	0.023	6.78	0.70	2.7
Bt3	43-71	5.4	2.70	0.68	0.12	0.06	3.56	0.45	9.6	19.2	37	0.60	0.023	3.79	0.35	1.6
2BC1	71-97	5.1	2.40	0.63	0.13	0.06	3.22	0.40	9.6	19.2	37	0.60	0.023	1.80	0.53	1.6
2BC2	97-150	5.6	3.38	0.94	0.26	0.08	4.66	0.35	10.7	33.4	44	0.80	0.017	1.00	0.18	0.5
Profile - LS 5	**Bottom slope**		**(Typic Haplustult, fine silty, mixed, semiactive, isohyperthermic)**													
Ap	0-23	5.2	2.18	0.68	0.15	0.07	3.08	0.10	7.9	30.3	39	0.90	0.030	6.98	0.88	6.6
Bt1	23-52	5.1	1.58	0.68	0.12	0.09	2.47	0.80	7.7	30.8	32	1.20	0.015	3.60	0.53	2.1
Bt2	52-83	5.3	1.88	0.94	0.23	0.11	3.16	1.10	13.1	28.2	24	0.80	0.020	2.79	0.70	1.1
Bt3	83-152	5.2	1.88	0.94	0.41	0.12	3.35	2.15	13.7	30.7	24	0.90	0.014	1.40	0.35	1.6

Organic carbon, total nitrogen and available phosphorus contents were all rated low and ranged between 1.00 and 11.57 gkg^{-1}, 0.18 and 1.23 gkg^{-1} and 0.5 and 15.6 mgkg^{-1} respectively (Table-2). The soils decreased in OC, TN and AP with increase in soil depth and was reflected in the significant correlation with TN and AP (r = 0.483*, 0.643**). This indicated that organic matter highly contributed to TN and AP in the soils. The generally low OC, TN and AP content of these soils may be due to low vegetation in the area along with annual cultivation without incorporation of crop residue into the soils. Other researchers attributed the low organic carbon content to continuous cultivation without fallow, bush burning, high rate of mineralization due to high temperature and crop removal for livestock feeding, fuel wood, fencing and building purposes (Odunze, 1998; Bownan *et al*., 1990). For optimum nutrient supply for crops, maximum doses of nitrogen and phosphorus from inorganic fertilizers should be applied to increase crop productivity. Incorporation of farm yard manure and crop residues is recommended to build organic matter as nutrient reservoir and improve drainage conditions of the soils. The incorporation of organic matter would also buffer soil CEC, hence increase nutrient retention.

Soils classification

All the soils were characterized by ochric epipedon as either too light in colour, too low in organic carbon content, too shallow to be mollic, umbric, histic or plaggen epipedon by USDA *Soil Taxonomy* System (Soil Survey Staff, 2010). The diagnostic subsurface horizon had argillic horizons and moderate base saturation (>35%), except for Pedon LS 5 that was low in base saturation. The prevailing soil moisture regime is ustic and soil temperature regime is isohyperthermic. Therefore, at the order level, the soils were classified as Alfisols, except for Pedon LS 5 which was classified as Ultisol. Pedons LS 1, LS 2, LS 3 and LS 4 were classified as Ustalfs at the suborder level, whereas, Pedon LS 5 Ustult because of the ustic moisture regime.

Pedons LS 1, LS 2, LS 3 and LS 4 were classified as Haplustalfs because they had no plinthite that constitutes one half or more of the horizons within 150cm of the mineral soil surface, and do not meet the conditions required for classification of the other great groups of Ustalfs. Pedons LS 1, LS 2, LS 3 and LS 4 were classified as Kanhaplic Haplustalfs because they had CEC of less than 24 cmol (+) kg^{-1} of clay. Pedon LS 5 at the bottom slope was classified as Typic Haplustalf being that it fits the core definition of Haplustalf subgroup and had CEC of greater than 24 cmol (+) kg^{-1} of clay. The detailed USDA Soil Taxanomic classification at the Family level and the World Reference Base (WRB) 2006 correlation for soils of the toposequence is presented in Table-3. The WRB correlation showed that soils at the crest to lower slope were Haplic Acrisols, whereas at the bottom of the slope the soil was Haplic Alisol, indicating that the soil is dominated by high activity clay (FAO, 2006).

Table-3. Summary of soil classification by USDA soil taxonomy and WRB 2006 of the study area.

Pedon	Slope position	USDA	WRB 2006
LS 1	Crest	Kanhaplic Haplustalf, fine loamy, mixed, subactive, isohyperthermic	Haplic Acrisol.
LS 2	Upper	Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic	Haplic Acrisol.
LS 3	Middle	Kanhaplic Haplustalf, fine silty, mixed, subactive, isohyperthermic	Haplic Acrisol.
LS 4	Lower	Kanhaplic Haplustalf, fine silty, mixed, semiactive, isohyperthermic	Haplic Acrisol.
LS 5	Bottom	Typic Haplustult, fine silty, mixed, semiactive, isohyperthermic	Haplic Alisol.

