REGRESSION MODEL OF TOPOGRAPHY WITH THE DISTRIBUTION OF SELECTED SOIL PROPERTIES IN NORTHEAST AKWA IBOM STATE, NIGERIA

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ABSTRACT

Regression model of topography with the distribution of selected soil properties in Northeast Akwa Ibom State, Nigeria was carried out. The aim was to establish a regression model of topography with the distribution of selected soil properties in Northeast Akwa Ibom State for soil properties predictions and management. Topographic map (or elevation map) of the study area was generated from digital elevation model (DEM) at 30m resolution acquired from United State Geological Survey (USGS). It was classified into three elevation classes of lower elevation (0-50 masl), middle elevation (50-100 masl) and higher elevation (100-150 masl) to guide field sampling. With the aid of Global Positioning System (GPS), the classes obtained from topographic map were cross-checked (ground-truthing) in the field. Modified Conditioned Latin Hypercube Sampling Method was used in selecting observation points. Each observation point was purposively selected to fall within the classes of topographic map to give a good coverage of both feature space (classes of topographic map) and geographical space (study area). A total of 120 soil samples were collected at a depth of 0-30cm and 30-60 cm using soil auger. The samples were taken to the laboratory for analysis. The results revealed variation in soil properties among the three topographic classes under study. Sand fraction was significantly higher ($p > 0.05$) in lower elevation than other elevation classes while silt and clay fractions were significantly higher ($p > 0.05$) in the middle and higher elevations than lower elevation in the study area. Soil pH was significantly higher ($p > 0.05$) (slightly acid) in the lower elevation than middle and higher elevations (moderately acid). Electrical conductivity and base saturation were significantly higher ($p > 0.05$) in the lower elevation than middle and higher elevations. Organic carbon, total N, ECEC, exchangeable Mg and exchangeable K were significantly higher ($p > 0.05$) in the middle elevation than that of lower and higher elevations. Available P of higher elevation was significantly higher ($p > 0.05$) than that of lower and middle elevations. The study also showed that topography accounted for 3 % variation of sand and silt fractions: 5 % variation of clay fraction and 4 % variation of soil pH. Topography also explained 19 % variation of available P, 8.4 % variation of exchangeable K and 5.5 % variation of organic carbon and total N in the study area. The remaining fractions of variation may be attributed to other factors of soil formation such as parent material, climate, organism and time.

KEYWORDS: *regression model, topography, Northeast Akwa State*

INTRODUCTION

Topography (or relief) is a term used to describe earth-surface such as mountain, lowland, valley, hill, plain, Lake etc (Carter *et al*., 1990). Topography is the measurement of differences in elevation across the earth surface, which is a distinguishing factor in topographic map. When lines that connect points of the same elevations are measured, it is called topographic contours. Topography of an area can be studied using topographic maps or digital elevation model (DEM) or both (Moor *et al.*, 1993). Topography is one of the factors of soil formation that influences the distribution of matter and energy occurring from climate and parent materials (Moor *et al.*, 1993). Topography determines the drainage and depth of a soil profile; for instance, soils on higher elevation are usually well drained whereas soil on the lower elevation is usually poorly drained and of fined texture. Soils on a hill or steep slope are usually very shallow and gravelly due to minimal rate of weathering and removal of soil by erosion while soil on gentle slope allow ample infiltration of water and develop into deep profile (Esu, 2010). According to Lawal *et al*., (2014), water velocity on a slope (changes in elevation with respect to distance) affect deposition of materials in suspension, as sand drops out of suspension first, while clay size particles can be carried further away from the upland before they are deposited on the floodplains. This kind of geological sorting brings about variation in soil in relation to the topography of the land surface.. Generally, topography influences soil morphological, chemical and physical properties and also affects the pattern of soil distribution over landscape even when the soils are derived from the same parent material (Esu *et al.,* 2008). This gives rise to a succession of soil types, known as a catena from the hilltop to the valley bottom (Aweto and Enaruvbe 2010). The catenary differentiation of soils is of pivotal importance to the management of soils in different topographic positions in the landscape. Therefore, understanding the regression model of topography with the distribution of soil properties in a landscape will help in assessing productive potentials of soils and most importantly, in developing strategies for effective and sustainable management thereby reducing uniform soil management which could result in some parts of an agricultural field receiving insufficient inputs, while other parts receive an excess (Oku *et al,* 2010).

Non-geostatistical techniques such as multiple regression, artificial neural network, classification and regression trees etc have been used to quantify the relationship between soil properties and environmental covariates for predicting soil properties (Moor *et al.*, 1993). This accounts for the deterministic portion of total variation (the other portion is the stochastic part using geostatistics) (Cook *et al*., 1996). Hence, the objective of this study was to quantify the relationship between topography and the distribution of selected soil properties in Northeast Akwa Ibom State, Nigeria for sustainable soil management.

MATERIALS AND METHODS

Study Area

The study was conducted in Northeast Akwa Ibom State. The state is located in south-South Nigeria. It lies between latitudes $4^0$30'and $5^0$30'N and longitudes 7^0 30'and $8^0$20'E. The study area is underlain mainly by coastal plain sands, sandstone/shale and alluvial deposits parent materials. The annual rainfall ranges from more than 2500 mm to about 3000 mm, with 1 – 3 dry months in the year. Mean annual temperature varies between 26 and 28^0C, while relative humidity varies between 75 – 80 %. The landscape of some parts of the study area consists of hills and ridges with steep sided.

The low-lying areas are underlain by alluvial deposits (Petters *et al.,* 1989).

