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Variation in Physico-Chemical Properties of Some Pedons of Sedimentary Parent Materials as Affected by Landscape Position and Depth

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ABSTRACT

A variability analysis of some pedons formed on sedimentary parent materials in south-western Nigeria was made, and their potential for sustainable crop productivity was evaluated. Three locations (Eggua, Esan and Papalanto) were surveyed and sampled for the experiment. Three landscape positions (Upper, Middle and Lower Slopes) were identified and soil sample was collected at the depth of 0-30cm and 30-60cm for each landscape position for physical and chemical analysis in each of the location. Data collected were subjected to 2-Way Analysis of Variance arranged in a randomized completely block design with Location, landscape position and soil depth as factors and soil physical and chemical properties as variables. Significantly different means were separated using LSD at ($P \leq 0.05$) level of probability. Descriptive statistical analysis was also carried out to evaluate measure of dispersion and mean for all variables. The variability of soil properties within and among pedons was measured by estimating the percentage coefficient of variation (%CV). The results of this study revealed that pH in water, pH in KCl, BS and BD had the least variation when compared with Na, ECEC and sand which showed low to moderate variation and TN, OC, P, Ca, Mg, K, Fe, Mn, Cu, Zn, silt and clay which shows low, moderate, high to very high variation. Also results from the analysis of variance also show that landscape positions have significant ($P \leq 0.05$) effects on P, Fe, Mn, Cu, Zn, BS, Mg, Na, ECEC and silt, whereas, TN, OC, Ca, K, pH in water, pH in KCl, sand, clay and BD were not significantly influenced by landscape positions. Soil depth did not significantly ($P \leq 0.05$) affect the availability, distribution and concentration of TN, P, Fe, Mn, Cu, Zn, BS, Ca, Mg, K, Na, ECEC, sand and silt. Significant ($P \leq 0.05$) differences in OC, pH in water, pH in KCl, Clay and BD were observed with soil depth in all the three locations investigated.

Introduction

Assessing land use induced changes in soil is essential for addressing agro-ecosystem transformation and sustainable soil productivity issues. Variations in soil quality could be consequent of the nature of parent material (Ibanga, 2006), land use types, topography and soil erosion. In the tropics, the selection of suitable land use type is of paramount importance for sustainable agriculture. Soil variability could either be spatial or temporal. Spatial variability is a variation in soil properties which occurs with distance, while temporal variability is a seasonal variation in certain soil properties that display continuous variation depending on the activities on them (Akinbola *et al*., 2010). Spatial variability could be attributed to changes in macro and micro flora and fauna (Lal, 2000). Stolt *et al*., (1993) also added that spatial variability is universal to all soils and could be induced by differences in weathering rates, lithology, topographic differences and hydrological characteristics of the soil. Temporal variability on the other hand, could arise from changes in soil properties such as bulk density, hydraulic conductivity, thermal conductivity, infiltration rate, water table depth, CO_2 accumulation, soil texture and even ground water quality (Cassel, 1983). 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). Land use patterns are often highly correlated with bio-physical variables such as slope and elevation gradients (Mottet and Ladet, 2006). Inappropriate land use can aggravate the rate of soil degradation affecting soil biological and physico-chemical qualities (Saikh *et al*., 1998). Understanding the role of several soil properties together, and their interactions, may help to explain the cause of variation in crop productivity as defined by site-specific management zones. Therefore, the objective of this study is to evaluate the variability of some pedons of sedimentary parent materials as affected by landscape position and depth and give recommendation on site-specific management zones for sustainable crop productivity.

Material and Method

Description of the Study Sites

The study was carried out based on data acquired from three different locations:

Location 1

North-east of Eggua town, the area is located within Latitudes 07.0º and 07.05º N and Longitudes 002.88º and 002.95º E, of Ogun State (Plate 1). Eggua area has a humid tropical climate, characterized by seasonal rainfall, high Temperatures and high humidity. The annual rainfall is about 1150 mm.

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The rains are usually torrential and may be accompanied by thunder and lightning particularly towards the end of the wet season between September and October. The temperature is high, with slight variations throughout the year. The maximum temperature range is about 27.9^{o}C – 34.7^{o}C and minimum temperature range is about 20.0^{o}C – 22.8^{o}C. Relative humidity is fairly high with ranges of about 73 – 878, 38 – 748 and 83 – 95% at 09 hours, 15 hrs and 21 hrs respectively. Higher percentages of relative humidity are recorded usually at the middle of the wet season when the sky may become unusually very cloudy and rainfall is heavy.

