Albanian j. agric. sci. 2016;15 (2): 112-124 *Agricultural University of Tirana*

RESEARCH ARTICLE **(Open Access)**

Effects of Toposequence and Soil Depth on Soil Physical Properties of a Typical Alfisols

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Abstract

Management options proffered with respect to the physical properties along a toposequence is a key to sustainable crop and soil productivity since inadequate information on the influence of landscape on soil properties is a major factor limiting agricultural productivity in Nigeria. A study was conducted to evaluate the effect of slope and depth on selected soil physical properties at the University of Ilorin Teaching and Research Farm in 2013. Three points: upper, middle and bottom slope, along a toposequence with an average distance of 200m apart were delineated and samples for soil analysis collected at depths of 0 – 30cm, 30 – 60 cm and 60 – 90 cm using core sampler and auger. Soil physical properties which included sand, silt, clay, saturated hydraulic conductivity (Ksat), bulk density, total porosity, field capacity, permanent wilting point and available water were determined in the laboratory / computed afterwards. Data from the analysis were subjected to ANOVA using 2 x 3 factorial combinations of factors – slope and depth - in randomized complete block design (RCBD) with five replicates. Results indicated that soil texture was loamy sand and sandy loam at the surface and sandy clay loam and clay loam at the sub-surface of the soil. Also, all properties studied were significantly affected by slope and depth except bulk density, total porosity and permanent wilting point for both, and field capacity for depth. Interaction effect was significant for all parameters studied except permanent wilting point at either the 1 or 5 % level of probability.

Keywords: slope, soil depth, physical properties, Alfisol.

1. Introduction

Topography is one of the five main factors of soil formation that influence the way soils develop. It is both an internal and external factor in pedogenesis that influences soil formation [20]. According to [10] and [15], strong associations exist between topography and soils. It relates to the configuration of the land surface and is described in terms of differences in elevation, slope and landscape position. In the basement complex regions, topography is closely related to the underlying parent rock [17]; [12]; [13]. Differences in soil formation along a hill slope result in differences in soil properties [5] which affect the pattern of plant and litter production, and decomposition [20].

Differences in properties of soils occupying different landscape positions on a toposequence are caused by water and material movement and distribution along a slope. Texture of the soil plays an important role in soil structural development resulting to nutrient availability in the soil due to aggregate formation. For instance, clay content may indicate that ability of the soil to supply or retain applied plant nutrient while sand and silt determines the degree of soil weathering and the relation between soils and their parent materials [6].

In his work, [19] observed a high degree of variability in crops stands and low average productivity on the West African landscape and noted that crop field tends to decrease from fertile valley bottom soil to generally infertile up lands.[17] noted that in spite of these reported variability in soil properties and crops yield along the toposequence, recommendation for agronomic practices are often made to farmers without due consideration for specific topographic locations that might influence the management options such as fertilizer rate and

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(Accepted for publication June 25. 2016)
***ISSN**: 2218-2020, © Agricultural University of Tirana*

types, tillage operations and herbicides application. This brings about sharp variations in crop yield.

Again, [10] noted that an understanding of the basic soil properties is essential for developing soil management practices that will maintain the productive potential of a soil. There is the movement of water from the crest of a toposequence to the valley bottom and this influences the distribution of soil organic matter, microorganisms, vegetation and chemical properties [13], thus affecting such physical properties of soils as bulk density and hydraulic conductivity (Ksat) at different level of the toposequence. Consequently, estimation of rates of water movement through soil and underlying strata is pertinent in many soil management decisions.

Saturated hydraulic conductivity (Ksat) integrates a variety of soil properties as well as exhibit variability especially within a soil mapping unit [3]. Soil texture is potentially a major factor influencing Ksat variability since fine textured materials in general conduct water at a lower rate than coarse textured material other factors being constant [16]. Hence, for sustainable land use options on variable toposequence, knowledge of the geomorphic position which is related to a systematic variability of soil hydraulic properties [13] among other soil physical properties is necessary. Therefore, the objectives of this study was to characterize the physical properties of soil on a typical *Alfisol* formed over basement complex parent material along a toposequence, and to study the effects of slope and soil depth on selected physical properties of the soil.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out along a toposequence of soil: upper (N 08 27´ 08.6" E004 39´42.2", 323m), middle (N 08 27´ 18.7" E004 39´ 49.8", 335m) and bottom (N 08 27´ 19.8" E004 39´ 51.5", 336m) slope at University of Ilorin Teaching and Research Farm, Ilorin, Kwara State, Nigeria. The vegetation of the area is a forest savanna mosaic with the soils formed over the basement complex [15]. Gravelly *Alfisols* dominates the landscape. The study area has been altered by cultivation though fallowed at the time of sampling. It is located in the Southern Guinea Savanna ecological zone of Nigeria approximately by longitudes $4^{0}\,35'$ E and latitude $9^{0}\,29'$ N of Nigeria, 307 m above sea level within a tropical climate characterized by a bimodal rainfall pattern with peaks in June and September and a dry spell between mid-July and August. Annual rainfall ranges from 1000 mm - 1240 mm. The daily temperature range is 20^{0}C - 35^{0}C [7].

2.2. Soil Sampling and Laboratory Analysis

Soil Samples from the layers of 0 - 30 cm, 30 - 60 cm and 60 - 90 cm were collected from fifteen mini pits dug along the toposequence, five on each of the toposequence. A total of 90 samples (45 disturbed and 45 undisturbed) were collected along the toposequence. From each soil depth, undisturbed samples were collected with metal cylinders of 8.3 cm height and 5.5 cm internal diameter. The soil was secured with a piece of calico tied round the cylinder and held firmly with a rubber band. The core samples were properly labeled. Disturbed samples were also collected with soil auger from each depth. The samples were placed in well labeled polythene bags. The samples (disturbed and undisturbed) were transported to the laboratory for soil physical properties determination using standard laboratory methods and/ or computed using established procedures.

2.3. Soil Samples Preparation

Disturbed samples were air-dried, crushed and made to pass through a 2 mm sieve and used for analysis.

2.4. Physical Properties Analysis

2.4.1. Particle Size Analysis

Particle size analysis was carried out using the hydrometer method described by [7]. Sodium hexametaphosphate (calgon) was used as dispersant. The textural class of the soil was determined using the USDA Soil Textural Triangle.

