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Variation in Some Physical Properties of Soils Formed on a Hilly Terrain under Different Land use Types in Nigerian Savanna

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ABSTRACT

Physical properties of soils formed on a hilly terrain were investigated in three identified landscape positions (upper, middle and lower positions) under two land use types (Fallowed and Cultivated land). Three soil profile pits were dug randomly in each landscape position, described and samples were taken from each horizon for laboratory analysis. SAS 8.2 and SPSS 16.0 were used to analize data. Mostely in detail showed significant differences in soil properties among the land use types, landscape positions (except in clay dispersion index) and pedons. Fallowed compared to continuously cultivated land got significantly higher values of silt and clay, organic carbon, aggregate stability indices, pore size classes and water retention capacities. Significantly ($p<0.0001$) higher sand fraction, macroaggregate stability, BD and lower water retention capacities were recorded at the upper landscape position compared to the other positions. The lower landscape position compared to the other positions got significantly ($p<0.0001$) higher silt and clay fractions, microaggregate stability indices, porosity, OC and water retention characteristics. The epipedons compared to the endopedons of the soils had significantly ($p<0.0001$) higher organic carbon, aggregate stability indices, pore size classe and moisture retention at various capacities. Of the three factors, the distribution of pore size classes (except macroporosity), BD and water retained at various capacities were to a greater extent influenced by changes in landscape positions whereas the distribution of OC and aggregate stability of the soils were more dependant on changes in land use.

Key words: Fallow, continuous cultivation, toposequense, pedons, physical properties

INTRODUCTION

Soil properties vary in vertical and lateral directions and such variation follow systematic changes as a function of the landscape position (slope), soil forming factors and/or soil management practices (land use) (Amusan *et al*., 2006; Mbagwu and Auerswald, 1999). Land use patterns are often highly correlated with bio-physical variables such as slope and elevation gradients (Overmars and Verburg, 2005; Mottet and Ladet, 2006; Reginster and Rounsevell, 2006). Inappropriate land use can aggravate the rate of soil degradation affecting soil biological and physico-chemical qualities (Saikh *et al*., 1998).

Landscape influences soil texture, penetration resistance (Bruand *et al.,* 2004) root development (Busscher *et al*., 2001) exchangeable basic and acidic cations (Stutter *et al*., 2004), soil exchange chemistry (Chien *et al*., 1997) and nutrient budget (Mallarino, 1996) hence important in fertilizer management (Paz-gonzalez *et al*., 2000).

The Nigerian savanna is made up of four ecological zones namely: Southern Guinea (SG), Northern Guinea (NG), Sudan (Su) and Sahel (Sa) Savanna. These agro-ecological zones cover an area of about 700,000 km^2. The whole of the Savanna covers about three quarters of Nigeria's total land area. The soils are characterized by low activity clay with kaolinite and sesquioxides (FeOH) forming 80-90% of clay fraction (Moberg and Esu, 1991) and highly weathered with soil types ranging from loamy sand to sandy loam in the top. The greater amount of kaolinite and sesquioxides leads to the lower CEC of the soils (Enwezor *et al.*, 1990).

In Nigeria, bush fire deforestation, increasing intensity of cultivation (Senjobi *et al.*, 2007), tillage related practices (Lal, 1986; Khurshid *et al.*, 2006), low input agriculture, accelerated erosion (Fahnestock *et al.*, 1995) and construction work are summarized as causes of land degradation.

The twin problems of population explosion and arable land scarcity in Nigeria are already driving more people to intensify farming on the highland. The Northern Savanna region of Nigeria is characterized by these problems.

Steep land research had previously been neglected because of their marginal agricultural crop returns. This lack of research does not imply such land is not extensively being cultivated. The pressure of expanding agricultural activities into steep lands makes research on them more pressing. Research activities on such physiographic outlay under different land use types in Nigerian Northern Guinea Savanna are not documented. A good knowledge of the spatial variability of soil as it relates to topography and land use is essential for good land evaluation, which is a prerequisite for sound land use planning (Amusan *et al.*, 2006). Based on the above, the objectives of this study were:

- To evaluate the changes in composition and vertical and spatial distribution of physical properties under various land use types and landscape positions
- To establish how the relationship between the various land use types, landscape positions and pedons as well as between selected variables influence soil physical properties