Location 2

South-easthern corner of the Esan West Local Government Area, located within latitudes 06.50833º and 06.56667º N and longitudes 006.18333º and 006.21667º E, of Edo State (Plate 1). The climate is characterized by two distinct seasons in the year. These are the rainy and dry season. The total annual rainfall is generally more than 2000mm. The temperature in the area is generally high with very little fluctuation, usually less than 5ºC throughout the year, both for the minimum and maximum temperature. The month of February, March and April record the highest daily maximum temperature (31-36ºC), while the month of July and August have the lowest mean daily maximum temperature (27-29ºC). The relative humidity is generally high throughout the year, being more than 55% at any given point in time. The month of December, January and February, being the dry season have the least relative humidity, ranging from 57-86%. The rainy months have higher range of relative humidity (66-93%).

Location 3

2 km, west of Papalanto along Papalanto-Ilaro road, located within latitudes 06.883º and 06.90º N and longitudes 003.16667º and 003.20º E in Ewekoro Local Government Area of Ogun State (Plate 1).

Plate 1. Map of the study locations

The area has a hot and humid tropical climate like the rest of the southwestern Nigeria, characterized by seasonal rainfall, high temperature and high humidity. The environment is characterized by two distinct seasons in the year. These are rainy and dry season. The total rainfall per annum ranges from about 790-1600mm. The rain is said to have been established when at least 100mm have fallen in a year. The temperature in the area like most other tropical environment is generally high with minimal fluctuations, usually less than 5ºC throughout the year. The highest of the mean-daily maximum temperature are recorded in the month of February and March (38ºC), while the month of July and August have the lowest maximum temperature (28.3ºC) in the year. The mean daily minimum temperature in the area shows a range of 15.7ºC in December and 26.1ºC in March. The relative humidity in the area is generally high throughout the year.

Sampling Collection and Method

Mapping units were identified in relation to physiographic position (i.e Upper, Middle and Lower Slope) on each of the site. Profile pits were sunk and described according to the FAO guideline (2006). After the description of the sites and soil profiles, samples were taken at a depth of 0-30cm and 30-60cm for each profile, put into polythene bags and appropriately labeled for laboratory analysis. Replicate soil core samples for bulk density determination were also taken from each profile using Anderson and Ingram (1993) method.

Laboratory Analysis

The soils samples that were taken from each pit were taken to the laboratory for chemical properties and particle size analysis. They were air-dried, crushed and sieved through a 2mm mesh. Particles size fractions were determined using the Bouyoucos (1951), hydrometer method. Soil pH was determined in 1:1 soil: water ratio, and by KCl media using a glass electrode pH meter with calomel electrode (Bates, 1954). Organic carbon was estimated by the dichromate wet oxidation method of Walkey and Black (1934). Total nitrogen was determined by the micro-Kjedahl method of Jackson (1962). Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945); while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral NH_4OAC. Calcium, K, and Na were measured through a flame photometer, while Mg was determined by atomic absorption spectrophotometer (Rhoades, 1982). Exchangeable acidity was determined by INKC1 extraction and titrated with 0.05N Na04 solution (Black, 1975). Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micronutrients (Fe, Mn, Zn and Cu) were determined in 0.1N HC1 extract and evaluated using the atomic absorption spectrophotometer (Jackson, 1962).

Statistical Analysis

Data obtained were subjected to 2-Way Analysis of Variance (ANOVA) arranged in a randomized completely block design (RCBD) using GenStat (Version 8.1) computer software. Significantly different means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability. Descriptive statistical analysis was used with the aid of statistical package (SPSS) Version 20 to evaluate standard deviation and mean for all variable. The variability of soil properties was measured by estimating the percentage coefficient of variation (%CV), which was calculated as:

$$CV (\%) = \frac{Sd}{X} \times 100$$

Where Sd = Sample standard deviation

Table 1. Chemical properties of the pedons along the toposequence of all the three locations