Preliminary Work

Topographic map (or elevation map) of the study area was generated from digital elevation model (DEM) (Fig.1) at 30m resolution acquired from United State Geological Survey (USGS). It was classified into three elevation classes of lower elevation (0-50 masl), middle elevation (50-100 masl) and higher elevation (100-150 masl) to guide field sampling.

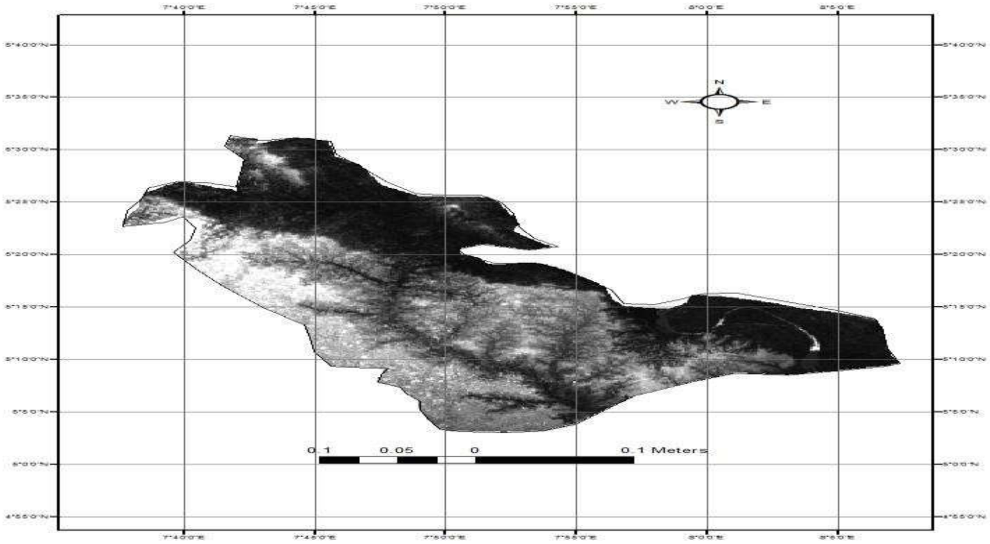


Fig. 1 Digital elevation model of the study area (30 m spatial resolution)

Field Sampling

With the aid of Global Positioning System (GPS), the classes obtained from topographic map were cross-checked (ground-truthing) in the field. Modified Conditioned Latin Hypercube Sampling Method was used in selecting observation points. Each observation point was purposively selected to fall within the classes of topographic map to give a good coverage of both feature space (classes of topographic map) and geographical space (study area). The method ensures that sampling was done in a fully stratified manner. A total of 120 soil samples were collected at a depth of 0-30cm and 30-60 cm using soil auger. The samples were taken to the laboratory for analysis

Laboratory analysis

The following analyses were carried out using appropriate standard procedures:

Particle size analysis was carried out using the Bouyoucos hydrometer method as described by Udo *et al;* (2009). Soil pH was determined in water using a 1:2.5 soil to water suspension and the soil pH was read using a glass electrode. Electrical Conductivity was determined using the conductivity bridge (Udo *et al;* (2009). Organic carbon was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). Available phosphorus was determined using the Bray P.1 extractant. The phosphorus in extract was measured by the blue method as described by Udo *et al;* (2009). Total nitrogen was determined by Kjeldahl digestion and distillation method as described by Udo *et al*; (2009). Exchangeable bases (Ca, Mg, Na, K) were extracted using normal ammonium acetate (Thomas, 1996). The exchangeable K and Na were determined by flame photometer while Ca and Mg were determined using atomic absorption spectrometer. Exchange Acidity was determined using one normal potassium chloride (1NKCl) and by titration method as described by Udo *et al*; (2009). Effective cation exchange capacity (ECEC) was determined by summing up exchangeable cations and exchangeable acidity. Base Saturation was calculated by dividing the total exchangeable bases by the effective cation exchange capacity and multiplied by 100.

$$\% \text{ BS} = \frac{Total\ Exchangeable\ Base\ \times 100}{ECEC} \quad \textit{(Udo et al., 2009).}$$

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) and means were separated using least significant difference (LSD) at 5% level of significance.

Regression model procedures:

The depth interval of 0-30cm and 30-60 cm was integrated to form depth interval of 0- 60 cm. The regression model was carried out in R statistical software. The topographic map which is a raster object (or elevation map) was imported into R. The point data (field observation) was overlaid on raster (topographic map) using sp package in R to produce point data frame with attributed values of predictor (topographic map). Thereafter, simple linear model was fitted for each selected soil property to generate the regression model of the study area (Venables and Ripley, 2002).

RESULT AND DISCUSSION

1. Distribution of Physicochemical properties of soils in the study area

The means physicochemical properties of soils in the study area as influenced by topography are shown in Table 1.