MATERIALS AND METHODS

Site description: The study was carried out in 2008/2009 on a fallowed and continuously cultivated hilly landscape in Nigerian Northern Guinea Savanna at Dumbi village. It lies between latitude 10° 58.675' N and longitute 7° 38.775' E. Tropical wet and dry climate prevails in the area with long-term mean annual rainfall of 1312 mm. The mean monthly maximum and minimum temperatures were 38.1°C by April and 16°C by January, respectively. The survey area geomorphologically consists of gently undulating plain of low relative relief to hill ranges on the plain. It is underlain by the Precambrian Basement Complex. The dominant rock types include granites and grandiorites, gneisses, migmatitis and syntites. Coluvial-alluvial materials are generally associated with the valley bottom land (Fadama). A schematic representation of the toposequense under study is shown in Fig. 1.

Field study: Five landscape positions namely: crest (0-2%), scarp face (7-12%), upper (2-4%), middle (1-2%) and lower (0-1%) positions were identified using Abney Level. Slope measurements were carried out along the toposequence starting from the crest to the lower landscape position across fallowed and cultivated lands. Three soil profile pits were dug in randomly selected sites in each landscape position (except the crestal and scarp face areas) and the morphological

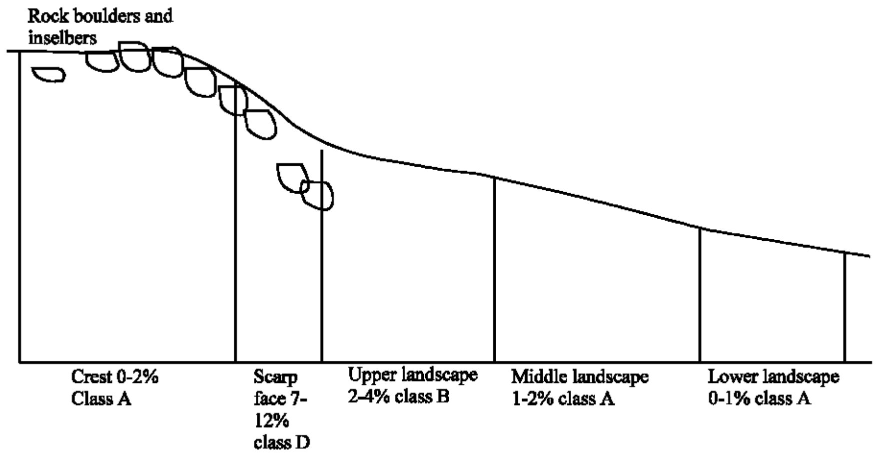

Fig. 1: Schematic cross profile of the study area (Dumbi)

characteristics were described according to the USDA Soil Taxonomy (Soil Survey Staff, 1999; FAO-UNESCO, 1990). Bulk and core samples were taken from each genetic horizon (pedon) for laboratory analysis totalling 132 samples.

Laboratory study: Samples for MWD were air-dried and passed through a 4.75 mm sieve while those for micro aggregate stability indices, water retention and OM were sieved with a 2 mm sieve after air-drying. Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). For micro aggregate stability, this involved the determination of the amounts of silt and clay in calgon-dispersed as well as water-dispersed samples using Bouyoucos hydrometer method of particle size analysis described by Gee and Or (2002). Mean weight diameter was determined by the wet-sieving method of Kemper and Rosenau (1986). Water-Stable Aggregates (WSA) was estimated as percentages of the original mass. MWD of WSA was calculated as:

$$\mathrm{MWD} = \sum_{i=1} X_i W_i \quad (1)$$

where, X_i is the mean diameter of the ith sieve size and W_i is the proportion of the total aggregates in the ith fraction.

Soil Organic Ocarbon was determined by the Walkley-Black as described by Allison (1965). Water retained at Field Capacity (FC) and Permanent Wilting Point (PWP) was determined by saturation water percentage-based estimation models of Mbagwu and Mbah (1998):

$$\mathrm{FC} = 0.79\ (\mathrm{SP})\text{-}6.22\ (r = 0.972) \quad (2)$$

$$\mathrm{PWP} = 0.51\ (\mathrm{SP})\text{-}8.65\ (r = 0.949) \quad (3)$$

where, FC and PWP are the field capacity (%) and permanent wilting point (%), respectively and SP is the saturation water (%); Available Water Capacity (AWC) was computed as the difference between moisture retained at FC and PWP.

