Variability Of Some Soil Properties Along Toposequence On A Basaltic Parent Material Of Vom, Plateau State Nigeria

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ABSTRACTS: Topography influences the distribution of soil physico-chemical properties. This study assessed soil properties variation resulting from topographic aspect on basaltic parent material at Vom Jos Plateau State in the Southern Guinea zone of Nigeria in order to understand the general soil behaviour, degree of development, nutrients availability and its response to management activites. The result revealed variations in soil properties among the landscape segments which were probably due to the toposequence characteristics in soils. The samples were collected at depth of 0-15cm and 15-30cm, parceled, labeled and taken to laboratory for analysis of the selected for analysis. Clay, silt and gravel contents were moderately variable (CV=22.9%, 15.42% and 32.55% respectively), while sand showed less variability (CV=8.47%). Organic carbon showed high variability (CV=38.08%) while soil pH in (H_2O and $CaCl_2$) showed less spatial variability (with CV=4.91% & 6.45% respectively). Available phosphorus has high variability (CV=37.59%). Magnesium, K and Ca showed high spatial variability (CV=42.60%, 35.85%, & 35.84% respectively), while Na and exchange acidity were moderately variable (CV=24.39% & 24.27% respectively). However, no regular pattern was observed in the distribution of the studied parameters. Therefore, further studies might be required to fully understand and clarify the influence of aspect, topography and vegetation types on soil properties for site-specific soil resource management practices in the study area.

Keywords: basaltic parent material, soil properties, toposequence, variability

INTRODUCTION

The spatial variation of soil properties is significantly influenced by some environmental factors such as topographic aspect induced microclimate differences, topographic positions, parent materials, and vegetation communities **[1**, **2**, **3, 4, 5, 6]**. Topography as a soil-forming processes is affected by erosion and deposition, thus leads to differentiation in soil properties and hydrological conditions [**7]**. Soil topography plays a major role as one of the factors that influence pedogenesis and in the process that dictates the distribution and use of soils on the landscape **[8]**. The concept of toposequence causes properties differentiation along hill slope and among soil horizons have improved evaluating the interacting of pedogenic and geomorphic process **[9]**. The influence of topography as a variants in soil properties has accounted for between 26 and 64% total variation in soil properties **[10,11,12]**. Variation in soil properties has been known and has been the subject of much research, as horizons may differ in organic matter content, structure, texture, pH, base saturation, cation exchange capacity (CEC), bulk density and water holding capacity, as well as many other soil physical and chemical properties. Variability of soil pH, for example, increases with depths **[13]**. **[14]**, worked on the variability of some soil properties along quartzite schist and banded gneiss toposequences in Southwestern Nigeria, noted there was relatively little work and literature on the variability of tropical soils, particularly for the forest zone of Nigeria, compared to the vast work and readily available literature on the availability of physical and chemical properties of temperate soils. In Nigeria, increase in population growth has pose an increasing demand on land resources, leading to clearing of soils on slopes and tilling soil without proper soil management. However, researches on the variation of soil properties along toposequence were conducted much in Forest ecologies compared to savanna biomes. There is need to evaluate the status and distribution of the soil properties along toposequence on basaltic parent materials.

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MATERIALS AND METHODS

Study location:

The study location was Vom, Jos Plateau State situated between longitude 08^0 45' 01 to 8^0 47' 56E'' and latitude 9^0 43' 17 to 9^0 45' 15N, with an elevation of about 1270m above sea level. It has a mean annual rainfall of about 1258mm and temperature of 24^{0}C. The soils of the study area were derived from Newer Basalts material with Ustic soil moisture and Iso hyperthermic temperature regime respectively **[15]**.

Sample Collection and Preparation:

Geographic Position System (GPS) was used to obtain the co-ordinates of the respective sampling sites which were identified using stratified purposive sampling procedure. Soil sampling was carried at 20m interval, at the depth of 0-15cm and 15-30cm at each sampling points. Soil samples were obtained along North-Eastern axis in three replicates.