Soil Texture

The mean sand fraction of lower elevation (0-50 masl) was 88.30 % in the surface soils (0-30 cm) and 87.6 % in the subsurface soils (30-60 cm). The silt fraction was 5.0 % and 4.3 % in the surface and subsurface soils respectively. The mean clay fraction was 6.8 % and 8.1 % in the surface and subsurface soils respectively. The mean sand fraction of middle elevation (50-100 masl) was 84.2 % in the surface soils and 76.0 % in the subsurface soils, the mean silt fraction was 6.3 % in both surface and subsurface soils while the mean clay fraction was 9.5 % in the surface soils and 17.7 % in the subsurface soils. The mean sand fraction of higher elevation (100-150 masl) was 83.1 and 81.4 % in the surface and subsurface soils respectively, the mean silt fraction was 6.9 % and 7.9 % in the surface and subsurface soils respectively, while mean clay fraction was 7.8 % and 11.7 % in the surface and subsurface soils respectively. The sand fraction of the lower elevation (0-50 masl) was significantly higher ($p < 0.05$) than that of the middle elevation (50-100 masl) and that of higher elevation (100-150 masl). Silt fraction on the other hand, was significantly higher ($p < 0.05$) in the higher elevation (100-150 masl) than that of lower elevation (0-50 masl) but not different from that of middle elevation (50-100 masl). The clay fraction of the middle elevation (50-100 masl) was significantly higher ($p < 0.05$) than that of lower elevation (0-50 masl) but not different from that of higher elevation (100-150 mas)l. In term of soil depth, sand fraction was significantly higher ($p < 0.05$) in the surface soil (0-30 cm) than subsurface soil (30-60 cm) while the reverse was the case for clay fraction. The high sand fraction in the lower elevation (0-50 masl); silt and clay fractions in the middle (50-100 masl) and higher elevations (100-150 masl) could be attributed to differences in elevation.. Surface runoff due to elevation differences removes the sand fraction from the higher elevation and deposited it at lower elevation (Ufot *et al.,* 2001). Also, the high clay fraction in the subsurface soil compared to surface soil could be attributed to clay translocation or clay illuviation from the surface horizons to subsurface horizons (Ufot *et al.,* 2001).

Soil pH

The mean soil pH of lower elevation (0-50 masl) was 6.3 (slightly acid) in the surface soil and 6.4 (slightly acid) in the subsurface soils. The mean soil pH of middle elevation (50-100 masl) was 5.7 (moderately acid) in the surface soil and 5.8 (moderately acid) in the subsurface soils while that of the higher elevation (100-150 masl) was 5.7 (moderately acid) in the surface soils and 5.5 (strongly acid) in subsurface soils. The mean soil pH of the lower elevation (0-50 masl) was significantly higher ($p < 0.05$) than that of the middle elevation (50-100 masl) and higher elevation (100-150 masl). There was no significant difference ($p < 0.05$) in soil pH between the surface (0-30 cm) and subsurface soil (30-60 cm) in the study area. The high pH values of the lower elevation (0-50 masl) compared to that of the middle (50-100 masl) and higher elevation (100-150 masl) could be attributed to strong downslope colloidal movement. The lower elevation received runoff water from the higher elevation (landscape) with soluble cations; thereby increased the pH of the soil (Kravchenko, 2002).

Electrical conductivity (EC)

The mean electrical conductivity (EC) of lower elevation (0-50 masl) was 0.16 dS/m in the surface soil and 0.19 dS/m in the subsurface soils. The mean EC of middle elevation (50-100 masl) was 0.11 dS/m in the surface soil and 0.06 dS/m in the subsurface soil. The mean EC of higher elevation (100-150 masl) was 0.11 dS/m in the surface soil and 0.07 dS/m in the subsurface soils. The mean EC of the lower elevation (0-50 masl) was significantly higher ($p < 0.05$) than that of the middle elevation (50-100 masl) and higher elevation (100-150 masl). There was no significant difference ($p < 0.05$) in EC between the surface (0-30 cm) and subsurface soil (30-60 cm) in the study area. The high EC values of the lower elevation (0-50 masl) compared to that of middle (50-100 masl) and higher elevation (100-150 masl) could be attributed to strong downslope movement of soluble salts. The lower elevation received runoff water from the higher landscape with soluble salts; thereby increased the electrical conductivity of the soil (Kravchenko, 2002).

Organic carbon (OC)

The mean organic carbon (OC) of lower elevation (0-50 masl) was 2.2 % in the surface soil and 2.3 % in the subsurface soils. The mean OC of middle elevation (50-100 masl) was 3.6 % in the surface soil and 3.0 % in the subsurface soil. The mean OC of higher elevation (100-150 masl) was 3.1 % in the surface soil and 2.3 % in the subsurface soils. The mean organic carbon of the middle elevation (50-100 masl) was significantly higher ($p < 0.05$) than that of lower elevation (0-50 masl) and higher elevation (100- 150 masl). The organic carbon of the surface soil (0-30 cm) was significant higher ($p < 0.05$) than that of subsurface soil (30-60 cm) in the study area. The lower rates of leaf litter decomposition resulting in the high accumulation organic carbon in the middle elevation (50-100 masl) may be attributed to floristic composition of the litter, high biomass input and favourable physical, chemical and biological properties of the soil in middle elevation (Shary *et al.,* 1991). The low organic carbon of the lower elevation could be due to lower input of biomass and higher decomposition pressure on the existing organic matter (Gray, *et al*, 2012).

