International Journal of Recent Innovations in Academic Research

E-ISSN: 2635-3040; P-ISSN: 2659-1561
Homepage: https://www.ijriar.com/
Volume-9, Issue-1, January-March-2025: 54-68

Research Article

Comparative Evaluation of Selected Soil Properties along Toposeqences on Acid Soils in Akwa Ibom State, Nigeria

[*a]Essien, O.A., [b]Etim, C.D., [c]Akata, O.R., [d]Ben, F.E. and [e]Essien, P.S.

[a&b]Department of Soil Science, Akwa Ibom State University, Obio Akpa Campus, Oruk Anam, Akwa Ibom State, Nigeria
[c-e]Department of Crop Science, Akwa Ibom State University, Obio Akpa Camps, Oruk Anam, Akwa Ibom State, Nigeria
*Corresponding Author Email: Otobongessien@aksu.edu.ng

Received: January 29, 2025 **Accepted:** February 19, 2025 **Published:** February 25, 2025

Abstract
A research was conducted to compare selected soil properties as effected by toposequence on acid soil in Akwa Ibom State, Nigeria. Three locations were selected for the study, at each location, soil sample were collected along toposequence (upper, middle and lower slope), giving a total of 27 samples. Soil samples were analysed in the laboratory for physical and chemical properties. Data generated were subjected to descriptive statistics, analysis of variance and correlation analysis. The result shows that lower slope (929.56g kg^{-1}) had the highest mean value of total sand > upper slope (918.89g kg^{-1}) > middle slope (916.22g kg^{-1}). Silt content had highest mean value at the middle slope (28.67g kg^{-1}) > upper slope (25.56gKg^{-1}) > lower slope (16.89gKg^{-1}). Clay content had highest mean value at upper slope (56.67gKg^{-1}) > middle slope (56.00gKg^{-1}) > lower slope (53.56gKg^{-1}). Saturated hydraulic conductivity had highest mean value at lower slope (4.68cmhr^{-1}) > upper slope (4.08cmhr^{-1}) > middle slope (3.69cmh^{-1}). Total porosity had highest mean value at middle slope (0.77m^{-3} m^{-3}) > lower slope (0.69m^{-3} m^{-3}) > upper slope (0.68m^{-3} m^{-3}). Result of the soil chemical properties shows pH had highest mean value at the lower slope (6.16) > middle slope (5.93) > upper slope (5.57), organic matter had high mean value at middle slope (3.90%) > lower slope (3.43%) > upper slope (3.13%). Av. P had highest mean at lower slope (5.83 mg/kg^{-1}) > middle slope (4.96 mgkg^{-1}) > upper slope (4.91 mgkg^{-1}). Exchangeable acidity had highest mean value at middle slope (5.09 cmolkg^{-1}) > upper slope (4.51 cmolkg^{-1}) > lower slope (3.62 cmolkg^{-1}). Effective cation exchanged capacity and base saturation had highest mean value at middle slope (10.57 cmolkg^{-1}) and lower slope (49.81%) > upper slope (8.2.9 cmolkg^{-1}) and middle slope (49.19%) > lower slope (7.29 cmolkg^{-1}) and upper slope (48.00%) respectively. There was no significant different at 5% level in all the physical properties of the soil. In chemical properties, ECEC at lower slope was significantly different from upper and middle slope at 5% level.
Keywords: Soil Physical Properties, Soil Chemical Properties, Upper Middle Lower Slope, Acid Soils.

Introduction

Topography is an independent soil-forming factor; most of the information on topography considers runoff and erosion in relation to slope, which deals with removal and destruction of soil (Jenny, 1941; Essien *et al*., 2023). Topography as a soil forming factor influences radiation and the amount of water that enters the soil, thus leading to leaching and the redistribution of elements and soil materials (Hook and Burke, 2000; Essien *et al.,* 2024a; Sam *et al*., 2025). Temgoua *et al.,* (2005) considered topography as both an internal and external factor in pedogenesis, thus influencing soil formation. Significant correlation between topographic indices and soil properties were reported by Seibert *et al.,* (2007), Essien *et al*., (2024b). Cox *et al.,* (2002), Bockheim (2005), Wilson *et al.,* (2004) reported differences in soil properties as a result of local effects of topography, which accounted for between 26 and 64% total variation in soil properties and moisture.

Durak and Surucu (2005) studied soil formation on different landscape positions and reported that the greatest degree of pedogenesis was observed on the summit followed by the back slope, with the least degree of soil development occurring at the toe slope. Hikmat *et al.,* (2003) confirmed that elevation significantly affect soil properties and the degree of weathering. Soil depth, clay content and structural development increased with decreasing altitude or down slope, soils on the crest and upper slope were weakly structured, while those at the lower slope were well developed according to Subardja and Buurman (1980), Idoga *et al*., (2006), Mark *et al.,* (2024) confirmed that elevation influenced soil properties, development and degree of weathering.

Essien and Ogban (2018) worked on the influence of topography and parent materials, the result revealed that gravel, coarse sand and clay contents were significantly influenced by topography. Similarly Brubaker *et al.,* (1993), Ogban *et al.,* (2022) collaborated that particle size distribution varied along toposequences, with higher sand content at the lower position. On the contrary, higher clay content was observed at the lower slope by Shariatmadari *et al.,* (2006). Essoka *et al.,* (2006) reported increased bulk density (BD) values with soil depth which also fluctuated along a toposequence on gneiss and granodiorite, however increase in BD with decreasing slope position was observed by Hikmat *et al.,* (2003). Soils exhibit tremendous spatial variability in their physical and chemical properties along a toposequence. Ollinger *et al.,* (2002) reported that variation of soil properties is significantly influenced by some environmental factors such as climate, topographic features (landscape position, topography, slope gradient and evolution), parent material, and vegetation. The concepts of slope position, which involves processes that cause soil properties differentiation along toposequence and among horizons have improved the evaluation of the interaction between pedogenic and geomorphic processes (Gessler *et al.,* 2000; Esu *et al.,* 2008).

The differences in soil properties as a result of slope position are associated to degree of detachment, transportation and deposition of soil materials. Also, the physiographic position on a slope determines the level of soil physical and chemical properties, vegetation distribution and soil textural distribution. The toposequencial differentiation of soils is of pivotal importance to the management of soils in different physiographic positions in the landscape. Studies on toposequencial differentiation of soils in the tropical rainforest of Nigeria concentrated on soil profile characteristics (Mark *et al.,* 2024).

Some researchers (Aweto and Enaruvbe, 2010; Osujieke, 2017) have reported on variation of soil properties along the toposequence on soils of southern Nigeria. Also, (Osujieke *et al.,* 2016) reported that soil properties such as OC, TN, Av. P and CEC recorded significant difference while, sand, silt and pH recorded a non-significant difference among the toposequencial physiographic positions. Since there is dearth information on effect of slope on soil properties, the study justification lies in it's potential to evaluate how toposequence affects, influence and has impact on soil properties in acidic soil environments of Akwa Ibom State, South-East Nigeria.