SP was then calculated as follows:

$$SP = 100 \times [(M^{\theta} + (Msa - Mso))/Mso] \tag{4}$$

Where:

$$Mso = 100 \times [Msa/(100 + \theta r)] \tag{5}$$

θr is the air-dry (residual) moisture percentage, M^{θ} is the mass of water absorbed (g), Msa is the mass of air-dry soil (g) and Mso is the mass of oven dry soil.

Bulk Density was determined using the core method as described by Anderson and Ingram (1993). Total porosity (P_t) was calculated from B_D values as follows:

$$P_t = [1-(B_D/P_D)] \times 100, \tag{6}$$

where P_D is particle density

Macroporosity (P_{mac}) and Microporosity (P_{mic}) were computed as follows:

$$P_{mac} = P_t - FC \tag{7}$$

$$P_{mic} = P_t - P_{mac} \tag{8}$$

Data analyses: Soil data were subjected to factorial Analysis of Variance (ANOVA) using SAS 8.2 and SPSS 16.0 computer programme. Significantly different means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability. Linear regression and Pearson correlation analysis were performed to determine the significantly related factors and variables.

RESULTS

Soil morphology: Morphological features of studied soils are shown in Table 1, indicating well drained, greyish brown, weak, medium structured and thin epipedons (0-3 cm) at the upper landscape position. The epipedons at the middle and lower positions were brown in color. At the middle position, it was well drained, moderate, medium, subangular blocky structured while it was poorly drained and weak, fine, granular-structured tending massive at the lower.

The endopedon at various landscape positions varied from brown to light brownish gray, reddish yellow and dark brown colours and from moderate, medium, subangular blocky structured to structureless (massive) at various pedal depths. The colours of endopedons at upper and middle landscape positions indicate that they are more oxidized at shallower depth than at deeper. The soils at upper landscape position were shallow whereas those at middle and lower levels were deep. The endopedon was generally poorly drained.

Variability in depth of soils could be as a result of colluviation although in a similar landscape in Sweden, Allen (2002) attributed it to vertical schistosity. Colour changes in the study site could be due to differences in physiographic position and drainage status since all the soils originated from the similar parent material (saprophyte).

Particle size distribution: Results on particle size distribution are presented in Table 2, showing that the land use types ($p = 0.0034$), landscape positions ($p = 0.0002$) and pedons

Table 1: Selected Soil morphological features at various landscape positions

Landscape position (% slope)	Horizon	Depth (cm)	Colour (moist)	Structure	Artifacts	Consistency	Drainage
Upper (2-4%)	AP	0-13	GB 10YR 5/2	2 m sabk	fw m rt	fr	WD
	AB	13-42	B 7.5YR 5/4	2 m sabk	Nil	F vst vp	WD
	Bt	42-80	LBG 10YR 6/2	0 ma	fw sic	F vs vp	PD
Middle (1-2%)	AP	0-10	5/3, 4/4	2 m sabk	C f m rt	fr F stp	WD
	B1	10-30	RY 5YR 5/6	2 m sabk	C m rt	F vst vp	WD
	B2t1	30-70	RB 2.5YR 5/6	2 m sabk	fw f rt	F vst vp	WD
	B2t2	70-150	DB 7.5YR 5/6	0 ma	fw f fa mo	F vst vp	PD
Lower (0-1%)	A	0-12	B 10YR 5/3	1fgr	Mn f m rt	F vst vp	IPePD
	AB	12-42	RB 5YR 4/6	v0 m sabk	Nil	F vst vp	IPePD
	2C	42-120	GB 10YR 5/2	0 ma	Nil	F vst vp	PD
	2C0	120-150	GB 10YR 5/2	0 ma	Nil	F vst vp	PD

GB: Grayish brown, LBG: Light brownish gray, RY: Reddish yellow, RB: Reddish brown, DB: Dark brown 0 = Structureless, 1 = Weak, 2 = Moderate, f: Fine, gr: Granular, m: Medium, ma: Massive, sabk: Subangular blocky, fw: Few, s: Soft, I: Iron, c: Concretions, C: Common, fa: Faint, mo: Mottle, Mn: Many, v: Very, fr: Friable, F: Firm; st: Sticky, p: Plastic, WD: Well drained, PD = poorly drained, IPePD = imperfectly or poorly drained