Soil Depth	pH	pH	TN	O.C	P	Ca	Mg	K	Na	ECEC	BS	Fe	Mn	Cu	Zn
	H_2O	KCl	(g/kg)		(mg/kg)	(cmol/kg)					(%)	(mg/kg)			
Location 1															
Upper Slope															
0-30	6.5	4.5	0.88	7.62	9.03	4.0	3.6	0.6	1.0	9.75	95.15	98.64	228.74	6.33	15.54
30-60	5.0	3.2	0.81	5.10	8.19	3.2	3.8	0.6	0.9	10.48	86.85	83.63	161.43	5.46	11.03
Middle Slope															
0-30	5.8	3.5	0.49	15.21	3.01	3.0	2.6	0.6	0.8	8.70	88.70	84.37	158.38	4.53	20.58
30-60	5.1	2.9	1.12	8.11	0.70	2.6	2.7	0.6	0.7	13.58	64.10	95.88	86.18	4.40	14.00
Lower Slope															
0-30	6.0	4.3	1.51	20.42	2.17	8.9	8.0	0.7	1.1	19.22	97.80	220.68	319.18	9.34	51.92
30-60	5.3	3.2	0.98	6.32	7.98	6.9	9.5	0.8	1.4	19.00	97.75	236.83	311.39	9.83	52.88
Location 2															
Upper Slope															
0-30	5.7	4.7	0.57	5.42	3.75	1.3	1.4	0.1	0.3	3.95	76.55	101.45	345.50	0.91	5.61
30-60	5.2	4.0	0.18	1.71	0.13	0.9	1.0	0.0	0.3	3.96	55.80	61.25	147.80	0.48	4.17
Middle Slope															
0-30	5.2	4.2	0.43	4.09	0.98	1.0	0.8	0.1	0.3	3.44	63.10	141.15	63.70	1.28	4.65
30-60	4.7	3.5	0.13	1.24	1.04	2.3	0.6	0.0	0.3	5.44	58.80	43.60	59.10	0.25	4.34
Lower Slope															
0-30	5.7	4.8	1.16	11.21	2.66	1.6	2.1	0.1	0.3	4.62	86.80	91.25	357.50	1.77	5.60
30-60	5.1	4.2	0.27	2.57	1.16	1.3	1.5	0.0	0.4	3.91	80.40	50.70	123.80	0.76	3.70
Location 3															
Upper Slope															
0-30	5.0	4.4	10.88	30.43	23.17	4.2	2.8	0.7	0.8	12.13	71.25	204.45	99.40	9.12	32.42
30-60	5.0	4.0	2.11	14.65	13.13	4.3	3.3	0.9	0.9	12.89	72.70	184.00	103.00	9.73	28.16
Middle Slope															
0-30	5.5	4.5	7.02	24.42	6.86	4.9	3.0	0.8	0.9	11.76	80.50	129.60	99.70	8.11	27.37
30-60	4.6	3.8	5.27	17.39	3.63	5.0	3.6	0.8	0.9	16.41	62.70	124.85	92.75	8.47	27.87
Lower Slope															
0-30	4.7	4.1	5.28	21.63	9.50	4.6	2.9	0.8	0.9	13.64	67.75	203.00	94.35	8.55	34.14
30-60	4.8	3.8	4.24	15.54	9.18	4.3	3.2	0.8	0.9	13.74	67.15	241.90	152.50	10.21	42.24

X = Sample mean

Results and Discussion

Chemical Properties of the pedons

The results in Table 1 show data on soil chemical properties of the three locations as influenced by landscape positions and depth. Soil pH in water was generally acidic with values ranging between 4.6-6.0, but slightly acidic the at the topsoil (0-30cm) of upper slope in location 1, while Soil pH in KCl was also generally acidic with value ranges between 3.2-4.8, the values along the toposequence were similar but that of the upper and lower slope were slightly higher than that of the middle slope. The trend of soil pH obtained in this toposequence is an evidence of chemical weathering. This is in conformity with the findings of Babalola *et al*. (2007) who did similar work on soil properties and slope position in a humid forest and observed same trend of pH. Total nitrogen was relatively low in location 1 and 2 with values ranging from 0.13-1.51 which is below critical level of 2.0g/kg. In location 3, Total nitrogen value was found to exceed the critical level. Organic carbon which has direct relationship with organic matter was high at the lower slope and reduces upward to the upper slope. This is in line with the findings of Paul and Clark (1989) which showed increase in Organic carbon down the toposequence. The available P values in all the slope position, except at the topsoil of upper slope of Location 3, is low ranging from 0.13-13.13mg/kg in all the three locations, landscape positions and depth, available P is below critical level.