Materials and Methods

Site Description

The research was conducted on acid soils of Akwa Ibom State, Nigeria. Akwa Ibom lies between Latitude 4°30' N and 5°30' N and Longitude 7°30' E and 8°20' E. The climate of the area is marked by two seasons namely; wet and dry seasons. The rainy season lasts between the month of April and October, while the dry season occurs between the months of November and March with mean annual rainfall ranging between 2500–3000 mm (Petters *et al.,* 1989). Annual temperature are uniformly high throughout the year, vary from 26°C to 28°C, solar radiation ranges from 6–15 mm/day, while relative humidity ranges from 75–95%. Evapotranspiration ranges from 4.11–4.95 mm (Enwezor *et al.,* 1990). The soils of the area are acid soils and are classified as Ultisol based on the USDA system of classification (Soil Survey Staff, 2011). The native vegetation is a secondary forest of predominantly woody shrubs and various grasses.

Field Method

Soil samples were collected in three (3) toposequence (upper, middle and lower slope) in three (3) local government areas (Oruk Anam, Etinan and Essien Udim Local Government Area) three random soil samples were collected in three locations. All the soil samples collected were put into different polythene bags and labeled. A total number of twenty seven (27) samples were collected and another was set of undisturbed core samples were collected for the determination of bulk density and hydraulic conductivity.

Laboratory Analysis

The bulk samples were air dried and pass through a 2mm sieve for the following analysis.

Particle Size Analysis

Particle size analysis was done using the Bouyoucos hydrometer method (Klute, 1986), after dispersion with sodium hexametaphosphate solution.

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity (Ksat) was determined using constant head permeameter method (Dane and Topp, 2002). The saturated hydraulic conductivity was calculated using the equation:

Ksat = QL/hAt

Where;
Ksat = saturated hydraulic conductivity (cm^3 hr^{-1})
Q = discharge rate (cm^3 min^{-1})
L = length of the soil column
h = change in hydraulic head (cm)
A = cross sectional area through which the flow takes place (cm^3)
t = time (minutes)

Bulk Density

Bulk density was determined using core samples as described by Dane and Topp (2002). Soil samples were oven dried 105°C to a constant mass and bulk density calculated using the equation:

Bd = Ms/Vt

Where;
Bd = bulk density
MS = dry soil mass (kg)
Vt = total volume (m^{-3}), this will be calculated from the internal dimension of the cylinder

Total Porosity

Total porosity was calculated from particle size and bulk density as follows: (Dane and Topp, 2002)
$f = (1-\ell b/\ell s))$

Where;
f = total porosity (m^3 m^{-3})
ℓb = bulk density (Mg m^{-3})
ℓs = particle density, assumed to be 2.6 Mg m^{-3}

Soil pH was determined using 1:2:5 soil and water suspension and the pH value read with glass electrode pH mater (Udo *et al.,* 2009). Available phosphorus was determined by the Bray P-1 method. The phosphorus in the extraction will be measured by the method of Murphy and Riley (1962). Exchangeable bases (Ca, Mg, Na and K) was determined by extraction using ammonium acetate in (NH, OAC) solution (Thomas, 1982). The available K and Na were determined by flame photo meter using Atomic Absorption Spectrophotometer. Exchangeable Acidity (H^+ and $Al3^+$) was determined using KCl extraction method (Mclean, 1982).

Effective cation exchange capacity was obtained by summation of the exchangeable bases and exchangeable acidity (Udo *et al.,* 2009).

Base saturation was calculated as % Bs = TEB x 100

Where,
Bs = Base saturation
TEB = total exchangeable bases

Statistical Analysis

The data was subjected into descriptive statistics, analysis of variance (ANOVA) and correlation analysis using Pearson correlation to determine the relationship among physical and chemical properties of the soil.

Results and Discussion

Effect of Toposequence on Some Selected Soil Physical Properties

Data for physical properties of the soils along toposequence are shown in (Figure 1). Total sand ranges from 870-950gkg^{-1} with mean value of 918–989 gkg^{-1} (CV=2.46 %) at the upper slope. In the middle slope, total sand ranges from 558–950 gkg^{-1}, with mean of 882–989 gkg-1 (CV=13.88 %). At the lower slope indicated that total sand ranges from 870–950 gkg^{-1} with a mean value of 929-956 gkg^{-1} (CV=3.16 %). It is shown that the mean value at the lower slope is high followed by the upper slope and the middle slope, respectively given their values which are significantly different. The upper slope (Figure 2) shows that silt ranges from 6.00-48.00 gkg^{-1} with a mean of 25.56 gkg^{-1} (CV=56.53). The result indicated that silt at the middle slope showing in (Table 1 b) ranges from 6.00-46.00 gkg-^{1} with mean of 27.25 gkg-^{1} (CV=41.14 %). the lower slope shows that silt ranges from 6.00-48.00 gkg-^{1} with mean 16.89 gkg-^{1} (CV=102.07 %). Clay fraction in upper slope (Figure 3) ranges from 42–104 6 gkg-^{1} with mean of 56.67 gkg-^{1} (CV= 35.33 %). The middle slope clay fraction ranges from 24–110 gkg^{-1}. Mean of 55.11 gkg^{-1} and CV = 42.82 %. While that of lower slope ranges from 24–122 gkg-^{1}, mean average of 53.56 gkg^{-1} (CV=27.53 %).

Figure 1. A graphical representation of sand fraction along toposequence (mean comparison).

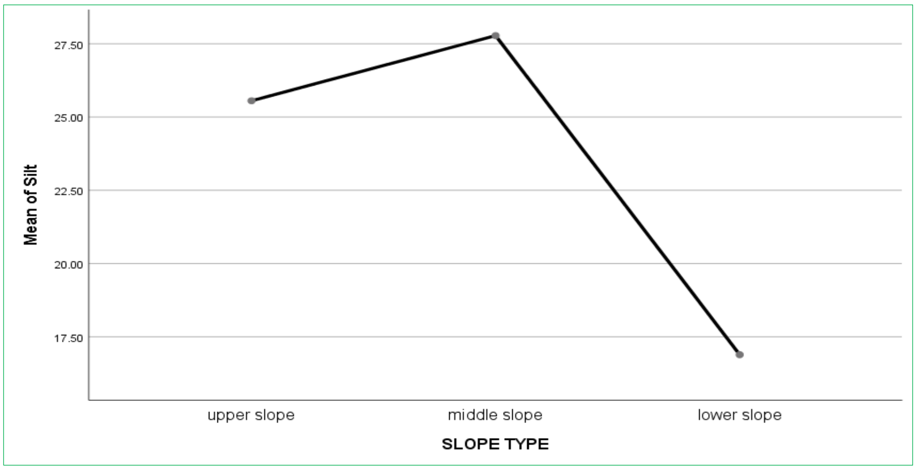

Figure 2. A graphical representation of silt fraction along toposequence (mean comparison).