Laboratory Analysis

The bulk soil samples collected were air-dried, gently crushed and passed through 2mm sieve to remove coarse fragments. Particle size analysis was carried out by the use of Bouyoucos hydrometer **[16]**. The soil pH was determined in water in the ratio of 1:5 soil water suspensions and read with a glass electrode pH metre **[17]**. Available P was determined using Bray ascorbic acid method **[18]**. Organic Carbon percentage was determined using Walkey and Black method as described by **[19]**. Exchangeable Ca and Mg were determined using EDTA titration methods as outlined by **[20]** while exchangeable Na and K were determined using flame photometer following procedure by **[21]**. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by **[22].**

Statistical Analysis

The data was subjected into descriptive statistics, analysis of variance (ANOVA) and correlation analysis using SAS 9.0 statistical software. Coefficient of variability was use for the variability analysis where CV <15% classified as less variable, CV between 15-35% classified as moderately variable and CV >35% classified as highly variable.

RESULTS AND DISCUSSION

Status, Variability and Distribution of Soil Particle Size and Gravel Content

From Table 1, irrespective of the slope location sand is the dominant particle size fraction (ranged 49.20% - 70.60%), followed by silt (19.40% -33.40%), with clay been the lowest (7.40% -25.40%). The gravel content ranged between 15.56% - 67.53% with a grand mean 34.5% (Table 1). Clay, silt and gravel content are moderately spatially variable (CV=22.9%, 15.42% & 32.55% respectively), while sand showed less variability (CV= 8.47%). Clay content was highly skewed (skewness=1.43) with silt, sand and gravel approximately symmetrical (Table 1). The analysis of variance in Table 2, showed a highly significant difference in gravel content and significant difference in clay content along a toposequence, while sand and silt are at par. Although there was no regular pattern along the slope in clay and gravel content, highest mean value was observed at uppermost slope location (1348 masl) and similar/lower values observed at 1341 & 1327 masl respectively. All the sampling points along the toposequence fell into sandy loam textural class (Table 2). The dominant of sand fraction over silt and clay could be due to the sorting of the soil materials and biological activities, clay eluviations and surface erosion or combination of both as reported by **[23, 24]**. The dominance of sand fractions could result to low or poor moisture retention capacityof the soil especially if organic matter content is low.

Status, Variability and Distribution of Soil pH, Organic Carbon and Available Phosphorus

Generally pH (H_2O) was higher than pH ($CaCl_2$). The values of pH (H_2O) were between 5.75 to 7.40, while pH ($CaCl_2$) ranged from 5.13 to 7.30. Organic carbon ranged between 0.76 to 3.11% with a grand mean of 1.92% from Table 3. The soil available phosphorus (Table 1) ranged between 4.82 to 25.00 mgkg^{-1}). Soil pH in (water and $CaCl_2$) showed less spatial variability (with CV = 4.91% & 6.45% respectively) with organic carbon and available phosphorus being highly variable (CV= 38.08% & 37.59% respectively). Available Phosphorus data were moderately skewed (skewness = 0.55) with pH (H_2O), pH ($CaCl_2$) and organic carbon content skewed symmetrically in Table 1. From Table 2, the Analysis of Variance showed a highly significant difference in pH ($CaCl_2$), with pH (H_2O) and organic carbon content being statistically similar along a toposequence (slope). All pH (H_2O) along the slope fell within slightly acid to neutral conditions. No regular distribution pattern along the slope was observed for pH ($CaCl_2$) despite is significant. Also pH (H_2O) and pH ($CaCl_2$) along the soil depth were statistically higher in surface (015cm) than the subsurface (15-30cm). Available phosphorus in Table 3 along the slope was statistically significant (p<=0.05). Highest mean of available phosphorus was observed at middle slope location (1327masl) and lower values observed at (1315masl). Organic carbon (Table 2) and available phosphorus (Table 3) decreased with depth even though they were at par. All the pH values fell within the acceptable range for normal crop growth and development **[25]**. Therefore no potential acidity or alkalinity problem was observed along the studied toposeqence. The organic carbon content was moderate to very high in status and available phosphorus was moderate. Therefore moderate phosphorus fertilizer application for optimal crop yield is required. Similar consistent least spatial variability of pH along the toposequence at all depth was also recoded **[26]**. Also it was reported similarly a high variability in available phosphorus content along a slope in temperate soils **[27]**.