Table 2: Particle size distribution as influenced by land use types, landscape positions and pedons

Results	Sand	Silt	Clay	Textural class
	----------(%)----------			
Land use types				
FL	37.3b	33.8a	28.9a	CL
CC	43.6a	30.1b	26.4b	L
Critical range	1.700	1.058	1.602	-
Pr	<0.0001	<0.0001	0.0034	
Landscape positions				
ULP(2-4%)	46.4a	29.6b	23.9b	L
MLP(1-2%)	42.3b	29.3b	28.5a	CL
LLP(0-1%)	34.1c	36.4a	29.5a	CL
Critical range	2.210	1.375	2.082	-
Pr	<0.0001	<0.0001	0.0002	
Pedons				
Epipedon	54.8a	24.8b	20.6c	SaCL
Endopedon1	38.3b	33.8ab	27.8b	CL
Endopedon2	33.9c	34.4ab	31.6a	CL
Endopedon3	32.0c	36.2a	31.8a	CL
Critical range	2.650	1.649	2.497	-
Pr	<0.0001	<0.0001	<0.0001	-

FL: Fallow; CC: Continuous cultivation; ULP: Upper landscape position; MLP: Middle landscape position; LLP: Lower landscape position; SaCL: Sandy clay Loam; CL: Clay loam; L: Loam; CR: Critical range. All means followed by the same letter within a column are not significantly different at 5% probability level using the Duncan Multiple Range Test

($p<0.0001$) differences significantly influenced sand, silt and clay distribution. Continuously Cultivated land (CC), Upper Landscape Positions (ULP) and epipedon got the highest sand whereas Fallowed Land (FL) and Lower Landscape Position (LLP) got the highest silt and clay contents. Silt and clay contents increased with pedal depths. FL and CC had clay loamy and loamy texture, respectively. Loamy texture was observed at the ULP and clay loamy texture at the Middle Landscape Position (MLP) and LLP. Epipedon was sandy clay loam, while the endopedons were clay loamy textured.

Table 3: Changes in organic carbon and aggregate stability as influenced by land use types, landscape positions and pedons

Results	Organic carbon (g kg^{-1})	MWD (mm)	DR	CDI	CFI	ASC
			----------	---------- %	----------	----------
Land use types						
FL	5.9a	1.66a	47.8b	42.4b	55.3a	11.7a
CC	3.2b	1.20b	53.6a	45.2a	53.0b	10.2b
Critical range	0.386	0.046	0.300	0.295	0.233	0.231
Pr	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Landscape positions						
ULP(2-4%)	3.4c	1.58a	49.6c	44.0	53.4c	10.4c
MLP(1-2%)	4.3b	1.43b	50.6b	43.9	54.1b	10.9b
LLP(0-1%)	5.6a	1.32c	51.6a	43.7	54.7a	11.3a
Critical range	0.502	0.060	0.390	0.383	0.302	0.300
Pr	<0.0001	<0.0001	<0.0001	NS	<0.0001	<0.0001
Pedons						
Epipedon	6.8a	1.64a	49.5d	43.0c	54.8a	11.5a
Endopedon1	4.5b	1.55b	50.5c	43.7c	54.2b	11.0b
Endopedon2	3.7c	1.36c	51.1b	44.3ab	53.7c	10.6c
Endopedon3	2.9d	1.04d	52.1a	44.5b	53.6c	10.4c
Critical range	0.602	0.071	0.468	0.460	0.363	0.360
Pr	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

FL: Fallow; CC: Continuous cultivation; ULP: Upper landscape position; MLP: Middle landscape position; LLP: Lower landscape position; MWD: Mean weight diameter; DR: Dispersion ration; CDI: Clay dispersion index; CFI: Clay flocculation index; ASC = Aggregated silt and clay; CR: Critical range. All means followed by the same letter within a column are not significantly different at 5% probability level using the Duncan Multiple Range Test

Organic carbon and aggregate stability

Organic Carbon (OC): The Land Use Types (LUT), Landscape Positions (LP) and pedons significantly ($p<0.0001$) differed in OC (Table 3). The highest OC mean value (5.9 g kg^{-1}) was recorded in FL exceeding the value in CC by 54.2%. The values consistently increased with decrease in elevation (from 3.5 to 5.6 g kg^{-1}) and decreased with increase in PD (from 6.8 to 2.9 g kg^{-1}).