Total N
The mean total nitrogen (TN) of lower elevation (0-50 masl) was 0.10 % in both surface and subsurface soils. The mean TN of middle elevation (50-100 masl) was 0.16 % in the surface soil and 0.82 % in the subsurface soil. The mean TN of higher elevation (100-150 masl) was 0.13 % in the surface soil and 0.10 % in the subsurface soils. The mean total N of middle elevation (50-100 masl) was significant higher ($p < 0.05$) than that of the lower elevation (0-50 masl) and higher elevation (100-150 masl). There was no significant difference ($p < 0.05$) in total N content between the surface (0-30 cm) and subsurface soil (30-60 cm) in the study area. The middle elevation (50-100 masl) received runoff water from the higher elevation (landscape) with dissolved total N thereby increased the total N content of the soil (Kravchenko, 2002). The low total N of the lower elevation could be due to lower input of biomass and higher decomposition pressure on the existing organic matter to release N (Gray, *et al*, 2012)

Available P
The mean available P of lower elevation (0-50 masl) was 34.4 mg/kg in the surface soil and 33.8 mg/kg in the subsurface soil. The mean available P of middle elevation (50-100 masl) was 38.3 mg/kg in the surface soil and 40.8 mg/kg in the subsurface soil. The mean available P of higher elevation (100-150 masl) was 51.2 mg/kg in the surface soil and 52.4 mg/kg in the subsurface soils. The mean available P of higher elevation (100-150 masl) was significantly higher ($p < 0.05$) than that of the lower elevation (0-50 masl) and middle elevation (50-100masl). There was no significant difference ($p < 0.05$) in available P content between the surface (0-30 cm) and subsurface soil (30-60 cm) in the study area. The high available P of the higher elevation (100-150 masl) could be attributed to local climate as influenced by the elevation. It has been reported that elevation influenced the local temperature and precipitation that enhances rapid organic matter decomposition resulting in the release available P (Kravchenko, 2002).

Exchangeable Bases (Ca, Mg, Na and K)
The mean exchangeable Ca of lower elevation (0-50 masl) was 3.7 cmol/kg in the surface soil and 2.8 cmol/kg in the subsurface soil. The mean exchangeable Ca of middle elevation (50-100 masl) was 2.9 cmol/kg in the surface soil and 3.5 cmol/kg in the subsurface soil. The mean exchangeable Ca of higher elevation (100-150 masl) was 3.1 cmol/kg in the surface soil and 2.5 cmol/kg in the subsurface soil. There was no significant different ($p <0.05$) in exchangeable Ca between the lower, middle and higher elevations as well as between the surface and subsurface soils in the study area.
The mean exchangeable Mg of lower elevation (0-50 masl) was 1.5 cmol/kg in the surface soil and 1.4 cmol/kg in the subsurface soils. The mean exchangeable Mg of middle elevation (50-100 masl) was 2.1 cmol/kg in the surface soil and 2.2 cmol/kg in the subsurface soil. The mean exchangeable Mg of higher elevation (100-150 masl) was 1.5 cmol/kg in the surface soil and 1.4 cmol/kg in the subsurface soil. Mean exchangeable Mg of the middle elevation (50-100 masl) was significantly higher ($p < 0.05$) than that of lower elevation (0-50 masl) and higher elevation (100-150 masl). The high exchangeable Mg in the middle elevation (50-100 masl) could be due to strong downslope colloidal movement. The middle elevation received runoff water from the higher elevation (100-150 masl) with soluble cations; thereby increased the exchangeable Mg of the soil (Kravchenko, 2002). The low exchangeable Mg of the lower elevation could be due to lower input of biomass and higher decomposition pressure on the existing organic matter to release Mg (Gray, *et al*, 2012)

The mean exchangeable Na of lower elevation (0-50 masl) was 0.3 cmol/kg in both the surface soil and subsurface soil. The mean exchangeable Na of middle elevation (50-100 masl) was 0.2 cmol/kg in both surface soil and subsurface soil. The mean exchangeable Na of higher elevation (100-150 masl) was 0.4 cmol/kg in both the surface soil and subsurface soil. There was no significant difference ($p <0.05$) in exchangeable Na between the lower, middle and higher elevations as well as between the surface and subsurface soils in the study area.

The mean exchangeable K of lower elevation (0-50 masl) was 0.15 cmol/kg in the surface soil and 0.11 cmol/kg in the subsurface soil. The mean exchangeable K of middle elevation (50-100 masl) was 0.25 cmol/kg in the surface soil and 0.15 cmol/kg in the subsurface soil. The mean exchangeable K of higher elevation (100-150 masl) was 0.06 cmol/kg in the surface soil and 0.10 cmol/kg in the subsurface soil. Mean exchangeable K of the middle elevation (50-100 masl) was significantly higher ($p < 0.05$) than that of lower elevation (0-50 masl) and higher elevation (100-150 masl). The high exchangeable K in the middle elevation could be due to strong downslope colloidal movement. The middle elevation received runoff water from the higher elevation with soluble cations; thereby increased the exchangeable K of the soil (Kravchenko, 2002). The low exchangeable K of the lower elevation could be due to lower input of biomass and higher decomposition pressure on the existing organic matter to release K (Gray, *et al*, 2012). There was no significant difference ($p <0.05$) in exchangeable K between the surface and subsurface soils in the study area.

Exchangeable Acidity
The mean exchangeable acidity (EA) of lower elevation (0-50 masl) was 3.1 cmol/Kg in the surface soil and 3.2 cmol/Kg in the subsurface soil. The mean EA of middle elevation (50-100 masl) was 4.0 cmol/Kg in the surface soil and 4.7 cmol/Kg in the subsurface soil. The mean EA of higher elevation (100-150 masl) was 3.5 cmol/Kg in the surface soil and 3.7 cmol/Kg in the subsurface soil. Mean exchangeable acidity of the middle elevation (50-100 masl) was significantly higher ($p < 0.05$) than that of lower elevation (0-50 masl) but not different from that of higher elevation

(100-150 masl). The high potential acidity of the middle elevation may also be attributed to downslope colloidal movement of H^+ and Al^{3+} ions (Kravchenko, 2002). There was no significant difference ($p < 0.05$) in exchangeable acidity between the surface and subsurface soils in the study area.