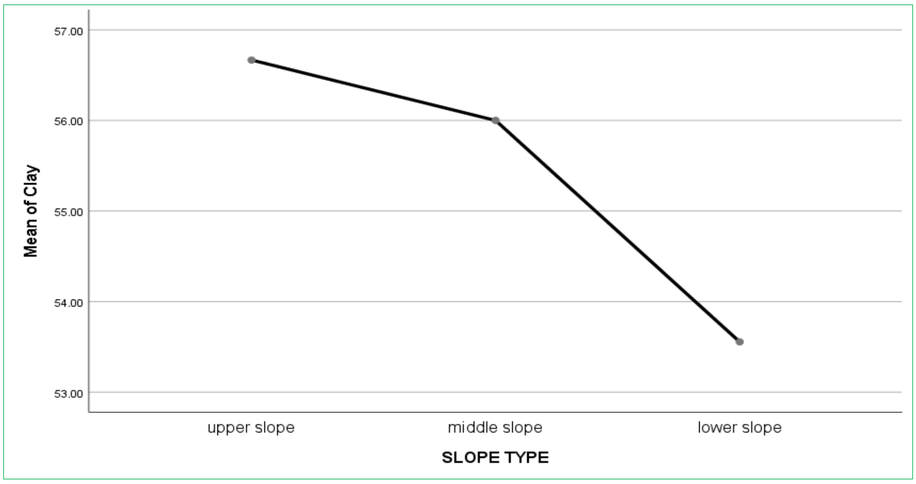

Figure 3. A graphical representation of clay fraction along toposequence (mean comparison).

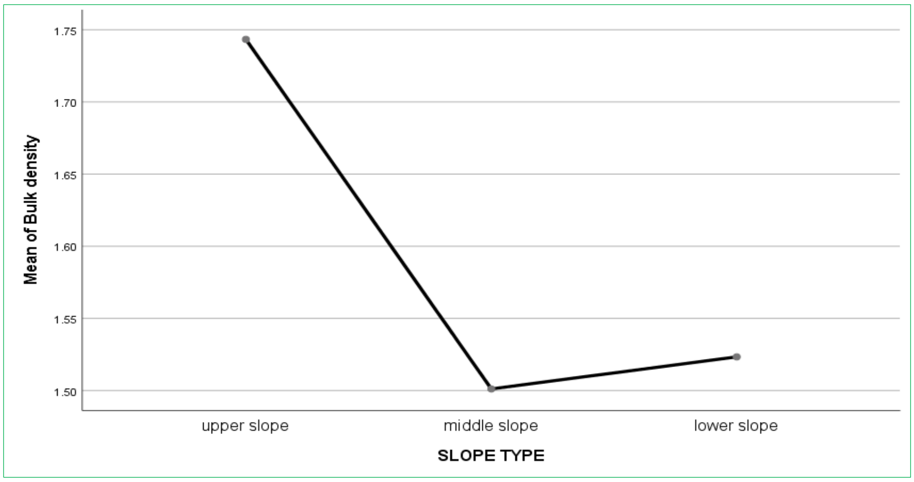

Figure 4. A graphical representation of bulk density along toposequence (mean comparison).

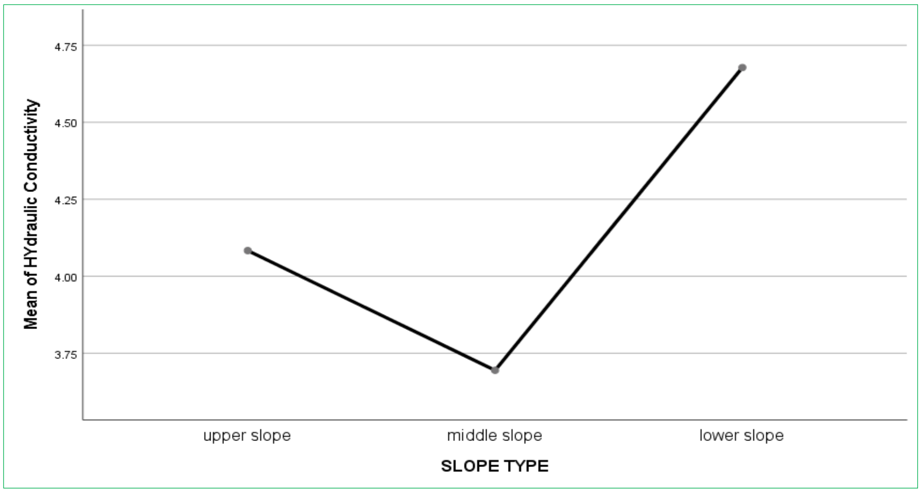

Figure 5. A graphical representation of hydraulic conductivity along toposequence (mean comparison).

Figure 6. A graphical representation of total porosity along toposequence (mean comparison).

According to the result, silt was high at the middle slope. This can be attributed to fine parent material (Simeon and Essien, 2023) as well as high organic matter which are high in silt and clay. Each toposequence were predominated by sand fractions, but the lower slope recorded the high sand fraction of 929.56 gkg^{-1} > 918 gkg^{-1} of upper slope > 882.89 gkg^{-1} of middle slope, the CV ranged from low to high, indicating variability along toposequence. Properties with larger CV values are more variable than those with smaller CV values (Wilding, 1985). Uniformity along the toposequence was inconsistent. Soil bulk density (Figure 4) averaged 1.74 Mgm^{-3} in upper slope > 1.50 Mgm^{-3} in the middle slope > 1.52 Mgm^{-3}. The magnitude of bulk density was attributed to the influence of particle size fractions of the parent material in consonance with work of

Ogban and Essien (2016). Total porosity (Figure 6) averaged 0.77% at the middle slope > 69% at the lower slope >68 % at the upper slope showing that the values recorded can lead to having larger macro spores. Saturated hydraulic conductivity (Ksat) (Figure 5) averaged 4.68 $cmhr^{-1}$ at the lower slope > 4.08 $cmhr^{-1}$ at the upper slope > 3.69 $cmhr^{-1}$ at the middle slope. The result indicates the lower slope had moderate hydraulic conductivity.

Effect of Toposequence on Soil Chemical Properties

The result in Table 1a, b, c, shows effect of toposequence on soil chemical properties. Soil pH reveals that the reaction of soil solution in the upper, middle and lower slope were weakly acidic (upper slope (5.57), < middle slope (5.93) < lower slope (6.16). Organic matter (OM) recorded in middle slope (3.90 %) >, lower slope (3.43 %) >, upper slope (3.13 %). The high value of organic matter was recorded at the middle slope, indicating maximum yields can be achieved (Ibanga *et al.,* 2023; Akata *et al*., 2024; Ben *et al*., 2024; Akpan*, et al.,* 2025) and increase in water holding capacity (Brady and Weil, 2008; Akpan *et al.,* 2021). Available phosphorus on the lower slope was recorded with the highest value (5.83 $mgkg^{-1}$) > (4.96 $mgkg^{-1}$) at the middle slope > (4.91 $mgkg^{-1}$) at the upper slope. Calcium recorded average value (3.85 $cmolkg^{-1}$) in the middle slope > (3.60 $cmolkg^{-1}$) in the upper slope > (1.76 $cmolkg^{-1}$) in the lower slope. The calcium content was irregularly distributed over the toposequence.