CONCLUSIONS

The study of the properties of loess soils along a toposequence at Funtua Northern Guinea savanna showed that landscape position, erosion and drainage significantly influenced variation in soil depth, particle size distribution, AWHC, exchangeable bases, CEC and base saturation. The soils were low to medium in exchangeable bases (Ca, Mg, K and Na) and BSP, low to high for CEC and low for organic carbon, total nitrogen and available phosphorus. Silt particle dominated particle sizes, except at crest position. Clay distribution significantly influenced variation in content of AWHC, exchangeable bases and CEC (r = 0.600**, 0.539** and 0.763**, respectively). Organic carbon significantly correlated with total nitrogen and available phosphorus; hence soil management involving use of organic matter will improve soil condition and their fertility for crop production. Pedogenic processes resulted in silt, clay, AWHC and CEC enrichment at lower and bottom slope positions and sand was high at the crest slope position.

Toposequence effect was not only on soil properties, but varied soil classification as Kanhaplic Haplustalfs for soils on crest to lower slope and soil on bottom slope as Typic Haplustult according to USDA *Soil Taxonomy*. The soils were also classified as Haplic Acrisols and Haplic Alisol respectively according to WRB 2006 (FAO, 2006).

REFERENCES

Adeoye K.B. 1983. Water movement studies in a ferruginous tropical soil at Samaru, Nigeria. I. Determination of Hydraulic properties. Nigeria Journal of Soil Science. 4: 53-68.

Akintola J.O. 1986. Rainfall distribution in Nigeria. 1892-1983. Impact Publishers (Nig.) Ltd. Ibadan, Nigeria. p. 380.

Amusan A.A., Oyedele D.J., Adepetu J.A. and Aina P.O. 1995. Characterization and management of soil developed in Eolian material in Northern Guinea Savanna of Nigeria. African Soils. 28: 79-99.

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Bennett J.G., Rains A.B., Gosen P.N., Howard W.J., Hutcheon A.A., Kerr W.B., Mansfield J.E., Rackmann L.R. and Innes R.R. 1979. Land Resources of Central Nigeria. Agricultural Development Possibilities. Vol. 5B. The Kaduna Plains. LRD, Tolworth Tower, Survey, England. p. 130.

Blake G.R. and Hartge K.H. 1986. Bulk density. In: Klute (Eds). Methods of soil analysis, Part 1: Physical and Mineralogical methods. 2nd Ed. ASA, SSSA. Madison, WI. pp. 377-382.

Bownan R.A., Reeder J.D. and Lober R.W. 1990. Changes in soil properties in a central plain rangeland soil after 3, 20 and 60 years of cultivation. Soil Science. 150: 851-857.

Bremner J.M. and Mulvaney C.S. 1982. Nitrogen-Total. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds). Methods of Soil Analysis. Part 2 Agron 9. Madison WI. pp. 595-624.

Brunner A.C., Park S.J., Ruecker G.R., Dikau R. and Vlek P.L.C. 2004. Catenary soil development influencing erosion susceptibility along hillslope in Uganda. Catena. 58(1): 1-22.

Buol S.W., Hole F.D., Mc Cracken R.J. and Southard P.J. 1997. Soil genesis and classification. 4th Edn. Iowa State University Press. p. 527.

Daniels R.B., Gamble E.E. and Chapman H.D. 1971. The relation between geomorphology, morphology and genesis. Advances in Agronomy. 23: 51-88.

Enwezor W. O., E. J. Udo, N.J. Usoroh, K.A. Ayotade, J.A Adepetu, V.O. Chude and C.E Udegbe. 1989. Fertilizer use and management practices for crops in Nigeria. Series No. 2 Federal Ministry of Agric. Water Resources and Rural Development. Lagos. p. 163.

Esu I.E. 1982. Evaluation of soils for irrigation in the Kaduna Area of Nigeria. Unpublished Ph.D. Thesis. A.B.U. Zaria, Nigeria. p. 305.

Esu I.E. 1991. Detail soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. IAR, ABU Zaria. p. 72.

Esu I.E., Ibanga I.J. and Lombin G. 1987. Soil- landscape relationships in the keffi plains of Northern Nigeia. Samaru Journal of Agricultural Research. 5: 109-123.

FAO. 1979. Soil survey for irrigation. Soil Bulletin, No. 42. FAO, Rome, Italy. p. 188.

FAO. 2006. World reference base for soil resources 2006 A framework for international classification, correlation and communication. World Soil Resources Reports 103. p. 128.