Ca values along the toposequence in all the three locations and depth were low except in the lower slope of Location 1, ranging from 1.0-5.0cmol/kg based on the critical values of 5.0cmol/kg (Amalu, 1997). Na values along the toposequence were high in all 3 Locations ranging from 0.3-1.4cmol/kg based on the critical values of 0.02cmol/kg (Amalu, 1997).

Mg values along the toposequence were also high in all the 3 Locations ranging from 0.6-9.5cmol/kg based on the critical values of 0.50cmol/kg (Onyekwere *et al*., 2003). The K values along the toposequence were above critical level ranging from 0.6-0.9cmol/kg in Location 1 and 3, and relatively low in Location 2 as against the critical level of 0.16–0.25 cmol/kg (Akinrinde and Obigbesan 2000).

The ECEC values in the toposequence in all the 3 Locations ranges from 3.44-19.22cmol/kg, which is also low (<24cmol/kg) in all the three locations. The low ECEC may have been attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly Kaolinite in their clay fractions. This finding is also in agreement with that of Korieocha *et al*. (2010), Ogeh and Ukodo (2012) who worked on inland valley soils of south eastern Nigeria and forest zone of South Western Nigeria respectively and observed low ECEC.

Particle Size Distribution and Bulk Density of the Pedons

The results in Table 2 show data on particle size distribution at each landscape position of the 3 Locations. The sand fraction generally dominated the soils along the toposequence. Within the horizons, the sand content decreased with depth in all the profiles, silt content decreased with depth except in middle slope of Location 1 and 3 in all the profile.

The removal by illuviation of silty materials by rainwater or by erosion from the top slope and subsequent deposition down the slope could be the reason for the trend. These results are also in agreement with the findings of Voncir *et al*., (2008) who worked on profile distribution of some physicochemical properties of soil along a toposequence. The clay content increased with depth in all the landscape position in all the locations. The trend in the clay content at the upper horizon maybe as a result of processes like pedoturbation and insitu weathering in the middle horizon, while the movement of clay down the profile through illuviation may have contributed higher content in the subsoil. Noma *et al.,* (2011) also reported similar results in a chrono-toposequence study of soils in Sokoto State, Nigeria. This is also in agreement with the findings of Udoh *et al*., (2010). The bulk density increases with depth in all the 3 Locations, except in Location 2 (upper and lower slope) where it decreases with depth.

Table 2. Bulk density and particle size distribution of the pedons along the toposequence of the three locations

Soil Depth (cm)	BD (g/cm3)	Particle Size Distribution(g/kg)		
		Sand	Silt	Clay
Location 1				
Upper Slope				
0-30	1.9	792	124	84
30-60	2.04	652	94	254
Middle Slope				
0-30	1.61	812	74	114
30-60	2.15	692	84	224
Lower Slope				
0-30	1.6	372	314	314
30-60	1.99	242	194	564
Location 2				
Upper Slope				
0-30	1.72	832	100	68
30-60	1.59	722	90	188
Middle Slope				
0-30	1.16	822	90	88
30-60	1.3	692	50	258
Lower Slope				
0-30	1.51	771	161	68
30-60	1.46	752	157	91
Location 3				
Upper Slope				
0-30	1.35	832	64	104
30-60	1.5	672	54	274
Middle Slope				
0-30	1.25	862	64	74
30-60	1.5	772	74	154
Lower Slope				
0-30	1.39	832	24	144
30-60	1.45	782	14	204

Variation in physical and chemical properties of the pedons

The Coefficient of Variation (CV) in percentage of all the parameters evaluated among the three locations as affected by Landscape position and Soil Depth is presented in Table 3. pHw, pHk, BS and BD with CV(%) value ranging from 6.3-10.2, 7.1-17.6, 8.5-17.8 and 7.1-14.0 respectively, appears to show the least variation in all the parameters tested in all three locations. K with CV(%) values ranging from 7.9-109.5 show a low variation in location 1 and 3 and very high variation in location 2. TN and OC with CV(%) values ranging from 34.0-59.1 and 26.9-59.3 respectively shows moderate variation in location1 and 3 and a high variation in location 2. Ca and Mg with CV(%) values ranging from 7.4-44.3 and 9.2- 48.9 respectively show low variation in location 3 and moderate variation in location 1 and 2. Sand, Na and ECEC with CV(%) values ranging from 7.2-44.4, 4.8-23.7 and11.8-33.5 respectively appears to show low variation in location 2 and 3, and moderate variation in location 1.