Magnesium averaged (1.29 $cmolkg^{-1}$) at the middle slope > (1.16 $cmolkg^{-1}$) at the lower slope > (0.92 $cmolkg^{-1}$) at the upper slope. Sodium was recorded with the highest value at the middle slope (0.30 $cmolkg^{-1}$) > (0.29 $cmolkg^{-1}$) at the lower slope > (0.28 $cmolkg^{-1}$) at the upper slope showing decrease in depth at the upper slope and increase in depth at the middle slope. Potassium content ranges (0.26 $cmolkg^{-1}$) at the upper slope which indicates the highest value followed by (0.16 $cmolkg^{-1}$) at the middle slope and (0.11 $cmolkg^{-1}$) at the lower slope respectively. Jimoh *et al*., (2020) reported that K content in the upper slope increases with depth. They attributed this trend to the leaching of basic cations, while the middle and lower slope values showed a decrease in K content with depth.

Table 1a. Effect of upper slope on soil chemical properties.

	Sample ID	pH (H_2O)	OM (%)	Av. P ($mgkg^{-1}$)	Ca	Mg	Na	K $cmolkg^{-1}$	EA	ECEC	Bs (%)
	OA/US	5.90	2.60	8.12	0.98	1.46	0.17	0.80	3.50	6.91	49.35
	OA/US	6.20	2.30	2.50	1.16	1.20	0.34	0.80	6.70	9.50	36.84
	OA/US	6.10	2.20	2.80	1.49	1.25	0.04	0.12	4.00	6.90	42.03
	EU/US	4.90	3.80	3.07	2.00	0.68	0.38	0.10	6.40	9.56	33.05
	EU/US	3.20	3.20	7.47	1.80	0.58	0.37	0.12	7.20	10.07	25.50
	EU/US	6.30	2.80	1.87	1.20	0.98	0.13	0.09	6.40	8.80	27.27
	ETI/US	5.60	4.60	7.00	1.56	0.53	0.31	0.12	3.20	9.76	67.21
	ETI/US	5.60	3.80	7.05	3.70	1.21	0.37	0.11	1.60	6.99	77.11
	ETI/US	6.30	2.90	4.30	3.60	0.40	0.39	0.09	1.60	6.08	73.68
Mean	-	5.57	3.13	4.91	1.94	0.92	0.28	0.26	4.51	8.29	48.00
SD	-	1.00	0.80	2.48	1.02	0.38	0.13	0.31	2.21	1.54	19.99
CV (%)	-	17.75	25.56	50.51	52.58	41.30	46.43	119.23	49.00	18.58	41.65
Min	-	3.20	2.20	1.87	0.98	0.40	0.04	0.09	1.60	6.08	25.50
Max	-	6.30	4.60	8.12	3.70	1.46	0.39	0.80	7.20	10.07	77.11

OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation, Min-Minimum, Max-Maximum.

Attributed to removal of nutrients by continuous cultivation of crop, exchangeable acidity was recorded with mean ranging from (4.51 $cmolkg^{-1}$) at the lower slope <, (5.09 $cmolkg^{-1}$) at the middle slope >, (3.62 $cmolkg^{-1}$) at the lower slope. FAO (2006) reported soils with base saturation < 50% were regarded as non-fertile soils. Bsat record at the upper slope (48.00 %) < (49.1 9 %) at the middle slope < (56.91 %) at the lower slope.

Relationship between Physical and Chemical Properties along Toposequence

In the upper slope significant relationship and patterns are observed among soil properties. Base saturation and calcium (0.701*) show a significant positive correlation with calcium. Base saturation is the percentage

(%) of cations exchange capacity (CEC) occupied by base cations including calcium, magnesium, potassium and sodium. Calcium is base cations that contribute to base saturation, and its concentrate in the soil is positively corrected with base saturation. A higher base saturation percentage is associated with a higher concentration of calcium in the soil, and a lower concentration of acid cations such as hydrogen and aluminum.

Exchangeable acidity correlated positively with effective cation exchange capacity (0.776*) it suggests that soils has a higher capacity to retain cation despite it acidic nature (Brady and Weil, 2008). Bulk density correlated positively with calcium (0.747*) it indicates that the soil tends to become denser as calcium content increases, this could lead to soil compaction, reduce pore space and potentially hindered root growth and water infiltration (Brady and Weil, 2008; Essien *et al*., 2022).

Saturated hydraulic conductivity correlated positively with magnesium (0.683*) it suggests that higher levels of magnesium are associated with increased water permeability, this indicates that soils with higher magnesium content have better drainage properties, potentially leading to improved soil aeration and reduced risk of waterlogging (Ghadiri and Payne, 2006). Saturated hydraulic conductivity correlated negatively with potassium (-0.764*) it suggests that higher level of potassium in the soils are associated with decreased water permeability.

Total sand shows a significant negative correlation with clay (-0.744*) this indicates that as the proportion in the soil sample increases, the proportion of clay decreases. Total porosity shows a negative correlation with exchangeable acidity (-0.676*) it entails that as the level of total porosity of a soil increases, the level exchangeable acidity decreases (Brady and Weil, 2008). Total porosity correlated positively with base saturation (0.771*) indicates that increase in total porosity of the soil, increase in the level of base saturation (Bradly *et al.*, 2008).

In the middle slope significant relationships were observed among soil properties. There is a positive correlation between pH and total sand (0.705*) the relationship between pH and total sand showed that there was increase in acidity with higher relation to sand proportion (Lal and Shukla, 2004). Calcium correlated negatively with total sand (-0.754*) which entails low calcium with higher sand proportion. Sand particles have layer pores and lower cation exchange capacity which can lead to lower retention of calcium ion in the soil. Calcium positively correlated with clay. The higher the clay contents the greater clay retention of calcium ions in the soil. Thus in a positive correlation between base saturation and clay (0.0728*) suggesting that higher base saturation is associated with higher clay content (Brady and Weil, 2008). Available phosphorus and total porosity (0.682*) this suggest a potential relationship between soil fertility and porosity, the higher porosity may lead to increased phosphate availability. Organic matter and potassium (-0.692*) this suggest that the higher organic matter content may lead to increased potassium availability absorption in the soil. Base saturation and calcium (0.752*) shows significant positive correlation with calcium base saturation refers to the % of cation exchange capacity in the soil that is occupied by base cations, such as calcium, magnesium, potassium and sodium. A higher base saturation percentage indicates that a larger proportion of CEC is occupied by these beneficial cations, which are essential for plant growth and development.