2.4.2. Bulk Density

Bulk density was determined by the core method described by [2]. The core samples were oven dried at a temperature of 105^{0}C to a constant weight. The bulk density was calculated from the mass volume relationship as:

$$\rho_b = \frac{Ms}{Vt} \quad (1)$$

Where, $\rho_b = bulk\ density\ (\frac{kg}{m^3})$,
Ms = Dry soil mass (Kg), and
Vt = Total volume of soil (m^3)

2.4.3. Total Porosity

Total porosity was calculated as:

$$\emptyset = [1 - \frac{\rho_b}{\rho_s}] \quad (2)$$

Where, $\emptyset = Total\ porosity\ (\frac{m^3}{m^3})$

$\rho_b = bulk\ density\ (\frac{kg}{m^3})$,
$\rho_s =$
$particle\ density\ asummed\ to\ be\ 2650$

2.4.4 Saturated Hydraulic Conductivity

The saturated hydraulic conductivity was estimated with a constant head permeameter and calculated according to transposed Darcy's formular for vertical flows of liquid as:

$$\frac{QL60}{\Delta hAt} \text{ in cm/hr} \quad (3)$$

Where,
Q = Quantity of water measured
L = Length of the soil column
$\Delta h = Change\ in\ the\ head$
A = Cross-sectional area
t = Time required for the quantity of water

2.4.5 Field Capacity

The core samples were saturated for 24 hours and weighed after three days and oven dried at a temperature of 105°C in determining the field capacity.

$$\text{Percent water at field capacity} = \frac{\text{Weight ofsaturated soil after three days} - \text{oven dried weight}}{Oven\ dried\ weight} x100\% \quad (4)$$

2.4.6. Permanent Wilting Point

Permanent wilting point was determined using the method described by [11]. 0.3kg of air-dried, 2 mm sieved soil collected from the various sampling points along the topographic positions of the toposequences, with enough water to give a good crumb structure were prepared. About 3 maize grains were sown in each pan and a little more water was added. The seedlings were thinned down to 1 per pan and aluminum ring were put round each plumule before the coleoptiles opened and were pressed a little way into the soil. The seedlings were allowed to develop about 4 leaves and the soil surface were later sealed up with a layer of molten paraffin wax about $^1/_4$ inches thick. The space between the stem of the seedling and the aluminum ring were plugged with cotton wool and the plants were left to grow until the first definite signs of wilting appear. On noticing wilting, the plants were placed under a shade and left over night to see if turgor is regained, if so it is taken out again until it cannot be able to regain turgor under a shade. When permanent wilting was established the stem was cut and the wax and roots was removed. The soil samples were weighed and then oven-dried and weighed again. The difference between the two weights was expressed as a percentage of the oven-dried soils known as permanent wilting point.

2.4.7. Available Water Capacity

The available water capacity was determined as the difference between field capacity and permanent wilting point water contents.

2.5. Statistical Analysis

Soil data collected from the experimental site are in normal distribution and in linear model, thus subjected to Analysis of Variance using SPSS 16.0 edition. The statistical design adopted for the study involving two factors (slope x depth) at three levels each was the 2 x 3 factorial combinations in a randomized complete block design (RCBD) with five replicates (r). The 3 levels of each factors: Depth ($D_{0\text{-}30\ cm}$, $D_{30\text{-}60\ cm}$ and $D_{60\text{-}90cm}$), and Slopes (Upper, Middle and Bottom) serve as blocks.

3. Results and Discussion

3.1. Effect of toposequence and depth on soil physical characteristics

Results obtained for the parameters measured for the soil physical characteristics are presented in Table 1 while the main effect using the Duncan's Multiple Range Test (DMRT) in testing the means at the various factors' level for different parameters measured is presented in Table 2 and the interaction in Table

3.2. Sand Fraction

From the soil data collected from the experimental site as shown in Table 1, sand fraction was high with values ranging from 400 g kg^{-1} to 885 g kg^{-1} with an overall mean value of 636.96 g kg^{-1}. By categorizing these sand fraction values according to the three levels of slope, it can be deduced from Table 1, that sand fraction values in the upper slope ranged from 400 g kg^{-1} to 825 g kg^{-1}. Also, sand fraction values in the middle slope ranged from 510 g kg^{-1} to 885 g kg^{-1}. Likewise, sand fraction values in the bottom slope ranged from 600 g kg^{-1} to 688 g kg^{-1}. It was generally observed that soil samples taken at the middle slope recorded the highest sand fraction (720.13 g kg^{-1}) which was significantly different from the other slopes at 0.0001 level of probability (Table 2). Bottom slope sand fraction (649.93 g kg-1) was also statistically different from the upper slope content (540.80 g kg^{-1}) which recorded the lowest. Also, interaction of the two factors – slope and depth – were found to be significant ($p < 0.0001$) (Fig. 1), with middle slope 0 – 30cm depth recording the highest (832.60 g kg^{-1}) (Table not included).

Sand dominated the mineral fraction in all the landscape positions studied which may be attributed to geological processes involving sorting of soil materials by biological activities, clay migration through eluviation and illuviation, or surface erosion by runoff or their combinations [9] and [1].

3.3. Silt Fraction

From the soil data collected from the experimental site as shown in Table 1, silt fraction values ranged from 31 g kg^{-1} to 270 g kg^{-1} with an overall mean value of 198.73 g kg^{-1}. By categorizing these silt fraction values according to the three levels of slope, it can be deduced from Table 1, that silt fraction values in the upper slope ranged from 80 g kg^{-1} to 270 g kg^{-1}. Also, silt fraction values in the middle slope ranged from 31 g kg^{-1} to 250 g kg^{-1}, whereas, silt fraction values in the bottom slope ranged from 210 g kg^{-1} to 250 g kg^{-1}. Main effect of silt fraction indicated that soil samples taken at the upper and lower slope recorded the highest silt fraction values (230.67 g kg^{-1}) which was higher and statistically different ($p < 0.0001$) than in the middle slope (135.53 g kg^{-1}) (Table 2). Similarly, soil depth was highly significant with the highest silt accumulation (238.67 g kg^{-1}) at the 60 – 90 cm depth which was statistically different from 0 – 30 cm (158.20 g kg^{-1}) and 30 – 60cm (199.33 g kg^{-1}). Interaction was also highly significant (Table 2).