Aggregate stability: At macroaggregate level, measured by Mean Weight Diameter (MWD), FL was better than CC (Table 3). Comparing the landscape positions, the value was significantly higher at the LLP than the one at the other positions. The epipedon recorded significantly higher MWD than the endopedon at various depths.

The microaggregate status was measured by Dispersion Ratio (DR), Clay Dispersion Index (CDI), Aggregated Silt + Clay (ASC) and Clay Flocculation Index (CFI). The DR and CDI values were lower while the CFI and ASC were higher in FL than CC. The highest values of DR and CDI were recorded at ULP while CFI and ASC were observed at LLP. DR and CDI consistently decreased, while CFI and ASC increased with decrease in elevation. The epipedon recorded the lowest DR and CDI which consistently increased with depth while it recorded the highest CFI and ASC which consistently decreased through all endopedal depths.

Bulk density (B_d) and porosity characteristics

Bulk density: Significant ($p<0.0001$) differences in B_D were observed among the land use types, landscape positions and pedal depths (Table 4). Fallowed land had the lowest B_D (1.50 g cm^{-3}). The

Table 4: Changes in bulk density and pore size classes as influenced by land use types, landscape positions and pedons

Results	Bulk density (g cm^{-3})	P_t	P_{mac}	P_{mic}
		----------(%)----------		
Land use types				
FL	1.50b	43.4a	15.5a	27.9a
CL	1.59a	40.0b	14.6b	25.4b
Critical range	0.014	0.551	0.210	0.419
Pr	<0.0001	<0.0001	<0.0001	<0.0001
Landscape positions				
ULP(2-4%)	1.63a	43.5a	14.4c	24.1c
MlP (1-2%)	1.53b	42.4b	15.1b	27.2b
LLP(0-1%)	1.50c	38.5c	15.5a	28.0a
Critical range	0.018	0.716	0.272	0.543
Pr	<0.0001	<0.0001	<0.0001	<0.0001
Pedons				
Epipedon	1.49c	43.8a	15.5a	28.2a
Endopedon1	1.53b	42.4b	15.3a	27.1b
Endopedon2	1.59a	40.1c	14.7b	25.5c
Endopedon3	1.59a	40.0c	14.6b	25.3c
Critical range	0.021	0.859	0.327	0.651
Pr	<0.0001	<0.0001	<0.0001	<0.0001

FL: Fallow; CC: Continuous cultivation; ULP: Upper landscape position; MLP: Middle landscape position; LLP: Lower landscape position; P_t: Total porosity; P_{mac}: Macroporosity; P_{mac}: Microporosity; CR: Critical range. All means followed by the same letter within a column are not significantly different at 5% probability level using the Duncan Multiple Range Test

lower landscape position also had the lowest B_D value 0f 1.50 g cm^{-3} while the upper position got the highest value of 1.63 g cm^{-3}. Considering the pedons, the lowest B_D value was recorded at the epipedon (1.49 g cm^{-3}) which consistently increased with depth all through the endopedal depths.

Porosity characteristics: The land use types, landscape positions and pedons significantly ($p<0.0001$) varied in total porosity (P_t), macroporosity (P_{mac}) and microporosity (P_{mic}). Regarding the land use types, the highest values of the pore size classes were recorded in FL. Considering the landscape positions, the upper position got the highest P_t of 43.5% which consistently decreased with elevation while at P_{mac} and P_{mic} levels, the lower position recorded the highest values of 15.5 and 28.0% respectively. The highest values of the pore size classes were recorded at the epipedon which significantly ($p<0.0001$) decreased with depth.

Water retention characteristics: The land use types, landscape positions and pedons significantly ($p<0.0001$) varied in soil water retained at saturation (SP), field capacity (FC), Permanent Wilting Point (PWP) and Available Water Capacity (AWC) (Table 5). Considering land use types, the mean values were recorded in FL. With respect to landscape position, the highest SP mean value was recorded at the upper position which significantly ($p<0.0001$) decreased with decrease in elevetion. However, the lower position got the highest values of soil moisture retained at FC, PWP and AWC which consistently decreased with increase in elevetion. Regarding the pedons, the highest values of all the parameters were recorded at the epipedon.