In the lower slope several significant relationships were observed. Magnesium and total porosity shows negative correlation (-0.686*), this relationship indicates that as magnesium increases total porosity decreases (Brady and Weil, 2008). pH and calcium correlate negatively (-0.752*) which indicates that higher soil pH is associated with low calcium content. pH and total porosity negatively correlate (-0.749*) this suggest that pH may indirectly affect porosity through its influence in soil properties such as bulk density and soil structure. Magnesium and organic matter correlate negatively (-0.708*) which indicates that low magnesium content may be as a result of reduced organic matter in the soil. Magnesium and pH correlate positively (0.705*) indicating a relationship between the two factors. This correlation is crucial as pH levels influence the availability in absorption of magnesium by plants impacting crop growth and yield (Brady and Weil, 2008).

Chemical properties showing mean comparison in Table 2, indicated that effective cation exchange capacity had significant difference in the lower slope from the upper and middle slope. This indicates that there was a spatial variability in soil characteristics along the slope gradient, where variations in soil properties occur due to factors such as erosion, transportation and deposition of material within the landscape (Bouma, 1989).

Table 1b. Effect of middle slope on soil chemical properties.

	Sample ID	pH (H_2O)	OM (%)	Av. P ($mgkg^{-1}$)	Ca	Mg	Na	K $cmolkg^{-1}$	EA	ECEC	Bs (%)
	OA/MS	5.90	3.00	1.89	1.32	1.07	0.43	0.11	8.00	10.93	26.80
	OA/MS	6.00	2.00	7.40	1.80	0.53	0.49	0.13	5.50	7.45	29.60
	OA/MS	5.90	4.30	2.80	1.10	1.33	0.18	0.06	5.70	8.37	31.90
	EU/MS	5.30	3.40	4.20	10.00	1.20	0.19	0.08	3.10	14.57	78.72
	EU/MS	6.20	6.80	7.00	1.60	1.32	0.21	0.04	4.60	7.77	40.80
	EU/MS	6.30	3.20	3.38	3.20	1.41	0.25	0.10	6.80	11.76	42.07
	ETI/MS	5.90	2.50	4.10	3.60	0.93	0.35	0.80	2.80	8.48	66.98
	ETI/MS	6.00	6.40	9.20	1.60	1.87	0.18	0.08	2.40	6.13	60.85
	ETI/MS	5.90	3.50	4.70	10.40	1.93	0.39	0.08	6.90	19.69	64.96
Mean	-	5.93	3.90	4.96	3.85	1.29	0.30	0.16	5.09	10.57	49.19
SD	-	0.28	1.66	2.40	3.70	0.44	0.12	0.24	2.00	4.29	18.97
CV (%)	-	4.72	42.56	48.39	96.10	34.11	40.00	150.00	39.29	40.59	38.56
Min	-	5.30	2.00	1.89	1.10	0.53	0.18	0.04	2.40	6.13	26.80
Max	-	6.30	6.80	9.20	10.40	1.93	0.49	0.80	8.00	19.69	78.72

OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation, Min-Minimum, Max-Maximum.

Table 1c. Effect of lower slope on soil chemical properties.

	Sample ID	pH (H_2O)	OM (%)	Av. P ($mgkg^{-1}$)	Ca	Mg	Na	K $cmolkg^{-1}$	EA	ECEC	Bs (%)
	OA/LS	6.00	3.37	1.82	1.29	1.08	0.38	0.12	3.1	5.97	48.07
	OA/LS	6.20	2.93	1.50	1.80	1.89	0.48	0.12	4.0	8.29	51.75
	OA/LS	6.20	3.15	7.80	1.43	1.09	0.39	0.18	4.0	7.09	43.58
	EU/LS	6.30	3.74	3.33	0.82	0.80	0.26	0.10	3.2	5.18	38.22
	EU/LS	6.40	3.80	6.58	1.01	1.08	0.24	0.11	3.5	5.94	41.08
	EU/LS	6.30	2.66	14.47	2.40	1.97	0.18	0.09	3.5	8.14	57.00
	ETI/LS	6.50	3.70	10.27	1.20	1.75	0.13	0.11	4.9	8.09	39.43
	ETI/LS	5.70	3.70	4.20	3.40	0.40	0.28	0.08	1.6	5.76	72.22
	ETI/LS	5.80	3.80	2.53	2.53	0.40	0.28	0.06	4.8	11.14	56.91
Mean	-	6.16	3.43	5.83	1.76	1.16	0.29	0.11	3.62	7.29	49.81
SD	-	0.27	0.42	4.38	0.85	0.60	0.12	0.03	0.99	1.86	11.00
CV (%)	-	4.38	12.24	75.13	48.30	51.72	41.38	27.27	27.35	25.51	22.08
Min	-	5.70	2.70	1.50	0.82	0.40	0.13	0.06	1.60	5.18	38.22
Max	-	6.50	3.80	14.47	3.40	1.97	0.48	0.18	4.90	11.14	72.22

OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation, Min-Minimum, Max-Maximum.

Table 2. Chemical properties showing mean comparison.

Soil properties	Upper	Middle	Lower	Sig
pH	5.57_a	5.93_a	6.16_a	0.66
OM	3.13_a	3.9_a	3.43_a	0.171
Av. P	4.91_a	4.96_a	5.83	0.572
Ca	1.94_a	3.85_a	1.76_a	0.77
Mg	0.92_a	1.29_a	1.16_a	0.138
Na	0.28_a	0.30_a	0.29_a	0.758
K	0.26	0.16	0.11	0.184
EA	4.51	5.09_a	3.62	0.117
ECEC	8.29_a	10.57_b	7.29_b	0.101
Bs	48.00_a	49.19_a	49.81_a	0.836

OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation.

Table 3a. Correlation matrix of upper slope showing the physical and chemical properties.