Effective Cation Exchange Capacity (ECEC)

The mean effective cation exchange capacity (ECEC) of lower elevation (0-50 masl) was 8.6 cmol/Kg in the surface soil and 7.7 cmol/Kg in the subsurface soil. The mean ECEC of middle elevation (50-100 masl) was 9.4 cmol/Kg in the surface soil and 10.7 cmol/Kg in the subsurface soil. The mean ECEC of higher elevation (100-150 masl) was 8.5 cmol/Kg in the surface soil and 8.1 cmol/Kg in the subsurface soil. Mean ECEC of the middle elevation was significantly higher ($p < 0.05$) than that of lower elevation and that of higher elevation. The high ECEC of the middle elevation may also be attributed to downslope colloidal movement of organic matter and clay fraction from the higher elevation (Kravchenko, 2002). There was no significant difference ($p < 0.05$) in exchangeable ECEC between the surface and subsurface soils in the study area.

Base saturation

The mean base saturation of lower elevation (0-50 masl) was 64.8 % in the surface soil and 60.4 % in the subsurface soil. The mean base saturation of middle elevation (50-100 masl) was 54.6 % in the surface soil and 53.9 % in the subsurface soil. The mean base saturation of higher elevation (100-150 masl) was 58.0 % in the surface soil and 53.5 % in the subsurface soils. There was no significant difference ($p < 0.05$) in base saturation between the surface and subsurface soils in the study area. The mean base saturation of the lower elevation was significantly higher ($p < 0.05$) than that of middle and higher elevations. The high base saturation of the lower elevation may also be attributed to downslope colloidal movement of exchangeable bases (Ca, Mg, Na and K) from the higher landscape (50-100 masl and 100-150 masl) (Kravchenko, 2002).

Table 1: Means of some physical and chemical properties of soils of the study area as influenced by elevation

Soil properties	Sand (%) Depth (cm)			Silt (%) Depth (cm)			Clay (%) Depth (cm)			pH Depth (cm)			EC (dS/m) Depth (cm)			Organic C (%) Depth (cm)		
Elevation	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean
Lower	88.3	87.6	87.9	5.0	4.3	4.6	6.8	8.1	7.4	6.3	6.4	6.3	0.16	0.19	0.18	2.22	2.30	2.26
Middle	84.2	76.0	80.1	6.3	6.3	6.3	9.5	17.7	13.6	5.7	5.8	5.8	0.11	0.06	0.08	3.63	3.03	3.30
Higher	83.1	81.4	82.2	9.0	6.9	7.9	7.8	11.7	9.7	5.7	5.5	5.6	0.11	0.07	0.09	3.09	2.33	2.71
Mean	85.2	81.7		6.7	5.8		8.0	12.5		5.9	5.9		0.13	0.11		2.98	2.55	
$LSD_{(0.05)}$	Elevation = 3.1			1.9			2.5			0.2			0.07			0.48		
	Depth (cm) = 2.5			1.6			2.0			0.1			0.06			0.39		
	Elevation x depth =4.4			2.7			3.5			0.3			0.10			0.68		

	Total N (%)			Available P (mg/kg)			Exch. Ca (cmol/kg)			Exch. Mg (cmol/kg)			Exch. Na (cmol/kg)			Exch. K (cmol/kg)		
Elevation	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean
Lower	0.10	0.10	0.10	34.4	33.8	34.1	3.66	2.76	3.21	1.48	1.38	1.43	0.29	0.25	0.27	0.15	0.11	0.12
Middle	0.16	0.82	0.17	38.3	40.8	39.5	2.86	3.47	3.17	2.08	2.20	2.41	0.22	0.22	0.22	0.25	0.15	0.20
Higher	0.13	0.10	0.12	51.2	52.4	51.8	3.13	2.46	2.79	1.51	1.44	1.47	0.39	0.36	0.38	0.06	0.10	0.07
Mean	0.13	0.13		41.3	42.3		3.22	2.90		1.69	1.67		0.30	0.28		0.15	0.12	
$LSD_{(0.05)}$	Elevation = 0.04			6.1			0.94			0.74			0.19			0.06		
	Depth (cm) = 0.03			5.0			0.77			0.61			0.16			0.05		
	Curvature x depth = 0.06			8.7			1.33			1.05			0.27			0.09		

pH = soil reaction (pH), EC = electrical conductivity, Organic C. = organic carbon, Total N. = total nitrogen, Available P. = available phosphorus, Exch. Ca = exchangeable calcium, Exch. Mg = exchangeable magnesium, Exch. Na = exchangeable sodium, Exch. K = exchangeable potassium

Means of some physical and chemical properties of soils of the study area as influenced by elevation (contd.)