Table 1. Physical Characteristics of the Soil samples taken at Unilorin Teaching and Research Farm

S/No.	Soil samples	Sand	Silt (g/kg)	Clay	Textural class	Bulk density (kg/m^3)	Total porosity (m^3/m^3)	Ksat (cm/hr)	Field capacity (%)	Permanent wilting point (%)	Available Water (%)
1.	$U_sD_1R_1$	688	210	102	SL	1571	0.407	15.91	32.26	20.00	12.26
2.	$U_sD_1R_2$	808	110	82	LS	1571	0.407	14.46	32.26	20.00	12.26
3.	$U_sD_1R_3$	825	80	95	LS	1318	0.503	17.36	38.46	11.11	27.35
4.	$U_sD_1R_4$	635	230	135	SL	1571	0.407	13.46	32.26	11.11	21.15
5.	$U_sD_1R_5$	684	210	106	SL	1571	0.407	12.84	32.26	20.00	12.26
6.	$U_sD_2R_1$	468	250	282	SCL	1318	0.503	6.94	57.69	11.11	46.58
7.	$U_sD_2R_2$	400	250	350	CL	1065	0.598	5.79	71.43	11.11	60.32
8.	$U_sD_2R_3$	450	270	280	CL	1571	0.407	4.34	32.26	25.00	7.26
9.	$U_sD_2R_4$	430	270	300	CL	1318	0.503	5.79	38.46	11.11	27.35
10.	$U_sD_2R_5$	468	250	282	SCL	1571	0.407	3.47	32.26	11.11	21.15
11.	$U_sD_3R_1$	488	270	242	SCL	1318	0.503	2.89	38.46	22.22	16.24
12.	$U_sD_3R_2$	400	250	350	CL	1318	0.503	2.31	38.46	11.11	27.35
13.	$U_sD_3R_3$	450	270	280	CL	1318	0.503	1.45	38.46	25.00	13.46
14.	$U_sD_3R_4$	430	270	300	CL	1698	0.359	0.87	37.31	11.11	26.20
15.	$U_sD_3R_5$	488	270	242	SCL	1698	0.359	1.16	37.31	12.50	24.81
16.	$M_sD_1R_1$	808	110	82	LS	1318	0.503	7.81	57.69	30.00	27.69
17.	$M_sD_1R_2$	800	100	100	LS	1318	0.503	10.12	57.69	11.11	46.58
18.	$M_sD_1R_3$	815	101	84	LS	1318	0.503	8.10	57.69	10.00	47.69
19.	$M_sD_1R_4$	855	61	84	LS	1318	0.503	11.57	57.69	10.00	47.69
20.	$M_sD_1R_5$	885	31	84	LS	1318	0.503	8.97	57.69	11.11	46.58
21.	$M_sD_2R_1$	788	130	82	LS	1571	0.407	6.65	32.26	11.11	21.15
22.	$M_sD_2R_2$	800	100	100	LS	1318	0.503	5.79	38.46	11.11	27.35
23.	$M_sD_2R_3$	775	140	85	LS	1571	0.407	5.21	48.39	11.11	37.28
24.	$M_sD_2R_4$	775	120	105	LS	1318	0.503	4.63	38.46	11.11	27.35
25.	$M_sD_2R_5$	875	20	105	LS	1571	0.407	4.34	32.26	10.00	22.26
26.	$M_sD_3R_1$	518	200	282	SCL	1318	0.503	3.18	57.69	11.11	46.58
27.	$M_sD_3R_2$	510	210	280	SCL	1318	0.503	2.89	57.69	12.50	45.19
28.	$M_sD_3R_3$	528	230	242	SCL	1318	0.503	4.34	57.69	20.00	37.69
29.	$M_sD_3R_4$	520	230	250	SCL	1318	0.503	5.79	57.69	11.11	46.58
30.	$M_sD_3R_5$	550	250	300	SCL	1318	0.503	3.54	38.46	25.00	13.46
31.	$B_sD_1R_1$	648	210	142	SL	1571	0.407	13.76	32.26	10.00	22.26
32.	$B_sD_1R_2$	680	230	90	SL	1318	0.503	10.03	76.92	11.11	65.81
33.	$B_sD_1R_3$	600	250	150	SL	1318	0.503	13.18	57.69	20.00	37.69
34.	$B_sD_1R_4$	688	230	82	SL	1571	0.407	12.04	48.39	10.00	38.39
35.	$B_sD_1R_5$	688	210	102	SL	1571	0.407	12.90	32.26	10.00	22.26
36.	$B_sD_2R_1$	608	250	142	SL	1318	0.503	11.41	38.46	20.00	18.46
37.	$B_sD_2R_2$	600	250	150	SL	1318	0.503	10.34	38.46	10.00	28.46
38.	$B_sD_2R_3$	670	230	100	SL	1318	0.503	7.81	38.46	20.00	18.46
39.	$B_sD_2R_4$	688	210	102	SL	1318	0.503	8.97	38.46	33.33	5.13
40.	$B_sD_2R_5$	600	250	150	SL	1318	0.503	6.65	38.46	10.00	28.46
41.	$B_sD_3R_1$	648	210	142	SL	1318	0.503	8.65	38.46	33.33	5.13
42.	$B_sD_3R_2$	688	210	102	SL	1318	0.503	8.44	38.46	10.00	28.46
43.	$B_sD_3R_3$	608	250	142	SL	1318	0.503	8.92	38.46	20.00	18.46
44.	$B_sD_3R_4$	670	230	100	SL	1571	0.407	6.21	32.26	20.00	12.26
45.	$B_sD_3R_5$	665	230	105	SL	1318	0.503	8.73	57.69	20.00	37.69
Mean value		636.96	198.73	166.53	NA	1402.36	0.471	7.78	44.05	15.51	28.54

SD (±)	140.15	70.37	88.38	NA	140.19	0.053	4.16	11.89	6.71	14.53
CV (%)	22.00	35.41	53.08	NA	10.00	11.25	53.47	26.99	43.26	50.91

Key: SL = Sandy Loam soil; CL = Clay Loam soil; LS = Loam Sand soil; SCL = Sandy Clay Loam soil; Note that U_s, M_s and B_s stands for the three levels of slope indicating Upper slope, Middle slope and Bottom slope respectively; D_1, $D_2$and D_3 stands for the three levels of depth of soil indicating soil depth within 0 – 30 cm, 30 – 60cm and 60 – 90 cm, respectively; and R_1, R_2, R_3, R_4 and R_5 stands as the replicates for each soil samples taken.