	Ts	**Si**	**Cl**	**Bd**	**Ksat**	**Tp**	**pH**	**OM**	**Av. P**	**Ca**	**Mg**	**K**	**Na**	**EA**	**ECEC**	**Bsat**
Ts	1.000															
Si	-0.492	1.000														
Cl	-0.744*	-0.199	1.000													
Bd	-0.293	-0.008	0.345	1.000												
Ksat	-0.151	0.478	-0.186	-0.597	1.000											
Tp	0.052	0.297	-0.332	0.613	-0.489	1.000										
pH	0.170	0.004	-0.344	-0.195	0.129	0.335	1.000									
OM	-0.477	0.456	0.215	0.656	-0.516	0.615	-0.340	1.000								
Av. P	0.038	0.520	-0.353	0.092	0.124	0.223	-0.454	0.435	1.000							
Ca	0.123	-0.346	0.101	0.747*	-0.602	0.467	-0.005	0.322	0.173	1.000						
Mg	0.231	0.198	-0.459	-0.631	0.683*	-0.346	0.381	-0.532	-0.017	-0.355	1.000					
K	-0.018	-0.363	0.326	0.382	-0.764*	0.165	-0.418	0.525	0.272	0.568	-0.576	1.000				
Na	0.288	0.031	-0.376	-0.907**	0.455	-0.435	0.257	-0.479	0.111	-0.495	0.613	-0.103	1.000			
EA	-0.152	-0.242	0.423	-0.400	0.103	-0.676*	-0.440	-0.226	-0.387	-0.645	-0.026	-0.047	0.152	1.000		
ECEC	-0.231	0.034	0.308	-0.103	-0.277	-0.186	-0.548	0.369	-0.069	-0.481	-0.328	0.282	-0.019	0.776*	1.000	
Bs	0.187	0.169	-0.404	0.446	-0.356	0.771*	0.369	0.402	0.413	0.701*	-0.111	0.300	-0.139	-0.948**	-0.579	1.000

Ts–Total sand, Si-Silt, Cl–Clay, Bd–Bulk density, Ksat–Saturated hydraulic conductivity, Tp–Total porosity, OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation.

Table 3b. Correlation matrix of middle slope showing the physical and chemical properties.

	Ts	Si	Cl	Bd	Ksat	Tp	pH	OM	Av. P	Ca	Mg	K	Na	EA	ECEC	Bsat
Ts	1.000															
Si	-0.400	1.000														
Cl	-0.890**	-0.049	1.000													
Bd	0.128	-0.004	-0.086	1.000												
Ksat	-0.166	0.583	-0.124	0.060	1.000											
Tp	0.025	-0.083	0.124	0.377	-0.306	1.000										
pH	0.705*	-0.246	-0.637	-0.134	-0.078	0.014	1.000									
OM	0.053	0.197	-0.088	-0.153	0.088	0.591	0.257	1.000								
Av. P	0.218	-0.412	0.036	0.312	-0.432	0.682*	0.206	0.519	1.000							
Ca	-0.754*	0.192	0.700*	0.244	0.375	-0.265	-0.613	-0.243	-0.149	1.000						
Mg	-0.268	0.414	0.149	0.301	0.5087	0.403	0.096	0.586	0.152	0.331	1.000					
K	0.447	-0.581	-0.247	0.395	-0.0305	-0.359	0.101	-0.692*	-0.118	0.005	-0.493	1.000				
Na	-0.068	0.301	-0.086	0.213	-0.392	-0.158	-0.046	-0.398	-0.144	-0.032	-0.360	0.248	1.000			
EA	0.390	-0.255	-0.358	-0.121	0.400	-0.541	0.338	-0.340	-0.557	-0.062	-0.019	0.487	-0.391	1.000		
ECEC	-0.526	0.148	0.456	0.194	0.572	-0.451	-0.369	-0.316	-0.413	0.881**	0.395	0.175	-0.179	0.396	1.000	
Bs	-0.822**	0.396	0.728*	0.305	0.039	0.198	-0.565	0.057	0.165	0.752*	0.389	-0.318	0.322	-0.641	0.429	1.000

Ts–Total sand, Si-Silt, Cl–Clay, Bd–Bulk density, Ksat–Saturated hydraulic conductivity, Tp–Total porosity, OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation.

Table 3c. Correlation matrix of lower slope showing the physical and chemical properties.

	Ts	Si	Cl	Bd	Ksat	Tp	pH	OM	Av. P	Ca	Mg	K	Na	EA	ECEC	Bsat
Ts	1.000															
Si	-0.399	1.000														
Cl	-0.819**	-0.199	1.000													
Bd	-0.047	0.528	-0.281	1.000												
Ksat	0.359	-0.411	-0.127	-0.304	1.000											
Tp	0.218	-0.132	-0.150	0.297	-0.281	1.000										
pH	-0.400	0.192	0.307	0.161	0.342	-0.749*	1.000									
OM	0.452	0.152	-0.578	0.444	-0.204	0.385	-0.178	1.000								
Av. P	-0.835**	0.061	0.855**	0.037	-0.215	-0.330	0.533	-0.387	1.000							
Ca	-0.063	-0.344	0.283	-0.237	-0.599	0.573	-0.752*	-0.133	0.023	1.000						
Mg	-0.629	0.217	0.536	-0.057	0.068	-0.686*	0.705*	-0.708*	0.538	-0.285	1.000					
K	0.611	-0.200	-0.528	-0.173	0.422	0.025	-0.342	-0.326	-0.669*	-0.009	-0.056	1.000				
Na	0.095	0.151	-0.197	0.198	0.409	-0.471	0.403	-0.348	0.103	-0.520	0.313	0.449	1.000			
EA	-0.322	0.304	0.153	0.657	0.158	0.159	0.443	-0.033	0.178	-0.382	0.370	-0.117	0.126	1.000		
ECEC	-0.306	0.007	0.322	0.401	-0.176	0.616	-0.167	-0.150	0.085	0.338	0.126	-0.039	-0.321	0.719*	1.000	
Bs	0.028	-0.332	0.178	-0.349	-0.563	0.488	-0.800**	-0.150	-0.091	0.976**	-0.303	0.099	-0.506	-0.525	0.199	1.000

Ts–Total sand, Si-Silt, Cl–Clay, Bd–Bulk density, Ksat–Saturated hydraulic conductivity, Tp–Total porosity, OM–Organic matter, Av. P–Available phosphorus, Ca–Calcium, Mg–Magnesium, K–Potassium, Na–Sodium, EA–Exchangeable acidity, ECEC–Effective cation exchange capacity, Bs–Base saturation.

Correlation matrix result of soil physical and chemical properties on the upper slope showed in Table 3a, revealed that Ts correlated negatively with Cl (- 0.744*). Bd correlation negatively with Na (- 0. 907**) and positively with Ca (0.747*). Ksat correlated negatively with K (- 0.764*) and positively with Mg (o. 683*). Tp correlated negatively with EA (- 0.676*) and positively with Bs (0.771*). Furthermore, Ca correlated positively with Bs (0. 701*). EA result shows negative correlation with Bs (- 0.948*), and positive correlation with ECEC (0.776*).

Correlation matrix result of soil physical and chemical properties on the middle slope shown in Table 3b, indicated that Ts correlated negatively with Cl (- 0. 890**), Ca (0. 754*), Bs (- 0. 822**) and positively with pH (0. 705*). Cl correlated positively with Ca (0.700*) and Bs (0.728*). Tp correlated positively with Av. P (0.682*), OM correlated negatively with K (- 0.692*). Ca correlated positively with ECEC (8.881**) and Bs (0.752*).