Relatioship between factors and dependant variables: Correlation due to regression showed that the land use types, landscape positions and pedons were related significantly positive in

Table 5: Variations in soil water retention characteristics as influenced by land use types, landscape positions and pedons

Results	Saturation percent	Field capacity	Permanent wilting point	Available water capacity
	------------------	(%)	------------------	
Land use types				
FL	43.2a	27.9a	13.4a	14.5a
CuL	40.0b	25.4b	11.8b	13.6b
Critical range	0.528	0.419	0.269	0.150
Pr	<0.0001	<0.0001	<0.0001	<0.0001
Landscape positions				
ULP(2-4%)	43.3a	24.1c	10.0c	13.2c
MLP(1-2%)	42.3b	27.2b	12.9b	14.3b
LLP (0-1%)	38.4c	28.0a	13.4a	14.5a
Critical range	0.686	0.543	0.349	0.195
Pr	<0.0001	<0.0001	<0.0001	<0.0001
Pedons				
Epipedon	43.6a	28.2a	13.6a	14.6a
Endopedon1	42.2b	27.1b	12.9b	14.2b
Endopedon2	40.1c	25.5c	11.8c	13.7c
Endopedon3	39.9c	25.3c	11.7c	13.6c
Critical range	0.822	0.651	0.419	0.234
Pr	<0.0001	<0.0001	<0.0001	<0.0001

FL:Fallow; CC:Continuous cultivation; ULP:Upper landscape position; MLP:Middle landscape position; LLP:Lower landscape position; All means followed by the same letter within a column are not significantly different at 5% probability level using the Duncan Multiple Range Test

Table 6: Correlation coefficient due to regression showing relationship between variables under various land use types, landscape positions and pedons

Variable	LUT	LP	PED	LUT x LP	LUT x PED	LP x PED	LUT x LP x PED
Sand	0.272*	0.717**	0.430**	0.509**	0.752**	0.767**	0.814**
Silt	0.273*	0.344**	0.564**	0.495**	0.627**	0.648**	0.703**
Clay	0.204ns	0.633**	0.680**	0.400**	0.710**	0.718**	0.746**
OC	0.554**	0.354**	0.528**	0.657**	0.765**	0.697**	0.890**
MWD	0.691**	0.308*	0.606**	0.756**	0.919**	0.640**	0.941**
DR	0.917**	0.249*	0.279*	0.950**	0.958**	0.345*	0.980**
CDI	0.767**	0.075ns	0.306*	0.770**	0.825**	0.332*	0.836**
CFI	0.803**	0.352**	0.314*	0.877**	0.862**	0.519**	0.956**
ASC	0.711**	0.352**	0.395**	0.794**	0.814**	0.583**	0.920**
BD	0.489**	0.549**	0.423**	0.741**	0.653**	0.761**	0.909**
P_t	0.482**	0.550**	0.424**	0.736**	0.647**	0.763**	0.906**
P_{mac}	0.517**	0.503**	0.370*	0.721**	0.636**	0.685**	0.858**
P_{mic}	0.469**	0.554**	0.427**	0.726**	0.634**	0.769**	0.901**
SP	0.468**	0.554**	0.430**	0.726**	0.636**	0.771**	0.902**
FC	0.469**	0.554**	0.427**	0.726**	0.634**	0.769**	0.901**
PWP	0.467**	0.553**	0.430**	0.724**	0.635**	0.770**	0.901**
AWC	0.473**	0.557**	0.419**	0.730**	0.631**	0.756**	0.899**

LUT: L and use types; LP: L andscape positions: PED: Pedons; BD: Bulk density; P_t: Total porosity; P_{mac} : Macroporosity; P_{mac}: Microporosity; FC: Moisture at field capacity; PWP: Moisture at permanent wilting point; AWC : Moisture at available water capacity; OC: Organic carbon; **: Significant at 1% probability level; *: Significant at 5% probability level

Table 7: Correlation coefficient showing relationship between dependant variables