Table 2: Main effect of selected physical properties as affected by toposequence and depth

Treatment	Sand	silt	Clay	Ksat	bulk density	total porosity	field capacity	PWP	Available water
Slope (S)									
S_1	540.80c	230.67a	228.53a	7.27b	1453	0.45	39.31b	15.57	23.73b
S_2	720.13a	135.53b	151.00b	6.20c	1368.6	0.48	49.83a	13.76	36.08a
S_3	649.93b	230.67a	120.07c	9.87a	1385.47	0.48	43.01ab	17.19	25.83b
SE±	2.95	2.24	1.78	0.09	8.14	0.003	0.64	0.43	0.78
Depth (D)									
D_1	740.47a	158.20c	101.33c	12.17a	1436.07	0.46	46.9	14.37	32.53
D_2	626.33b	199.33b	174.33b	6.54b	1385.47	0.48	40.95	14.48	26.47
D_3	544.07c	238.67a	223.93a	4.62c	1385.53	0.48	44.3	17.67	26.64
SE±	2.95	2.24	1.78	0.09	8.14	0.003	0.64	0.43	0.78
Interaction									
S × D	***	***	***	***	*	*	**	NS	*

Mean with different letters along the same row are statistically different from each other at $p \leq 0.05$, S_1 = Upper slope; S_2 = Middle slope, S_3 = Bottom slope; D_1 = soil depth from 0 – 30 cm; D_2 = soil depth from 30 – 60 cm; and D_3 = soil depth from 60 – 90 cm.; Ksat = hydraulic conductivity
* = 5% probability level; ** = 1% probability level; *** = 0.01% probability level

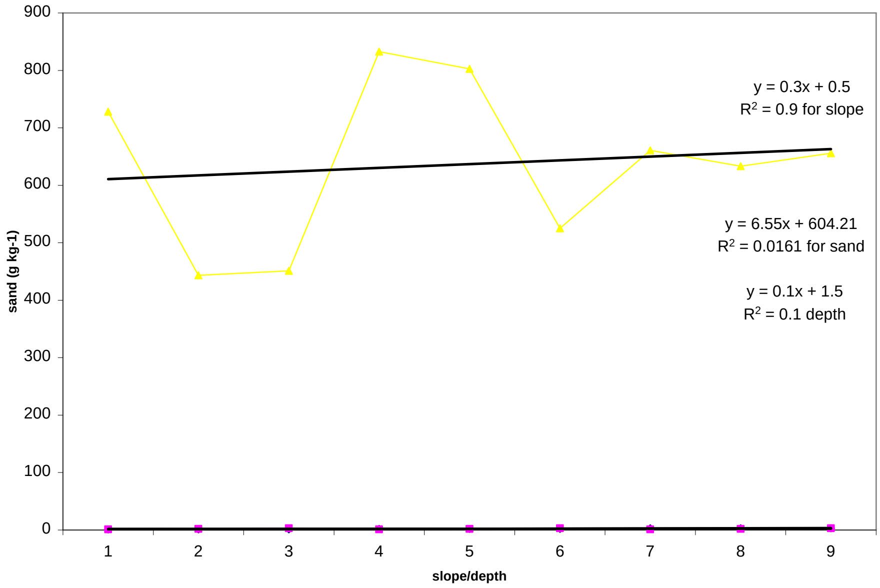

Figure 1. Interaction of slope and depth on sand content

The contents of silt in the soils were comparatively lower than those of the sand fraction. There was no consistent pattern of distribution of silt based on slope (Fig. 2). The low silt contents of the soil irrespective of their location are in line with the reports of several researchers who worked in similar environment in the Basement Complex area [14].

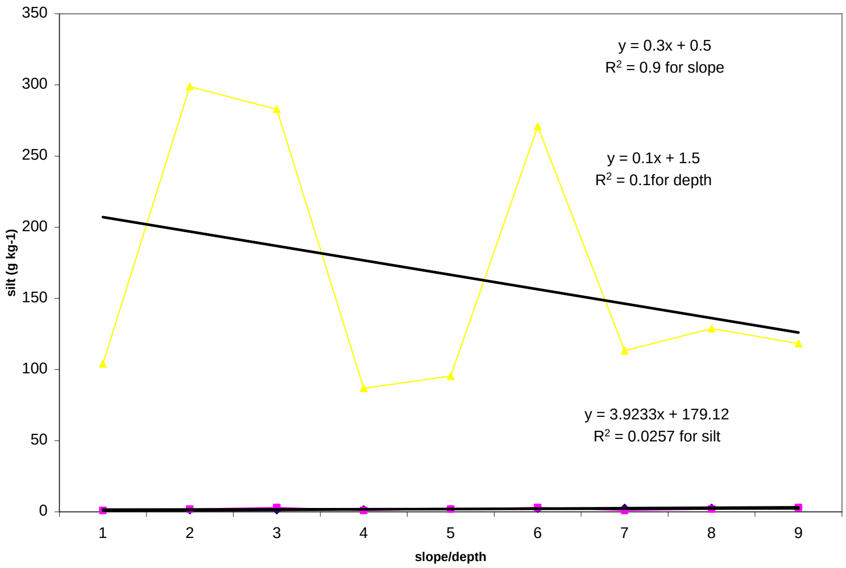

Figure 2: Interaction of slope and depth on silt content

3.4. Clay Fraction

From the soil data collected from the experimental site as shown in Table 1, clay fraction values ranged from 82 g kg^{-1} to 350 g kg^{-1} with an overall mean value of 166.53 g kg^{-1}. By categorizing these clay fraction values according to the three levels of slope, it can be deduced from Table 1, that clay fraction values in the upper slope ranged from 82 g kg^{-1} to 350 g kg^{-1}.

Also, clay fraction values in the middle slope ranged from 82 g kg^{-1} to 300 g kg^{-1}. Likewise, clay fraction values in the bottom slope ranged from 82 g kg^{-1} to 150 g kg^{-1}. It was generally observed that soil samples taken at the upper slope recorded the highest numbers of clay fraction values followed by those in the middle slope and lastly followed by those in the bottom slope. This simply means that clay fraction significantly reduced down slope.