Soil properties	Exch. Acidity (cmol/kg)			ECEC (cmol/kg)			Base sat. (%)		
	Depth (cm)			Depth (cm)			Depth (cm)		
Elevation	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean
Lower	3.06	3.17	3.12	8.64	7.67	8.15	64.8	60.4	62.6
Middle	3.96	4.68	4.32	9.37	10.72	10.04	54.6	53.9	54.3
Higher	3.48	3.71	3.59	8.52	8.06	8.29	58.0	53.5	55.7
Mean	3.50	3.85		8.84	8.82		59.1	55.9	
LSD(0.05)				1.52			7.06		
	Elevation = 0.85								
	Depth (cm) = 0.69			1.24			5.77		
	Elevation x depth = 1.20			2.15			9.99		

Exch. Acidity = exchangeable acidity, ECEC = effective cation exchange capacity, Base sat. = base saturation

2. Summary statistics and normality test of the selected soil properties for regression analysis

The measured values of the selected soil properties were subjected to normality test to assess the skewedness and Kurtosis of the data as one of the requirements for regression analysis (Emadi *et al*., 2008). The summary statistics are presented in Table 2. The results showed that among the selected soil properties, the mean values of silt fraction, clay fraction, soil pH, available P and exchangeable K were greater than the median, indicating that the data distributions were right-skewed (positive skewness) with the majority of the data values greater than the mean. This shows that these variables are not normally distributed and required transformation. The mean value of sand fraction was less than median value, indicating that the data distribution was left-skewed (negative skewness) with the majority of the data values less than the

Table 2: Summary statistics and normality test of the selected soil properties

Soil property	Minimum	Maximum	Mean	Median	Skewness	Kurtosis	Distribution type
	Before transformation						
Sand (%)	63.86	94.64	84.43	84.54	-0.454	3.5	Leptokurtic
Silt (%)	1.28	14.08	7.81	7.18	0.573	3.6	Leptokurtic
Clay (%)	2.64	21.48	7.74	7.21	0.780	3.0	Mesokurtic
pH	4.6	7.5	5.7	5.6	0.812	4.3	Leptokurtic
Org. C (%)	0.76	4.97	2.6	2.6	0.091	2.2	Platykurtic
Total N (%)	0.03	0.3	0.12	0.12	0.262	2.4	Platykurtic
Av. P (mg/kg)	27.3	72.83	43.3	43.0	0.324	1.9	Leptokurtic
Exch. K (cmol/kg)	0.002	0.61	0.14	0.09	4.428	27.9	Leptokurtic
	After Log-transformation						
Log sand					-0.679	3.9	
Log silt					-0.909	3.7	
Log clay					-0.177	2.5	
Log pH					0.467	3.7	
Log Av.P					0.063	1.8	
Log exch. K					-1.586	8.0	

Leptokurtic shows sharp peak on the graph, platykurtic shows flat-top, mesokurtic shows bell curve. Normal distributions are mesokurtic distributions with coefficient of kurtosis equal to 3 or approximately close to 3. If the coefficient of skewness equal to 0 or approximately close to 0, the graph is symmetric and the distribution is normally distributed.

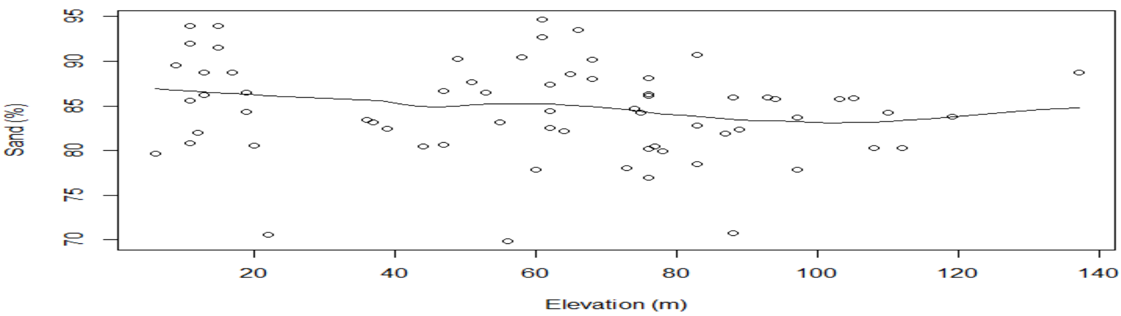
mean, required transformation. The mean values of soil organic carbon and total N were similar to the median values, indicating symmetry and are normally distributed. After logarithmic transformation, skewness value of silt reduced from 0.57 to -0.91, clay reduced from 0.78 to -0.18, pH reduced from 0.81 to 0.47, available P reduced from 0.32 to 0.06 while exchangeable K reduced from 4.43 to -1.59. This shows that the skewness of logarithmic transformed data values were closer to 0 (symmetry) than the non- transformed data values. The skewness value of sand fraction on the other hand increased from -0.45 to -0.68 (left-skewed) after log transformation. Organic carbon and total N were near 0 (symmetric)' Logarithmic transformation resulted in smaller skewness and kurtosis, causing the distribution to approach Gaussian (normal distribution), which is a requirement for regression analysis (Emadi *et al*., 2008)

3. Regression model of topography with selected soil properties in the study area

The regression model between the selected soil properties (dependent variables) and topography (independent variable or predictor variable) are presented in Table 3 and the graphical forms are presented in Figures 2 to 9. Topography explained about 19 % ($R^2 = 0.19$) variation of available P, 8.4 % ($R^2 = 0.084$) variation of exchangeable K and 5.5 % ($R^2 = 0.055$) variation of organic carbon and total N in the study area. Topography equally explained about 3 % (R^2=0.0.025) variation of sand fraction, 3 % ($R^2 = 0.028$) variation of silt fraction and 5 % ($R^2 = 0.051$) variation of clay fraction, 4 % ($R^2 = 0.040$) variation of soil pH in the study area although not statistically significant ($p < 0.05$). The results showed low predictability of topography for the selected soil properties. This observation is in agreement with Obi (2015) who observed relative low coefficient of determination (R^2) of the linear regression of soil properties with terrain attributes in coastal plain sand soils of Akwa Ibom State