Fe with CV(%) values ranging from 25.0-44.8 was found to show moderate variation in all three locations. Mn and Cu with CV(%) values ranging from 18.5-64.8 and 8.8-54.6 respectively show between low, moderate and high variation in location 3, 1 and 2. Zn with CV(%) values ranging from 16.4-60.8 was found to show low variation in location 2 and 3, and high variation in location 1. Silt with CV(%) values ranging from 40.9-55.2 exhibit a moderate variation in location 1 and 2 and a high variation in location 3. EA and Clay with CV(%) values ranging from 30.4-65.1 and 41.2-53.3 respectively show moderate variation in location 2 and 3 and a high variation in location 1. P with CV(%) values ranging from 50.6-74.4 appears to show high variation in all three locations in all the parameters tested.

Influence of physiograghic position and depth on soil chemical properties

Result in table 4 shows the analysis of variance of soil chemical properties of all three locations as influenced by landscape position depth. Total nitrogen loss was not significantly ($P \leq 0.05$) different in all the three locations and soil depth. This implies that Nitrogen loss in all the three locations across the landscape (upper, middle and lower slope) are the same due to their unstable nature and sensitive to slope in all the sites. There was no significance ($P \leq 0.05$) difference in Organic carbon loss in all three landscape positions (upper, middle and lower slope) in all the locations, but significance ($P \leq 0.05$) difference in Organic carbon loss was observed in soil depth and interaction in all three locations. The amount of Organic carbon loss seems to be reduced as we move down the profile; this may be as a result of changes in slope, i.e from steeper to gentle. Organic carbon which has direct relationship with organic matter is expected to be high at the valley bottom which was not included in the present study. A significant ($P \leq 0.05$) difference was observed in the loss of Available phosphorus in all landscape positions (upper, middle and lower slope), but soil depth and interaction does not significantly affect available phosphorus loss in all the three locations. Fe, Mn, Cu, Zn and BS shows a significant ($P \leq 0.05$) difference in losses in landscape positions (upper, middle and lower slope) and interaction, but were not significantly affected by soil depth in all the three locations.

Influence of physiograghic position and depth on exchangeable cations and ECEC in the three locations

Table 5 shows the result of analysis of variance of Exchangeable cations and Effective cation exchange capacity of the three locations as influenced by landscape positions and depth. Ca and K loss were not significantly affected by landscape position and soil depth, but a significant ($P \leq 0.05$) difference was observed in interaction. This implies that the rate at which Ca and Potassium are lost in the toposequence are the same for each location investigated. Mg, Na and ECEC shows a significance ($P \leq 0.05$) difference in loss in both landscape position and interaction, but significant ($P \leq 0.05$) difference was not observed in soil depth in all the three locations. This can be attributed to either the type of tillage operation or land use pattern the land are being put into.

Table 3. Variation in the physical and chemical properties of soils in Location 1 (Eggua), Location 2 (Essan) and Location 3 (Papalanto)