	BD	P_t	P_{mac}	P_{mic}	SP	FC	PWP	AWC	OC
BD	-	-0.997**	-0.763**	-0.994**	-0.993**	-0.994**	-0.993**	-0.993**	-0.763**
OC	-0.763**	0.767**	0.735**	0.761**	0.762**	0.761**	0.762**	0.758**	-
MWD	-0.475**	0.466**	0.462**	0.453**	0.454**	0.453**	-0.454**	0.450**	0.594**
DR	0.449**	-0.440**	-0.442**	-0.424**	-0.430**	-0.429**	-0.428**	-0.430**	-0.586**
CDI	0.591**	-0.579**	-0.590**	-0.563**	-0.563**	-0.563**	-0.561**	-0.566**	-0.598**
CFI	-0.820**	0.811**	0.795**	0.797**	0.797**	0.797**	0.796**	0.798**	0.825**
ASC	-0.841**	0.836**	0.783**	0.830**	0.830**	0.830**	0.829**	0.832**	0.795**

BD: Bulk density; P_t: Total porosity; SP: saturation percent; FC : Moisture at field capacity; PWP : Moisture at permanent wilting point; AWC: Moisture at available water capacity; P_{mac} : Macroporosity; P_{mic}: Microporosity; OC: Organic carbon; **: significant at 1 % probability level; *= Significant at 5% probability level; ns = Not significant at 5% probability level

changing the distribution trend of the studied soil physical properties except clay and CDI which were non-significantly affected by the land use types and landscape positions, respectively (Table 6).

The relationship of OC with all the studied physicals properties (except macroporosity) was significant (Table 7), however, the particle size classes were non-significantly related with all the physical properties. The B_D of the soils was also significantly related with all the studied physical parameters, thus following similar trend with OC.

DISCUSSION

Particle size distribution: The high sandiness in CC and its decrease downslope and with depth could be due to larger size of sand and its decreased transportability while silt and clay sizes are smaller and lighter hence easily moved in suspension. Changes in the soil sand content were to a greater extent influenced along the toposequence while that of silt and clay were greater along the profile depths. According to Esteban (2000) the soils of the study site are medium-textured. Coarse-textured soils lack both nutrient and water holding capacities, while fine-textured soils often have structural and infiltration problems.

Organic Carbon (OC) and aggregate stability: The higher OC detected in Fallowed Land (FL) compared to Continuously Cultivated (CC), as well as at the Lower Landscape Position (LLP) compared to the other positions was probably as a result of either the accumulation of litter from continuous residue addition or absence of soil disturbance for an extended period (Manjoka *et al.*, 2007). The relatively higher OC content found at the top layer also agrees with the report of Manjoka *et al.* (2007), which associates such with the mixture into the epipedon of biomass that is returned to the soil. This explains the relatively lower bulk density in FL, at LLP and at epipedon. This is supported by the strong significantly negative relationship between OC and B_D in the present study (r = -0.763). This is also consistent with the reports of other researchers (Paul and Clark, 1996; Nyakatawa *et al.*, 2001; Igwe *et al.*, 1995; Mbagwu *et al.*, 1983; Oguike *et al.*, 2006) which show decreases in B_D due to increases in OC.

The values obtained with the indices of macro- and microaggregate stability under the CC showed that its stability was lower than FL. This may be connected with the lowest OC content observed under the CC. It is supported by the strong significantly possitive relationship of OC with MWD, CFI and ASC and the negative relationship with DR and CDI which indicates that the lower OC in CC resulted to higher DR and CDI whereas the higher OC in FL resulted to higher MWD, CFI and ASC. It is also supported by the reports by other authours (Oguike and Mbagwu, 2009; Igwe *et al*., 1995; Igwe, 2004; Gijsman, 1996).

The higher MWD (macroaggregate index) observed at the ULP compared to other positions was probably due to less frequent wetting and drying of the position. The continued wetting and drying at the lower landscape position could be responsible for decreased macroaggregate stability which is supported by Caron *et al*. (1992). This probably led to decrease in macro-porosity and production of finer particles and micro-aggregates which agrees with the reports by Levy and Miller (1997) and Scalenghe *et al*. (2004). The higher stability of microaggregates at the lower landscape position, as indicated by higher CFI and ASC, could be attributed to the relatively high OC. This is supported by the strong and significantly positive relationship of OC with the indices.