Main effect for clay particle (g kg^{-1}) presented in Table 2, it can be deduced that slope, soil depth and the interaction between the effect of slope and soil depth were significant at 0.01% probability level (Fig. 3).

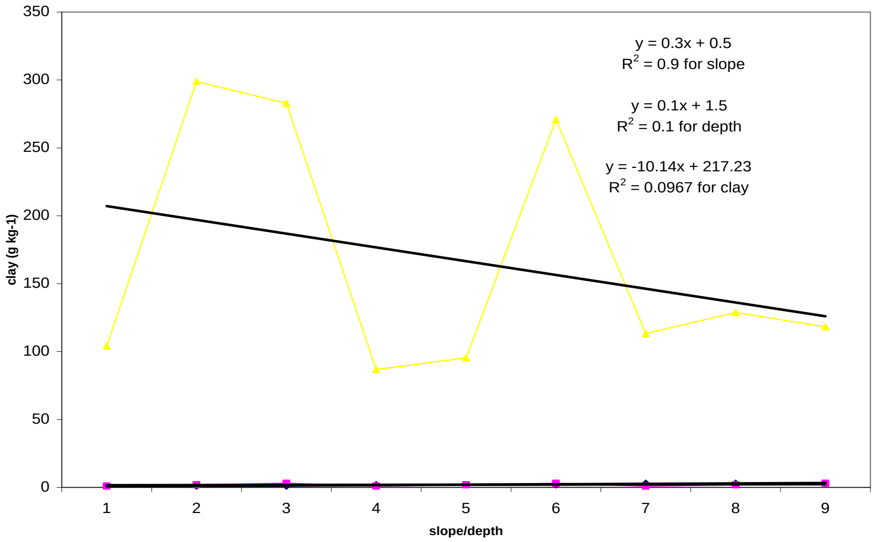

Figure 3: Interaction of slope and depth on clay content

3.5. Saturated Hydraulic Conductivity

The values of the saturated hydraulic conductivity of the soil samples taken at the experimental site as presented in Table 1 ranged from 0.87 cm hr^{-1} to 17.36 cm hr^{-1} with an overall mean value of 7.78 cm hr^{-1}. The wide variability may be as a result of the differences in the soil physical properties. These values ranged from low to rapid in ranking.

Saturated Hydraulic Conductivity (cm hr^{-1}) main effect presented in Fig. 4, indicate that slope, soil depth and the interaction between the effect of slope and soil depth were highly significant ($p<0.0001$).

3.6. Soil Textural Class

Results obtained for soil textural class as shown in Table 1 showed a total of four soil textural classes, namely loamy sand, sandy loam, sandy clay loam and clay loam in the forty five (45) soil samples taken at the experimental site.

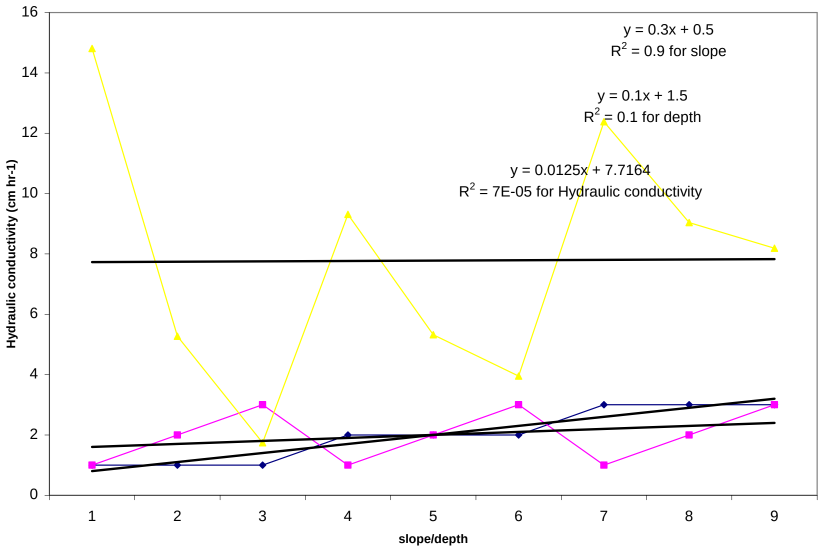

Figure 4: Interaction of slope and depth on hydraulic conductivity content

Among these four soil textural classes, the upper slope level had the four soil textural classes in place. The middle slope level had only two of the soil textural classes in place, namely loamy sand and sandy clay loam. While the bottom slopes level recorded just one of the soil textural classes, namely sandy loam. It was generally observed that soil textural classes obtained from the forty five (45) soil samples taken at the experimental site varies from loamy sand and sandy loam at the surface and while that of sandy clay loam and clay loam are predominantly found at the sub-surface of the soil.

3.7. Bulk Density

Results obtained for bulk density as shown in Table 1 ranged from 1065 kg m^{-3} to 1698 kg m^{-3} with an overall mean value of 1402.36 kg m^{-3}. Bulk density values in the upper slope were the highest followed by those in the bottom slope and lastly followed by those in the middle slope. The variations in the results of bulk density obtained from the forty five (45) soil samples taken at the experimental site is as a result of their differences in the total pore space. The finer-textured soils have more pore space and lower bulk densities than sandy soils [4]. The bulk density of soil varies according to its degree of compaction and over burden weight tends to compact the lower horizons and give them higher bulk densities than the A horizons.

Main effect for Bulk Density (kg m^{-3}) presented in Table 2, indicate that slope and soil depth were not significant at either the 1 or 5% probability level. However, the interaction between the effect of slope and soil depth was significant at 5% probability level. This implied that bulk density was not affected by slope and soil depth alone but their interaction (Fig. 5).