Soil Properties	Location 1			Location 2			Location 3		
	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)
pH(H_2O)	5-6.5	5.8	10.2	4.7-5.7	5.2	7.4	4.6-5.5	5.1	6.3
pH(KCl)	2.9-4.5	3.7	17.6	3.5-4.8	4.2	11.5	3.8-4.5	4.2	7.1
TN (g/kg)	0.49-1.51	1.0	34.0	0.13-1.16	0.7	59.1	2.11-10.88	6.5	45.6
OC (g/kg)	5.10-20.42	12.8	47.2	1.24-11.21	6.2	59.3	14.65-30.43	22.5	26.9
P (mg/kg)	0.7-9.03	4.9	74.4	0.13-3.75	1.9	68.4	3.63-23.17	13.4	50.6
Ca (cmol/kg)	2.6-8.9	5.8	44.3	0.90-2.30	1.6	31.6	4.2-5.0	4.6	7.4
Mg (cmol/kg)	2.6-9.5	6.1	48.9	0.60-2.1	1.4	40.5	2.8-3.6	3.2	9.2
K (cmol/kg)	0.6-0.8	0.7	12.0	0.0-0.1	0.1	109.5	0.7-0.9	0.8	7.9
Na (cmol/kg)	0.7-1.4	1.1	23.7	0.30-0.40	0.4	11.7	0.8-0.9	0.9	4.8
EA(cmol/kg)	0.43-4.87	2.7	65.1	0.55-2.25	1.4	47.4	2.32-6.13	4.2	30.4
ECEC(cmol/kg)	8.7-19.22	14.0	33.5	3.44-5.44	4.4	15.9	11.76-16.41	14.1	11.8
Fe (mg/kg)	83.63-236.83	160.2	44.8	43.6-141.15	92.4	40.1	124.85-241.90	183.4	25.0
Mn (mg/kg)	86.18-319.18	202.7	45.7	59.10-357.5	208.3	64.8	92.75-152.5	122.6	18.5
Cu (mg/kg)	4.4-9.83	7.1	33.5	0.25-1.77	1.0	54.6	8.11-10.21	9.2	8.8
Zn (mg/kg)	11.03-52.88	32.0	60.8	3.7-5.61	4.7	16.8	27.37-42.24	34.8	16.4
BS (%)	64.1-97.8	81.0	15.8	55.8-86.8	71.3	17.8	62.7-80.5	71.6	8.5
Sand (g/kg)	242-812	527	44.3	692-832	762	7.2	672-862	767	8.8
Silt (g/kg)	74-314	194	47.7	50-161	105.5	40.9	14-74	44	55.2
Clay (g/kg)	84-564	324	53.3	68-258	163	48	74-274	174	41.2
BD (g/cm^3)	1.6-2.15	1.9	12.2	1.16-1.72	1.4	14	1.25-1.5	1.4	7.1

Table 4. Effect of landscape position and depth on soil chemical properties of the three locations

Landscape Position	TN	OC	P	Fe	Mn	Cu	Zn	BS
	(g/kg)			(mg/kg)				(%)
Upper Slope	2.57	10.82	9.57	122.0	181.0	5.34	16.20	76.40
Middle Slope	2.41	11.74	2.70	103.0	93.0	4.51	16.50	69.60
Lower Slope	2.24	12.95	5.44	174.0	226.0	6.74	31.70	82.90
$LSD_{0.05}$	NS	NS	4.42	63.90	102.5	1.70	13.27	11.35
Depth								
0-30	3.13	15.60	6.79	142.0	196.0	5.55	22.0	80.80
30-60	1.68	8.07	5.01	125.0	138.0	5.51	20.90	71.80
$LSD_{0.05}$	NS	4.10	NS	NS	NS	NS	NS	NS
Landscape position X Depth								
$LSD_{0.05}$	NS	7.10	NS	90.30	145.0	2.41	18.77	16.05

LSD = Least Significance Difference at 5% level of probability

NS = Not Significant

Influence of physiograghic position and depth on soil pH in water, pH in KCl, Particle size distribution and Bulk density in the three locations

The results of analysis of variance of Soil pH in water, pH in KCl, Particle size distribution and Bulk density of the three locations as influenced by landscape position and soil depth is shown in Table 6. pH in water, pH in KCl and bulk density were not significantly ($P \leq 0.05$) affected by landscape position, but a significant ($P \leq 0.05$) difference was recorded in both soil depth and interaction in all the three locations studied. There was no significant ($P \leq 0.05$) difference in movement of sand fraction in both landscape position and soil depth in all the three locations but there was significant ($P \leq 0.05$) difference in interaction.

Table 5. Effect of landscape position and depth on Exchangeable cations and effective cations exchange capacity of the three locations

Landscape Position		Ca	Mg	K	Na	ECEC
		(cmol/kg)				
Upper Slope		2.98	2.67	0.49	0.70	8.86
Middle Slope		3.12	2.21	0.49	0.64	9.89
Lower Slope		4.59	4.53	0.54	0.83	12.35
$LSD_{0.05}$		NS	2.10	NS	0.19	3.26
Depth						
0-30		3.73	3.03	0.51	0.71	9.69
30-60		3.39	3.25	0.51	0.74	11.04
$LSD_{0.05}$		NS	NS	NS	NS	NS
Landscape position X Depth						
$LSD_{0.05}$		2.78	2.97	0.10	0.27	4.41