Status, Variability and Distribution of Exchangeable Bases and Exchangeable Acidity

Calcium was the dominant basic cation in the exchange complex with a range of 2.17- 4.00 cmolkg^{-1}, followed by Mg (range 0.50-0.83 cmolkg^{-1}), then K (range 0.27-0.52 cmolkg^{-1}) and Na (range 0.12-0.21 cmolkg^{-1}). Exchangeable acidity range from 0.33 to 3.17 cmolkg^{-1} with a grand mean of 1.70 cmolkg^{-1}. Magnesium, K and Ca showed high spatial variability (CV = 42.60%, 35.85%, & 35.84% respectively), while Na and exchange acidity were moderately variable (CV = 24.39% & 24.27%). K and Mg were highly skewed (skewness = 1.66 & 1.36 respectively). Na and exchange acidity were moderately skewed (skewness = 0.96 & 0.59), while Ca skewed symmetrically (skewness = 0.26). From Table 3, the Analysis of Variance showed significant differences in the amount of exchangeable Na and K along a toposequence while Ca, Mg and exchange acidity were at par. Despite there was no regular pattern of along a slope position in terms of Na and K distribution, the highest mean values were observed at uppermost slope location (1348masl) and the lowest at (1315masl) for Na, while K have highest mean value at (1304masl) and lowest at (1333masl & 1315aslm). Along the depth, Na was statistically higher in the subsurface compared to surface which was contrary to K distribution along the two depths. The exchangeable bases (Ca, Mg, Na and K) fell within low to moderate condition. Similar results were also obtained in soils from Bauchi and Gombe states, respectively **[28]**. This could lead to low CEC and probably indicative of leaching/erosion and presence/dominance of 1:1 Kaolinitic and/or Fe and Al oxide clays. Exchange acidity values were high (more than 1 cmolkg^{-1}) across all the depths and slope locations. In general, the physical properties of the sampled soils were less variable than the chemical properties. The findings of this study are similar to the outcome of **[29]** who also observed that soil physical properties tend to be less variable than the chemical properties

Summary and conclusion

The result revealed that topography influences the distribution of soil physical and chemical properties across the different slope positions. Soil pH was within the optimum range for normal crop growth and development, organic carbon and available phosphorus were moderate to high in status, exchangeable bases were all within low to moderate conditions. Sodium found to increase with increasing depth as opposed to pH and potassium which significantly decreased with increasing depth. For optimum crop production, moderate application of phosphorus and exchangeable bases are required and more in-depth research should be conducted in order to understand the pattern of distribution of soil properties along toposequence in the studied area.

Table 1: *Descriptive Statistics of the Studied Soil Parameters*

Property	Mean	Max	Min	ST.D	Skewness	Kurtosis	CV (%)
Gravel (%)	34.50	67.58	15.56	11.22	0.39	-0.25	32.55
Sand (%)	61.00	70.60	49.20	5.16	-0.50	-0.22	8.47
Silt (%)	25.96	33.40	19.40	4.00	0.10	-0.91	15.42
Clay (%)	13.04	25.40	7.40	2.99	1.43	3.64	22.90
pH (water)	6.60	7.40	5.75	0.32	-0.10	0.40	4.91
pH (CaCl)	5.99	7.30	5.13	0.39	0.50	0.72	6.45
OC (%)	1.92	3.11	0.76	0.73	0.10	-1.25	38.08
Av. P (mg/kg)	11.93	25.00	4.82	4.49	0.55	-0.13	37.59
Na (cmol/kg)	0.16	0.29	0.08	0.04	0.96	2.44	24.39
K (cmol/kg)	0.35	0.92	0.10	0.13	1.36	4.33	35.85
Ca (cmol/kg)	3.27	5.50	1.00	1.17	0.26	-0.99	35.84
Mg (cmol/kg)	0.68	2.10	0.42	0.29	1.66	6.15	42.60
Ex Acid (cmol/kg)	1.70	3.17	0.33	0.41	0.59	3.91	24.27