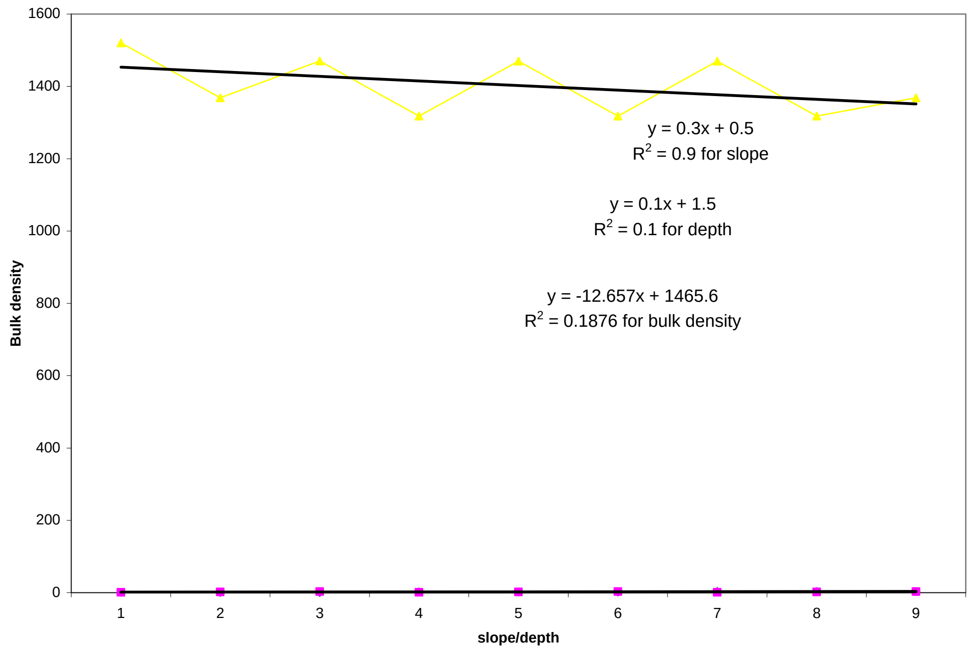

Figure 5: Interaction of slope and depth on bulk density

3.8. Total Porosity

Results obtained for total porosity as shown in Table 1 ranged from 0.359 m^3 m^{-3} to 0.598 m^3 m^{-3} with an overall mean value of 0.471 m^3 m^{-3}. This is an indication that the soil is moderately porous. Total porosity values in the middle slope recorded the highest followed by those in the bottom slope and lastly followed by those in the upper slope.

Main effect for Total Porosity (m^3 m^{-3}) presented in Table 2, indicate that slope and soil depth were not significant at either the 1 or 5% probability level. However, the interaction between the effect of slope and soil depth was significant at 5% probability level. This implied that total Porosity was not affected by slope and soil depth alone but their interaction (Fig. 6).

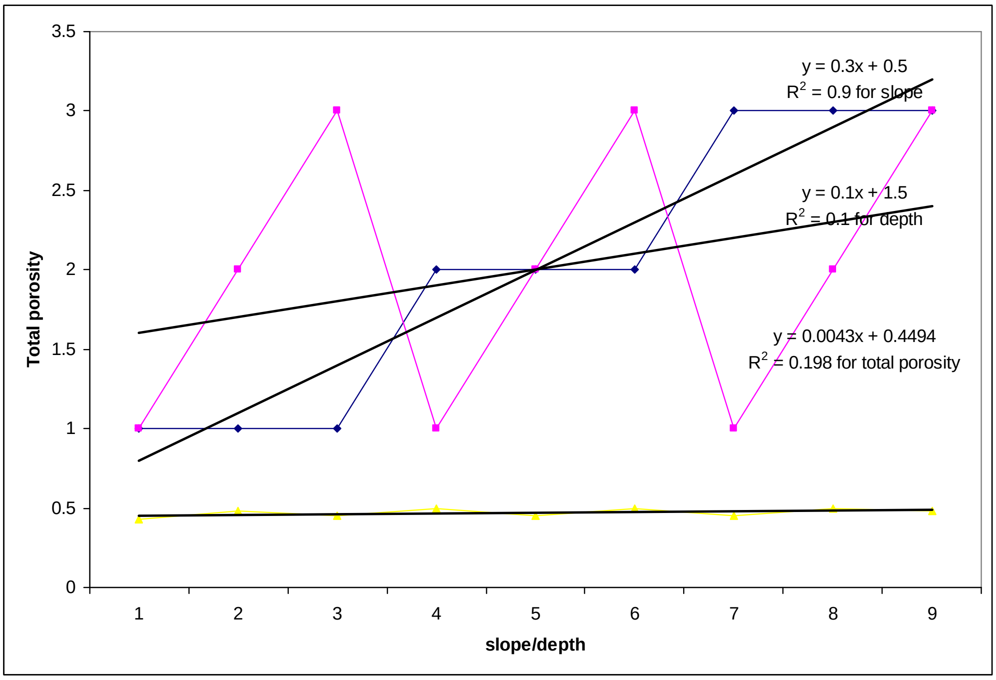

Figure 6: Interaction of slope and depth on total porosity

3.9 Field Capacity

Results obtained for field capacity as shown in Table 1 ranged from 32.26% to 71.43% with an overall mean value of 44.05%. Field capacity values in the middle slope recorded the highest followed by those in the bottom slope and lastly followed by those in the upper slope. Clay layers with small pores delay downward water movement by their low levels of permeability, but they also exert strong tensions that pull water from adjoining loamy layers. A loamy layer above a sandy layer will hold more water at field capacity than with the same texture in a uniform soil.

Table 2, indicate that slope and the interaction between the effect of slope and soil depth were significant at 1% probability level. However, effect of depth alone was not (Fig. 7).