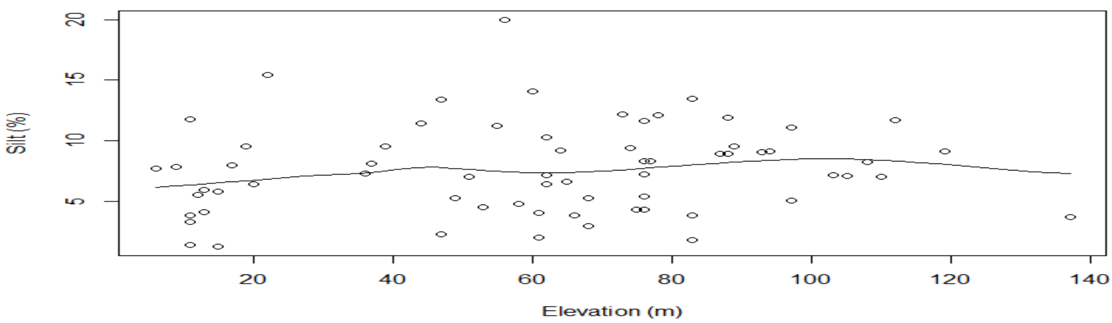
Table 3: Simple linear regression between the selected soil properties and topography

Soil property	Regression (Y = a + bX)			R^2	P -value
	Slope				
	a		**b**		
Log (Sand) (%)	4.453	–	0.000315	0.025	0.20
Log (Silt) (%)	1.724	+	0.0029	0.028	0.18
Log (Clay) (%)	1.754	+	0.0033	0.051	0.07
Log (pH)	1.773	–	0.00056	0.040	0.11
Org. C (%)	0.521	+	0.0045	0.055	0.05*
Total N (%)	-2.470	+	0.0038	0.055	0.06'*
Log (Av. P) (mg/kg)	3.532	+	0.0031	0.194	0.0002***
Log (Exch. K) (cmol/kg)	-1.905	+	0.00948	0.084	0.02*