LSD = Least Significance Difference at 5% level of probability

NS = Not Significant

Table 6. Effect of landscape position and depth on Soil pH in water, pH in KCl, particle size distribution and bulk density of the three locations

Landscape Position	pH (H_2O)	pH (KCl)	Sand	Silt	Clay	BD
			(g/kg)			(g/cm^3)
Upper Slope	5.4	4.1	750	88	162	1.68
Middle Slope	5.1	3.7	775	73	152	1.49
Lower Slope	5.3	4.1	625	144	231	1.57
$LSD_{0.05}$	NS	NS	NS	75.60	NS	NS
Depth						
0-30	5.5	4.3	770	113	118	1.50
30-60	5.0	3.6	664	90	246	1.66
$LSD_{0.05}$	0.34	0.30	NS	NS	109.10	0.16
Landscape positionX Depth						
$LSD_{0.05}$	0.60	0.52	243.7	NS	NS	0.27

LSD = Least Significance Difference at 5% level of probability

NS = Not Significant

This implies that the rate at which sand is removed from the upper slope and deposited down the lower slope or valley bottom is same in all the three locations investigated. The sand fraction generally dominates the soils along the toposequence. A significant ($P \leq 0.05$) difference was observed in the movement of silt fraction as result of changes in landscape position (ie, from upper to lower slope), but depth does not have any effect on movement and loss of silt in all the three locations studied, similarly, so do interaction. The removal by eluviations of silty materials by rainwater or by erosion from the top slope and subsequent deposition down the slope could be the reason for this trend. These results is in agreement with the findings of Ogeh and Ukodo (2012) who worked on profile distribution of physical and chemical properties in soils of a toposeqence in Benin, Nigeria. Clay shows a significant ($P \leq 0.05$) difference in soil depth, but no significant ($P \leq 0.05$) difference was observed in landscape position and interaction in all the three locations studied. This may be attributed to the fact that the amount of clay content increases as we move down the profile, and this amount vary for each pedon even if they are formed under the same parent material as a result of the process of illuviation and eluviations. Noma *et al*., (2011) also reported similar results in a chrono-toposeqnence study of soils in Sokoto State, Nigeria. This is also in agreement with the findings of Udoh *et al*., (2010).

Conclusion

Soil variation occurs naturally from pedogenic factors and across multiple geographic scales ranging from small to very large field. Thus, evaluating agricultural land management practice requires the knowledge of soil spatial variability and understanding the relationship of soil properties in a toposequence. Since farmers are beginning to crop on marginal lands including farming on slope in many tropical countries, these findings also allow prediction or estimation of values of un-sampled locations within the region and serve as a basis for defining different management zones on a field or an area, as different soils occur at different position on the landscape even though they are formed from the same parent materials. This various positions can have effect on yield of crops. Depending on the location on a slope, physical and chemical properties of soil will also vary either minimally or maximally. Several attempts has been made to relate soil properties to landscape position for many landscape, this may be partly due to the realization of the role of topographic position plays in influencing runoff, soil erosion and hence soil formation. This study has shown the relationship between soil properties, landscape position (upper, middle and lower slope), soil depth (0-30, 30-60cm) and the potentials of the soil properties to crop production, The results of this study reveal that pH in water, pH in KCl, BS and BD has the least variation when compared with Na, ECEC and sand which shows least to moderate variation and TN, OC, P, Ca, Mg, K, Fe, Mn, Cu, Zn, silt and clay which shows least, moderate, high to very high variation in the 3 Locations investigated. Results from the analysis of variance also shows that landscape positions has a significant ($P \leq 0.05$) effect on P, Fe, Mn, Cu, Zn, BS, Mg, Na, ECEC and silt, whereas, TN, OC, Ca, K, pH in water, pH in KCl, sand, clay and BD do not show any significant ($P \leq 0.05$) difference in landscape positions. Soil depth does not significantly ($P \leq 0.05$) affect the availability, distribution and concentration of TN, P, Fe, Mn, Cu, Zn, BS, Ca, Mg, K, Na, ECEC, sand and silt, a significant ($P \leq 0.05$) difference in OC, pH in water, pH in KCl, Clay and BD was observed in soil depth in all three Locations investigated.

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