Correlation matrix result of soil physical and chemical properties on the lower slope shown in Table 3c, indicated Ts correlated negatively with Cl (-0.819**) and Av. P (- 0.835**). Cl correlated positively with Av. P (0.855**). Tp correlated negatively with Tp (-0.749*) and Mg (- 0.686*). pH correlated negatively with Ca (- 0.752*) and Bs (- 0.800**) and positively with Mg (0.705*). OM correlated negatively with K (- 0.669*). Ca correlated positively with Bs (0.976**), while EA correlated positively with ECEC (0.719*).

Conclusion

The study was geared toward the comparison evaluation of selected soil properties along toposequence in acid soil of Akwa Ibom State. Based on the study, the following conclusion was made. Particle size analysis was dominated by sand which are highly susceptible to erosion and has low water and nutrients holding capacity. pH content of the soil are slightly acidic which decreases nutrient of the soil which is not suitable for the soil.

Recommendations

The evaluation of selected soil properties along toposequence provide information and guide necessary on how to improve the soil for better use and avoid less productivity of the soil. To obtain an effective soil, proper attention should be given to how the soil is been taken care and methods to maintain it from degrading.

Declarations

Acknowledgements: We gratefully acknowledge all of the people who have contributed to this paper.

Author Contributions: EOA: Design of study, statistical analysis and interpretation, manuscript preparation, editing and manuscript revision, submission of article; ECD: Data collection, data analysis, implementation of study protocol; AOR: Review manuscript, literature survey, date analysis; BFE: Concept, literature survey, manuscript revision; EPS: Concept, design, literature survey, data collection.

Conflict of Interest: The authors declare no conflict of interest.

Consent to Publish: All authors agree to publish the paper in International Journal of Recent Innovations in Academic Research.

Date Availability Statement: The data are presented in this study are available upon request from the corresponding author.

Finding: This research received no external finding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Research Content: The research content presented in this manuscript is original and has not been previously published elsewhere.

References

1. Akata, O.R., Essien, O.A., Ben, F.E., Enyong, J.K. and Tochukwu, N.E. 2024. Effect of different level of poultry manure on growth and yield of Amaranthus plant (*Amaranthus hybridus*) in Obio Akpa, Akwa Ibom State, Nigeria. Asian Journal of Soil Science and Plant Nutrition, 10(4): 744–751.
2. Akpan, E.A., Bernard, A.E., Essien, O.A., Akata, O.R. and Ben, F.E. 2025. Effect of organic fertilizers on growth and yield of garlic (*Allium sativum* L.) in Obio Akpa. Asian Journal of Agriculture, 18(1): 61–69.
3. Akpan. E.A., Elijah, A.A. and Essien, O.A. 2021. Response of carrot (*Daucus carota* L.) to different organic fertilizer in Obio Akpa, Akwa Ibom State. Nigerian Journal of Agricultural Technology, 8: 46–52.

4. Aweto A.O. and Enaruvbe G.O. 2010. Catenary variation of soil properties under oil palm plantation in Southwestern Nigeria. Ethiopian Journal of Environmental Studies and Management, 3(1): 1-7.
5. Ben, F.E., Essien, O.A., Enyong, J.F. and Essien, I.A. 2024. Effect of poultry manure and super-grof fretilzer on the performance of sweet potato in the lowland rainforest of Obio Akpa. Nigerian Journal of Horticulture Science, 28(3): 28–33.
6. Bockheim, J.G. 2005. Soil endemism and its relation to soil formation theory. Geoderma, 129: 109–124.
7. Bouma, J. 1989. Using soil survey data for quantitative land evaluation. Advances in Soil Science, 9: 177-213.
8. Brady, N.C. and Weil, R.R. 2008. The nature and properties of soils. 14th Edition, Pearson Education.
9. Brubaker, S.C., Jones, A.J., Lewis, D.T. and Frank, K. 1993. Soil properties associated with landscape position. Soil Science Society of America Journal, 57(1): 235-239.
10. Cox, S.B., Willing M.R. and Scatena F.N. 2002. Variation in nutrient characteristics of surface soils from Luquillo experimental forest of Puerto Rico: A multivariate perspective. Plant and Soil, 247: 198–189.
11. Dane, J.H. and Topp, G.C. 2002. Methods of soil analysis, part 4: Physical methods. Soil Science Society of America Book Series No. 5.
12. Durak, A. and Surucu, A. 2005. Soil formation on different landscape in a semi-humid region of Turkey. Journal of Agronomy, 4(3): 191-195.
13. Enwezor, W.O., Udo, E.J., Ayotade, K.A., Adepetu, J.A. and Chude, V.Q. 1990. A review of soil and fertilizer use research in Nigeria. Federal Ministry of Agriculture: Water Resources and Rural Development, 109-200.
14. Essien, O.A. Akpan, E.A. and Akata, O.R. 2023. Comparative methods of land use practices effect on clay dispersion in coastal plain sand soils in Southeastern Nigeria. Journal of Agriculture, Environmental Resources and Management, 5(6): 1022-32.
15. Essien, O.A. and Ogban, P.I. 2018. Effect of slope characteristics on aggregate size distribution in soils formed on coastal plain sands in Akwa Ibom State, Nigeria. Card International Journal of Agricultural Research and Food Production, 3(1): 77–118.
16. Essien, O.A., Ogban, P.I., Arthur, G.J., Sam, I.J. and Edet, I.G. 2024a. Effect of organic matter quality in aggregate size fraction on coastal plain sand soils Southeastern, Nigeria. Asian Journal of Soil Science and Plant Nutrition, 10(4): 480–492.
17. Essien, O.A., Sam, I.J. and Udoinyang, U.C. 2024b. Gully category, slope position and soil depth studies of 'acid sand': Their effects upon soil physical properties in Akwa Ibom State, Southeastern Nigeria. Asian Journal of Soil Science and Plant Nutrition, 10(4): 776–794.
18. Essien, O.A., Umoh, F.O., Ekwere, O.J., Idonyesit G. Edet, I.G. and Akpan, E.A. 2022. Structural stability and erodibility of soil under different land and usetypes in Akwa Ibom State, Nigeria. Akwa Ibom State University Journal of Agriculture and Food Science, 6: 10-21.
19. Essoka, P.A., Jaiyeoba I.A. and Essoka A.N. 2006. A toposequence study of soils developed on gneiss and granodiorite on the cross river rainforest zone. Proceedings of the 31st Annual conference of the Soil Science Society of Nigeria, Ahmadu Bello University Zaria.
20. Esu, I.E., Akpan-Idiole A.U. and Eyong, M.O. 2008. Characterization and classification of soils along a tropical hillslope in Afikpo area of Ebonyi State. Nigerian Journal of Soil and Environment, 8: 1-6.
21. FAO. 2006. Guidelines for soil description. Fourth Edition, Food and Agricultural Organisation of United Nations, 97p.
22. Gessler, P.E., Chadwick, O.A., Chamran, F., Althouse, L. and Holmes, K. 2000. Modeling soil–landscape and ecosystem properties using terrain attributes. Soil Science Society of America Journal, 64(6): 2046-2056.
23. Ghadiri, H. and Payne, D. 2006. Effect of soil structure and hydraulic conductivity on overland flow generation: Scale effects process interactions. Journal of Hydrology, 331(3-4): 688-702.
24. Hikmat, H., Subagyo, H. and Prasetyo, B.H. 2003. Soil properties of the eastern toposequence of Mount Kelimutu Flores Island East Nusa Tenggara and their potential for agricultural use. Indonesian Journal of

Agricultural Science, 4(1): 1–11.