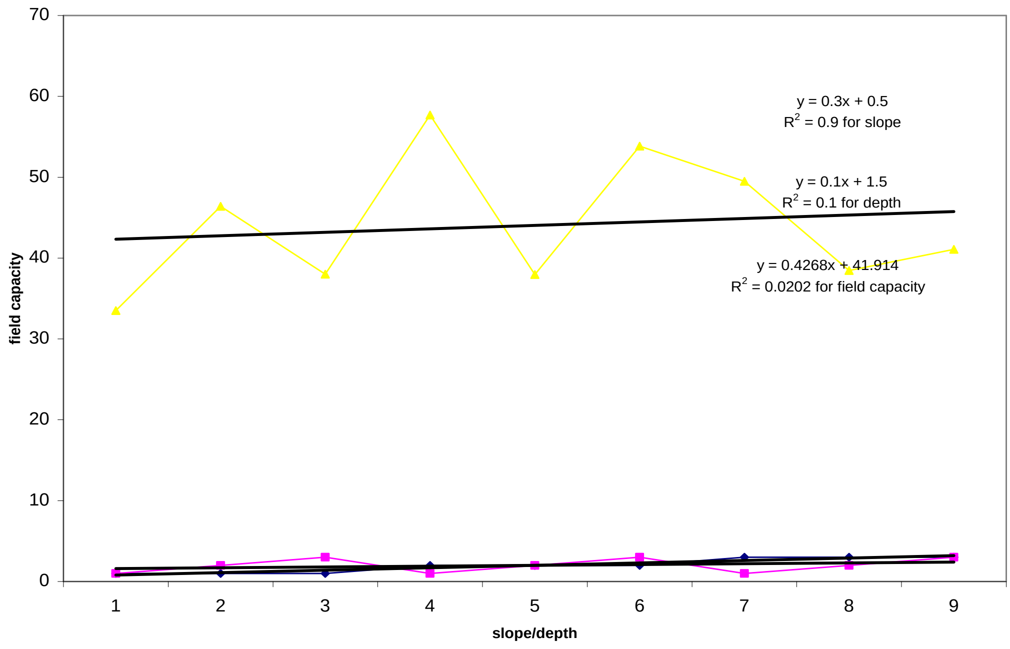

Figure 7: Interaction of slope and depth on field capacity

3.10. Permanent Wilting Point

Results obtained for permanent wilting point as shown in Table 1 ranged from 10.00% to 33.33% with an overall mean value of 15.51%. Permanent wilting point values in the bottom slope recorded the highest followed by those in the upper slope and lastly followed by those in the middle slope. However, neither of the two factors alone nor their interaction was significant at 5% probability level (Table 2). This would imply that permanent wilting point was not affected by slope, soil depth and the interaction etween the effect of slope and soil depth (Fig.8).

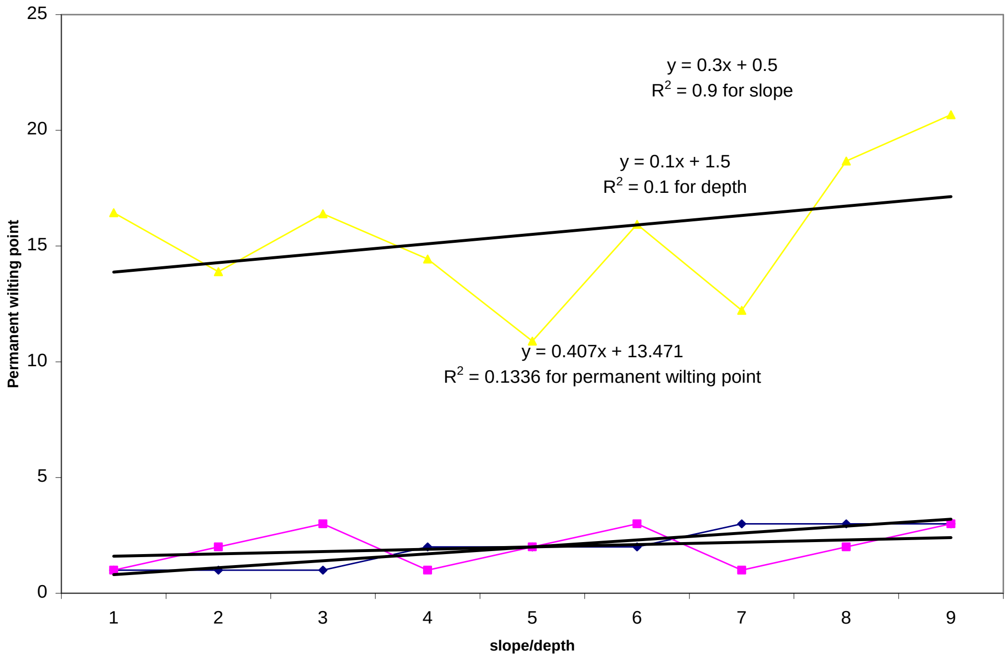

Figure 8: Interaction of slope and depth on permanent wilting point

3.11 Available Water

Results obtained for available water as shown in Table 1 ranged from 5.13% to 60.32% with an overall mean value of 28.54%. Available water values in the middle slope recorded the highest followed by those in the bottom slope and lastly followed by those in the upper slope. Clay particles hold much more water than sands particles because they have large surface area to be coated with water. [21] reported that sandy loam soil has characteristics of high density and poor water holding capacity. Since clay reduces down the slope it means that erosion was washing the sand down the slope. The bottom slope had only sandy loam textural class.

Table 2, indicate that slope and the interaction between the effect of slope and soil depth were significant at 5% probability level. However, depth was not significant. Results obtained (Table 2) showed that slope at upper and bottom levels were found to be statistically the same but different from the middle slope.

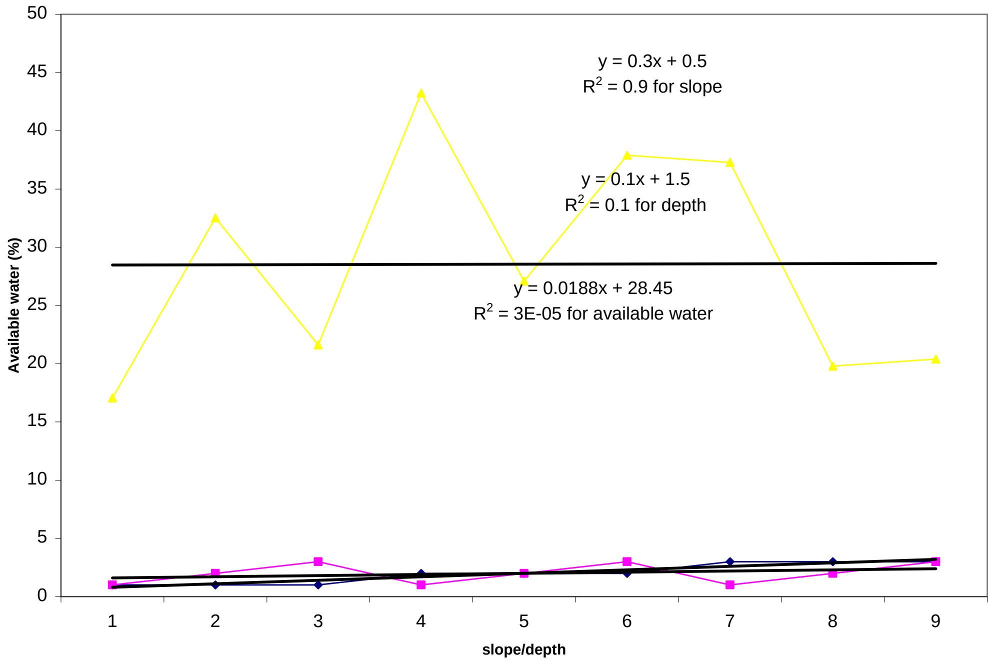

Figure 9: Interaction of slope and depth on available water

4. CONCLUSIONS

At the University of Ilorin Teaching and Research farm soil samples were taken at three different levels of slope and soil depth. Based on the outcome of this study, the following conclusions were drawn.