Table 2: *Distribution of particle size fractions, gravel content, pH and organic matter along a slope and soil depth*

Treatment	Clay (%)	Silt (%)	Sand (%)	Textural class	Gravel (%)	pH (water)	pH ($CaCl_2$)	OC (%)
Slope (S)								
1348m	16.00a	26.73	57.30	SaL	30.29c	6.80	6.39a	1.75
1343m	15.63ab	28.40	55.97	SaL	37.10bc	6.33	5.89cde	2.00
1341m	10.43c	27.10	62.50	SaL	29.61c	6.60	5.99bcde	1.12
1339m	13.90abc	27.73	58.40	SaL	32.04bc	6.61	6.03bcd	2.02
1333m	11.83bc	24.10	64.10	SaL	29.34c	6.50	6.13abc	2.43
1327m	11.70c	26.73	61.60	SaL	32.12bc	6.81	6.30ab	1.70
1320m	12.43abc	24.73	62.83	SaL	33.79bc	6.50	5.66e	1.77
1315m	14.33abc	23.10	62.60	SaL	32.90bc	6.35	5.79cde	2.12
1311m	14.23abc	26.73	59.03	SaL	35.80bc	6.48	5.69de	2.40
1304m	12.23abc	24.73	63.03	SaL	54.99a	6.59	6.10abc	2.07
1298m	12.13abc	26.10	61.80	SaL	44.92ab	6.66	5.96bcde	1.75
1292m	11.73bc	25.40	62.87	SaL	25.97c	6.58	5.92cde	1.95
SE±	1.18	1.56	1.89		4.04	0.11	0.11	0.29
	*	ns	ns		**	ns	**	ns
Depth (D)								
Surface	13.10	26.40	60.53		35.13	6.64a	6.20a	2.03
Subsurface	13.02	25.51	61.50		33.84	6.50b	5.78b	1.82
SE±	0.48	0.64	0.77		1.65	0.05	0.04	0.12
	ns	ns	ns		ns	*	**	ns
Interaction								
S*D	ns	ns	ns		ns	ns	ns	ns

Table 3: Available phosphorus, Exchangeable bases and acidity along a slope and soil depth

Treatment	Av. P (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Ex. Acidity (cmol/kg)
Transect (T)						
A(0m)	13.98a	0.21a	0.40ab	2.96	0.76	1.60
B(20m)	12.20ab	0.14bc	0.40ab	3.33	0.76	1.81
C(40m)	13.59a	0.17bc	0.38b	3.50	0.69	1.72
D(60m)	7.63b	0.18ab	0.29b	2.96	0.69	1.61
E(80m)	10.95ab	0.13c	0.27b	3.42	0.60	1.42
F(100m)	15.58a	0.16bc	0.40ab	2.17	0.50	1.40
G(120m)	12.10ab	0.17abc	0.30b	4.00	0.76	1.97
H(140m)	7.30b	0.12bc	0.27b	3.71	0.69	1.83
I(160m)	10.40ab	0.15bc	0.32b	3.67	0.60	1.61
J(180m)	13.52a	0.16bc	0.52a	3.25	0.83	1.89
K(200m)	13.40a	0.15bc	0.37b	3.75	0.69	1.83
L(220m)	12.70ab	0.16bc	0.33b	2.63	0.69	1.80
SE±	1.74	0.01	0.04	0.47	0.13	0.18
	*	*	*	ns	ns	ns
Depth (D)						
Surface	11.82	0.15b	0.40a	3.32	0.66	1.70
Subsurface	12.05	0.17a	0.32b	3.23	0.71	1.72
SE±	0.71	0.01	0.02	0.19	0.05	0.07
	ns	*	**	ns	ns	ns
Interaction						
T*D	ns	ns	ns	ns	ns	ns

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