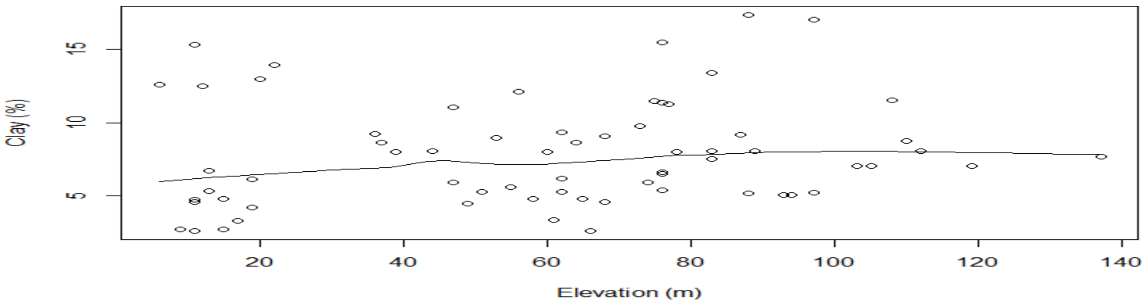
$R^2 = 0.03$ $p \leq 0.19$

Fig. 2: Simple linear regression between sand fraction and topography



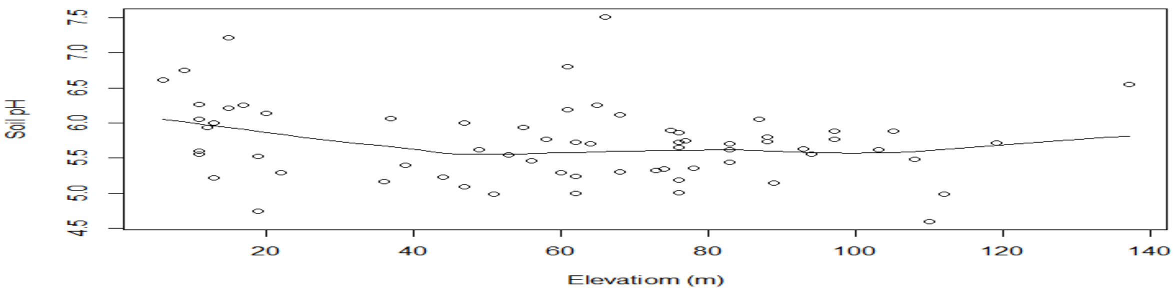
$R^2 = 0.03$, $p \leq 0.18$

Fig.3: Simple linear regression between silt fraction and topography



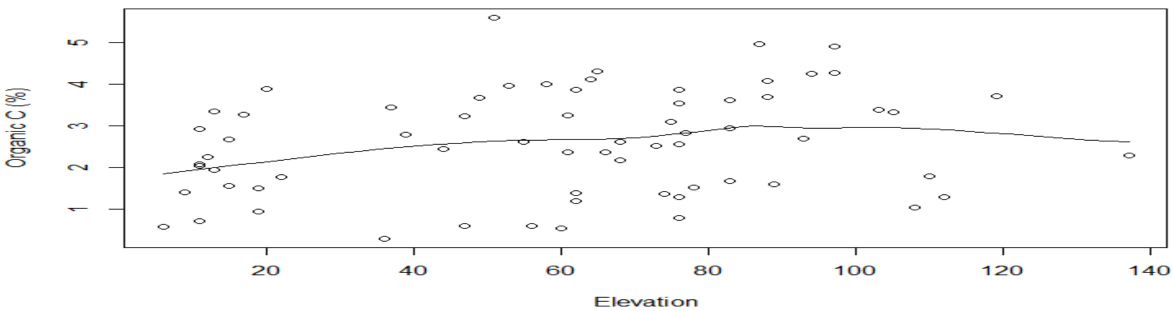
$R^2 = 0.05$, $p \leq 0.07'$

Fig.4: Simple linear regression between clay fraction and topography



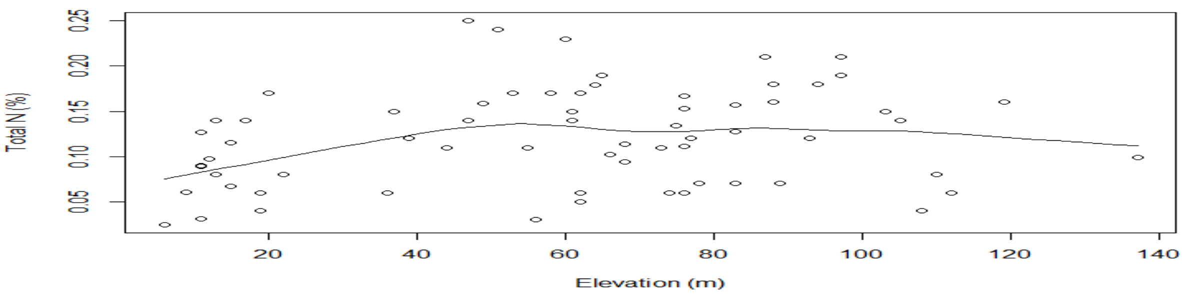
$R^2 = 0.03$, $p \leq 0.05*$

Fig. 5: Simple linear regression between soil pH and topography



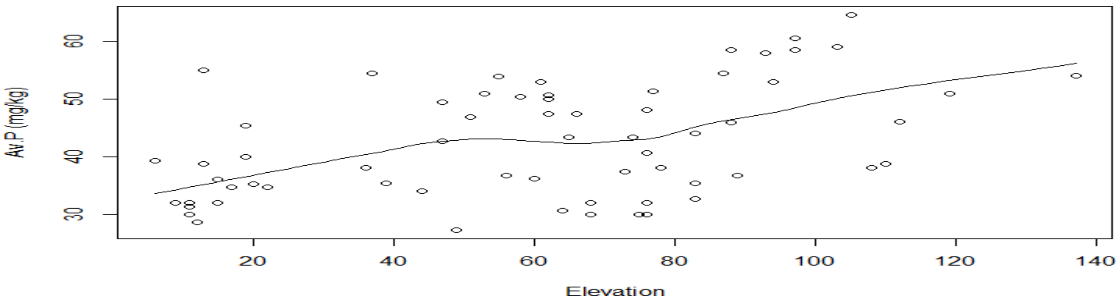
$R^2 = 0.06$, $p \leq 0.05*$

Fig. 6: Simple linear regression between organic carbon and topography



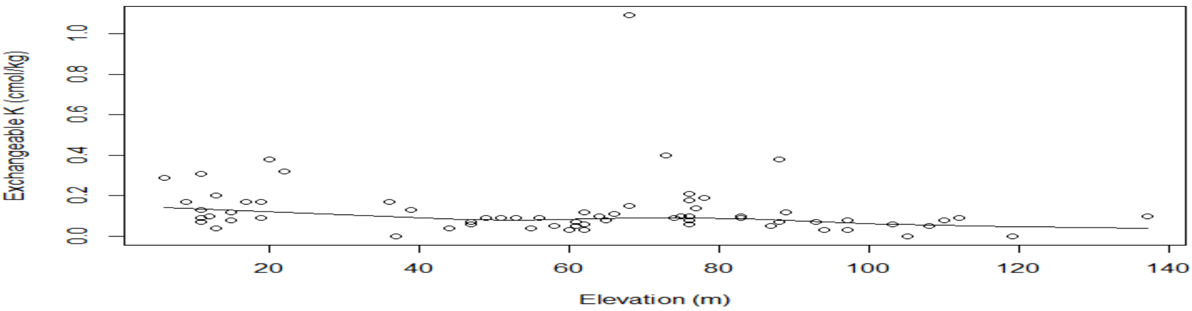
$R^2 = 0.05$, $p \leq 0.06'$

Fig. 7: Simple linear regression between total N and topography



$R^2 = 0.19$, $p \leq 0.0002$**

Fig.8: Simple linear regression between available P and topography



$R^2 = 0.08$, $p \leq 0.02$*

Fig. 9:.Simple linear regression between exchangeable potassium and topography

Conclusion

The study revealed variation in soil properties among the topographic classes under study. Sand fraction was higher at lower elevation while silt and clay fractions were higher in the middle and higher elevations in the study area. Soil pH was slightly acid in the lower elevation and moderately acid in the middle and higher elevations. Electrical conductivity and base saturation were higher at the lower elevation than middle and higher elevations. Organic carbon, total N, ECEC, exchangeable Mg and exchangeable K were higher in the middle elevation than that of lower and higher elevations. Available P of higher elevation was higher than that of lower and middle elevations. The study also showed that topography explained 3 % variation of sand and silt fractions; 5 % variation of clay fraction and 4 % variation of soil pH. Topography also explained 19 % variation of available P, 8.4 % variation of exchangeable K and 5.5 % variation of organic carbon and total N in the study area. The remaining variation may be due to other factor of soil formation such as parent material, climate, organism and time.

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