1. Soil physical characteristics of the study area such as sand, silt, clay, saturated hydraulic conductivity, field capacity and available water were affected by slope and the interaction between the effect of slope and soil depth.
2. Soil physical characteristics of the study area such as sand, silt, clay and saturated hydraulic conductivity were affected by soil depth.
3. Soil physical characteristics of the study area such as bulk density, total porosity and permanent wilting point were not affected by slope, soil depth and the interaction between the effect of slope and soil depth.
4. Soil physical characteristic of the study area such as available water was not affected by soil depth.
5. A total of four soil textural classes, namely loamy sand, sandy loam, sandy clay loam and clay loam dominated the soils of the experimental site with the upper slope level having the four soil types involved, middle slope level having been dominated by loamy sand and sandy clay loam and while that of bottom slope level was found to be dominated by sandy loam soil only.

5. REFERENCES

1. Akinbola, G. E., Anozie, H.I. and Obi, J.C. "**Classification and characterization of some pedons on basement complex in the forest environment of south-western Nigeria**". *Nigerian J. of Soil Sci*, 2009. 19, (1) 109-117.
2. Blake, G. R., and Hartge, K. H. "Bulk density", In: Klute A (Ed) **Methods of Soil Analysis. Physical and Mineralogical Methods, part 1**, 2nd edition. Madison, *WI.:* ASA-SSSA, 1986.363-375.
3. Bouma, J. "**Soil survey interpretation: estimating using the potentials of clay soil under various moisture regimes**", *Geoderma.1981. 26:165-177.*
4. Brady, C.N., and R.R. Weil. '**The nature and properties of soil'**, 12th edition, Prentice hall, Englewood, nj. 1999.
5. Brubaker. S.C., Jones, A.J., Lewis, D. T., and Frank, K. **Soil properties associated with landscape position**. *Soil Science*

*Society of America Journal*1993. 57: 235-239.

6. Enya, O. O., Omueti, J. A. I. and Akinbola, G. E. **Particle Size and Free Iron Oxides Distribution along Two Toposequences in South Western Nigeria**. *Continental J. Agronomy*. 2011. *5* (2): 22 - 31.
7. Gee, G.W, and Or, D. "**Particle size analysis**," In: Dane, J. H., Toop, G. C. (Eds.), *Methods of Soil Analysis Part 4*, SSSA. Book Series No.5. Madison, Wi USA Soil Sci. Society of Am., 2002.: 255-293.
8. Kolo, E., Takim, F. O. and Fadayomi, O. **Influence of planting date and weed Management practice on weed emergence, growth and yield of maize (*Zea mays* L.) in Southern Guinea Savanna of Nigeria**. *African crop science journal*, 2012. *9 (*4) 615-627.
9. Malgwi, W. B., Ojanuga, A.G., Chude, V. O. Kparmwang T. and Raji, B. A "**Morphological and Physical Properties of Some Soil at Samaru Zaria, Nigeria**". *Nigerian Journal of Soil Research*, .2000. (1): 58–64.
10. Moorman, F. R **Representative of toposequence of soils in southern Nigeria and their pedology. In characterization of soils in relation to their classification and management for crop production**. D. J. Greenland (ed) Clarendo press Oxford . 1981.29pp.
11. Odu, C. T. I., Babalola, O., Udo, E. J., Ogunkunle, A. O., Bakare, T. A., and Adeoye, G. O. ***Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology***, University of Ibadan. 1986.
12. Ogunkunle, A. O. **Topographic location, soil characteristics and soil classification in three bio-geological locations in Mid-Western Nigeria**. *Malaysian Journal of Tropical Geography*. 1990. 19: 22-32.
13. Ogunkunle, A. O. **Variation of some soil properties along two toposequences on Quartzite Schist and Banded Gneiss in South Western Nigeria**. *An International Journal of Physical, Social, and Economic Geography and Application in Environmental Planning and Ecology*. 1993. 30.4: 397 - 402.
14. Okusami, T. A. and Oyediran, G. O. **Slope-Soil Relationship on an Aberrant Toposequence in Ife Area of Southwestern Nigeria: Variabilities in Soil Properties**. *Ife Journal of Agriculture,* 1985. 7: (1&2): 1-15.
15. Okusanmi, T. A., R. H. Rust and A. S. R. Juo. **Characterization and classification of some soil formed on post-cretaceous sediments in southern Nigeria**. *Soil Sci.* 1985, *140: 110 – 119.*
16. Olaniyan, J. O. ***An Evaluation of the Soil Map of Nigeria for Land use Planning in kwara State.*** A Ph.D thesis Dept of Agronomy, University of Ibadan, Nigeria. 2003. 211pp.
17. Oluwatosin, G. A., J. O. Ojo-Atere, O. Osiname and J. A. Adeniran **Influence of topographic position on crop responses to different rates of fertilizer in southwestern Nigeria**. *Moor J. Agric. Res* 2001., *2: 1 - 7.*
18. Smyth, A. J. and Montgomery, R. F. **Soils and land use in Central Western Nigeria**. *The Government Press*, Ibadan-Nigeria. 1962. 1962.
19. Stoop, W. A. **Adaptation of Sorghum maize and sorghum pear millet intercrop to the toposequence land types in North Sudanian zone of West Africa Savannah**. *Field Crops Res.* 1978. 16: 255 – 272.
20. Wang, Projietu and Liding Chen **Soil Nutrients in Relation to Land Use and Landscape Position in the Semi-Arid Small Catchment on the Loess Plateau In China**. *J. Arid. Env.* 2001.48: 537-550.
21. Willocks, T. J. **The tillage of clod-forming sandy loam soils in the semi-arid climate of Botswana**. *Soil Tillage and Research,* 1984. 1:323-530.