Bulk density (B_d) and porosity characteristics: Organic carbon (Organic Matter, OM) could be inffered to have play role in the B_D, P_t and P_{mic} status of the land use types. The higher B_D values recorded in CC compared to FL and with increase in pedal depths and elevation is associated with the lower OC (OM) values. The mean value range of B_D obtained show that the soils were slightly compacted at the epipedon, which could restrict root development (De Geus, 1973; Taylor *et al*., 1966) especially in CC.

As revealed by the correlation study, increase in OC (OM) probably resulted to increase in P_t, P_{mac} and P_{mic} which supported the higher value observed under FL than CC. This is consistent with the reports by Oguike *et al*. (2006), Ekeh *et al*. (1997) and Oguike and Mbagwu (2009) which indicated enhancement in P_t and P_{mac} with improved OM status.

Water retension characteristics: According to Ellerbrook *et al*. (2005) and Eynard *et al*. (2006), soil organic matter interacts with other soil properties to influence water behaviour in soils. Thus, the high soil moisture retained at SP, FC, PWP and AWC under the FL a reflection of its relatively high OC or Organic Matter (OM) content and a manifestation of the affinity of OC or OM for water (Oguike and Mbagwu, 2004; Mbagwu *et al*., 1994).

The significant increase in the water retention characteristics with decrease in elevation is associated with the relatively higher clay and OC content. This agrees with the findings by other researchers (Onweremadu and Mbah, 2009; Dekker *et al.,* 1999) which indicates increases in water holding capacity downslope with increase in clay and organic matter content in soils. Similarly, the decrease in these values with pedal depth increase could be associated with the decrease in OC content with depth.

Relationship between factors and dependant variables: Linear regression analysis indicated that particle size distribution was to a greater extent influenced by the differences in pedal depths and to a lesser extent by the changes in landscape positions and in land use.

The distribution of OC and aggregate stability at both macroaggregate and microaggregate levels was most influenced by changes in land use.

At total and microporosity levels, their distribution was most influenced by changes in landscape positions and followed by the changes in land use while at macroporosity level changes in land use exerted greater influence compared to the one exerted by the changes in landscape positions and pedal depths.

Soil water retention at FC, PWP and AWC was to a greater extent influenced by changes in landscape positions than land use and pedal depths. The additional structure and porosity with increased organic matter in FL exerted greater influence on water held at field capacity (33 kPa), but lesser influence at wilting point (1500 kpa). This agrees with the report by Hillel (1998) and Hudson (1994).

The lowest AWC recorded under CC and at ULP could be explained by the medium texture observed at these locations. Bauer and Black (1992) reports that increase in organic carbon do not change the available water capacity of sandy soils but reduces in medium and coarse textured soils which support the findings in the present study. The soil moisture at SP was most influenced by changes in landscape positions compared to land use and pedal depths.

The distribution of pore size classes (except P_{mac}), B_D and water retained at various capacities were to a greater extent influenced by changes in landscape positions, whereas the distribution of OC and aggregate stability of the soils were more dependant on changes in land use.

Hence, increased aggregate stability, reduced bulk density, enhanced porosity and improved water-holding capacities observed in FL, at LLP and epipedon are associated with increased amounts of soil OC (organic matter).

Generally, paired association between the factors exerted greater influence on the distribution of studied physical properties than individual factors did. Similarly, the association between the three factors exerted greater influence on the properties than the one by paired factors.

CONCLUSION

This study indicated that continuous cultivation led to increased sand fraction and bulk density (B_D), reduced porosity, Organic Carbon (OC), aggregate stability and water retention capacity compared to fallow land use type. The differences in slope gradient at various landscape positions resulted to accumulation of higher sand fraction, high macroaggregate stability, B_D and lower water retention capacity at the upper landscape position and higher silt and clay fraction, microaggregate stability, porosity, OC and water retention characteristics at the lower compared to the other positions. The epipedons compared to the endopedons of the soils had higher organic carbon which promoted better aggregate stability, distribution of pore size classe and moisture retention at various capacities.

The distribution of pore size classes (except P_{mac}), B_D and water retained at various capacities were to a greater extent influenced by changes in landscape positions whereas the distribution of OC and aggregate stability of the soils were more dependant on changes in land use.

Since OC significantly influenced all the status of all the physical properties of the soils in the study site, agricultural use of land of such physiographic outlay should take into account all cultural practices which enrich soil with organic matter for ensuring maximum productivity.

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