25. Hook, P.B. and Burke I.C. 2000. Biogeochemistry in short grass landscape: Control by topography, texture and microclimate. Ecology, 81(10): 2686–2703.
26. Ibanga, U.P., Essien, O.A., James, U.F. and Emmanuel, A.F. 2023. Organic manure in cocoyam based intercropping system. American Journal of Life Science, 11(3): 50–55.
27. Idoga, S., Ibanga I.J. and Malgwi W.B. 2006. Variation in soil morphology and physical properties and their management implications on a toposequence in Samaru area Nigeria. Proceedings of the 31st Annual Conference of the Soil Science Society of Nigeria, Ahmadu Bello University Zaria.
28. Jenny, H. 1941. Factors of soil formation: A system of quantitative pedology. Dover Publications Inc. New York, 675p.
29. Jimoh I.A. Mbaya L.A., Akande, D., Agaku, T. and Haruna S. 2020. Impact of toposequence on soil P properties and classification in Zaria Kaduna State, Northern Guinea Savanna, Nigeria. International Journal of Environment Quality, 38: 48–58.
30. Klute, A. 1986. Methods of soil analysis, No. 9, Part 1, physical and mineralogical properties. America Society of Agronomy monographs. Madison, WI, USA. 1174p.
31. Lal, R. and Shukla, M.K. 2004. Principle of soil physics. Marcel Dekker, Inc. New York, 682p.
32. Mark, I.F., Udoh, B.T. and Essien, O.A. 2024. A comparison of soil characteristics under different agricultural land use systems in a coastal plain sand soils of Akwa Ibom State, Nigeria. Nigerian Journal of Agricultural Technology, 20: 1–19.
33. McLean, E.O. 1982. Soil pH and lime requirement. Methods of soil analysis: Part 2 chemical and microbiological properties, 9: 199-224.
34. Murphy, J. and Riley, J.P. 1962. Modified single method for the determination of phosphorus in natural eaters. Analytica Chimica Acta, 27: 31–36.
35. Ogban, P.I. and Essien, O.A. 2016. Water-dispersible clay and erodibility in soils formed on different parent materials in Southern Nigerian. Nigerian Journal of Soil and Environmental Research, 14: 26 –40.
36. Ogban. P.I., Ibotto, M.I., Utin, U.E., Essien, O.A. and Arthur, G.J. 2022. Effect of slope curvature and gradient on soil properties affecting erodibility of coastal plain sands in Akwa Ibom State, Nigeria. Agro-Science International Journal, 21(2):12-23.
37. Ollinger, S., Smith, M., Martin, M., Hallett, R., Goodale, C. and Aber, J. 2002. Regional variation in foliar chemistry and nitrogen cycling among forests of diverse history and composition. Ecology, 83(2): 339–355.
38. Osujieke, D. 2017. Characterization and classification of soils of two toposequences formed over different parent materials in Imo State, Nigeria. International Journal of Agriculture and Rural Development, 20(1): 2872–2884.
39. Osujieke, D.N., Onweremadu, E.U., Ahukaemere, C.M. and Ndukwu, B.N. 2016. Classification of soils of a toposequence underlain by coastal plain sand in South-East Nigeria. Nigerian Journal of Soil and Environmental Resources, 14: 256–263.
40. Petters, S.W., Usoro, E.J., Udo, E.J., Obot, U.W. and Okpon, S.N. 1989. Physical background of soils and landuse and ecological problems. Technical Report of the Task Force on Soils and Survey, Akwa Ibom State Government Print Office, Uyo, 603p.
41. Sam, I.J., Edet, I.G., Essien, O.A. and Thomas, U.F. 2025. Effect of agricultural land use practices on selected soil properties and macro-aggregate stability: A case study of coastal plain sand, Akwa Ibom State, Nigeria. Asian Journal of Soil Science and Plant Nutrition, 11(1): 25–36.
42. Seibert, J., Stendahl, J. and Sørensen, R. 2007. Topographical influences on soil properties in boreal forests. Geoderma, 141(1-2): 139-148.
43. Shariatmadari, H., Shirvani, M. and Jafari, A. 2006. Phosphorus release kinetics and availability in calcareous soils of selected arid and semiarid toposequences. Geoderma, 132(3-4): 261-272.
44. Simeon, S.D. and Essien, O.A. 2023. Evaluation of some soil physicochemical properties and implication

on soil fertility in Etinan, Akwa Ibom State, Nigeria. AKSU Journal of Agriculture and Food Science, 7(3): 86–93.

45. Soil Survey Staff. 2011. Soil survey laboratory information manual. Soil survey investigations report No. 45, Version 2.0. Burt, P. (Ed.), U.S. Department of Agriculture, Natural Resources Conservation Service, 506 p.

46. Subardja, D. and Buurman P. 1980. A toposequence of latosols on volcanic rocks in the Bogor–Jakarta area. In: Buurman, P., (Ed.), Red soils in Indonesia. Agricultural Research Report No 889, Bulletin No 5, 25-45p.

47. Temgoua, E., Tchapnga, H.B.D., Tanawa, E., Guenat, C. and Pfeifer, H.R. 2005. Groundwater fluctuations and footslope ferricrete soils in the humid tropical zone of southern Cameroon. Hydrological Processes: An International Journal, 19(16): 3097-3111.

48. Thomas, G.W. 1982. Soil pH and soil acidity. In: Methods of soil analysis Part 3. Chemical methods, Sparks, L.D., (Ed.), SSSA Book Series, 159–165p.

49. Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.O. and Esu, I.E. 2009. Manual of soil, plant and water analysis. Lagos: Sibon Books, Publishers Ltd., Nigeria, 183.

50. Wilding, L.P. 1985. Spatial variability: Its documentation, accommodation and implication to soil surveys. In: Nielsen, D.R. and Bouma, J., (Eds.), Soil spatial variability: Pudoc, Wageningen, Netherlands, 166-194p.

51. Wilson, D.J., Western A.W. and Grayson R.B. 2004. Identifying and quantifying sources of variability in temporal and spatial soil moisture observations. Water Resources Research, 40(2): 1-10.

Citation: Essien, O.A., Etim, C.D., Akata, O.R., Ben, F.E. and Essien, P.S. 2025. Comparative Evaluation of Selected Soil Properties along Toposeqences on Acid Soils in Akwa Ibom State, Nigeria. International Journal of Recent Innovations in Academic Research, 9(1): 54-68.