Gee G.W. and Bauder J.W. 1986. Particle size analysis. In: Klute, A. (Eds). Methods of soil Analysis, Part 2: Chemical and Microbiological properties. 2nd Ed. Agron. Monograph 9. ASA and SSSA, Madison, WI, USA.

Gessler P.E., Chadwick O.A., Chamran F., Althouse L. and Holmes K. 2000. Modelling soil-landscape and ecosystem properties using terrain attributes. Soil Science Society of America Journal. 64: 2046-2056.

IITA. 1979. Selected methods for soils and plant analysis. International Institute of Tropical Agriculture. Manual Series. 1: 70.

Klute A. 1986. Water retention. Laboratory methods. In: Klute (Eds). Methods of soil analysis, Part 1: Physical and Mineralogical methods. 2nd Ed. ASA, SSSA. Madison, WI. pp. 635-662.

Kowal J.M. and Knabe D.T. 1972. An agroclimatological Atlas of Northern States of Nigeria. First edition. ABU Press Zaria. p. 111.

Lawes D.A. 1962. The influence of rainfall conservation on the fertility of loess plain of Northern Nigeria. Nigeria Geographical Journal. 5: 33-38.

Malgwi W.B. 1979. A study of soil in the high plains of Hausaland, Samaru, Zaria, Nigeria. Unpublished M.Sc. Thesis. ABU Zaria, Nigeria. p. 156.

Maniyunda L.M., Kparmwang T., Raji B.A. and Yaro D.T. 2007. Land suitability evaluation of Haplustults for rainfed crop production in A Sub-Humid environment of Nigeria. Proceedings of the 31st Annual Conf. of Soil Sci. Society of Nigeria, NAERLS, ABU, Zaria, Nigeria 13th - 17th November, 2006. pp. 60-66.

Mc Curry P. 1973. Geological degree sheet 21, Zaria Nigeria. Overseas Geology and Mineral Research. 45: 36.

Nelson D. W. and Sommers L.E. 1982. Organic carbon. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds). Methods of Soil Analysis. Part 2 Agron 9. Madison WI. pp. 538-580.

Odunze A.C. 1998. Soil management strategy under continuous rainfed-irrigation agriculture. Proceedings of the 12th National Irrigation and Drainage Seminar. Irrigation in sustainable Agriculture. 14 -16th April, IAR, ABU, Zaria, Nigeria. pp. 178-186.

Odunze A.C. 2006. Soil properties and management strategies for some sub –humid savanna zone Alfisols in Kaduna State, Nigeria. Samaru Journal of Agricultural Research. 22: 3-14.

Ovalles F.A. and Collins M.E. 1986. Soil-landscape relationship and soil variability in north central Florida. Soil Science Society of America Journal. 50: 401-408.

ARPN Journal of Agricultural and Biological Science

Rhoades J.D. 1982. Cation exchange capacity. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds). Methods of Soil Analysis. Part 2 Agron 9. Madison, WI. pp. 149-157.

Schumacher B.A., Miller B.J. and Day W.J. 1987. A chronotoposequence of soils developed in loess in Central Louisiana. Soil Science Society of America Journal. 51: 1005-1010.

Soil Survey Staff. 2010. Soil Taxanomy. A basic system of soil classification for making and interpreting soil surveys. 2nd Edition. Agric. Handbook. No. 436. U.S. Gov. Print., Office. Washington, DC., USA. p. 346.

Soil Survey Division Staff. 1993. Soil Survey Manual. Agric. Handbook. No. 18. U.S. Gov. Print. Office. Washington, DC. Handbook. 18: 437.

Sombroek W.G. and Zonneveld I.S. 1971. Ancient dunefields and fluviatile deposits in Rima-Sokoto River Basin (NW Nigeria). Soil Survey Paper No. 5. Soil Survey Inst. Wageningen. The Netherlands. p. 109.

StatPoint. 2005. The User's Guide to STATGRAPHIC Centurion XV. (www.statgraphic.com.).

Switzer R.E. and Pettry D.E. 1992. Phosphorus distribution in loessial soil parent material in North West Oregon. Soil Science Society of America Journal. 56: 849-856.

Thomas G.W. 1982. Exchangeable cations. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds). Methods of Soil Analysis. Part 2 Agron 9. Madison, WI. pp. 159-165.

USDA, NRCS (United States Department of Agriculture, Natural Resources Conservation Service). 1995. Soil survey laboratory information manual. National Soil Survey Center, Soil Survey Laboratory Lincoln, Nebraska. Soil Survey Investigation Report No. 45 version 1.0 May 1995. pp. 50-61.

Young F.J. and Hammer R.D. 2000. Soil-landform relationships on a loess-mantled, upland landscape in Missouri. Soil Science Society of America Journal. 64: 1443-1454.