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Research Article

Assessment of Soil Physico-Chemical Properties on a Toposequence of an Erosion Site in Ikeduru, Southeastern Nigeria

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ABSTRACT

The study was carried out to assess soil physic-chemical properties of an erosion site in Ikeduru, Imo State Nigeria, which has experienced land degradation over the years. Three profile pits were dug, described and samples collected for the physico-chemical laboratory analysis. Data obtained were analyzed using Genstat Discovery, Edition 4 for a CRD experiment. The outcome shows soils was deep, fine weak, dark brown, brown, red and dark reddish brown in the Munsell colour code. An LSD, a correlation at 5% probability level was used to separate the means significantly. Correlation investigation was carried out to explain relationships among selected physico-chemical properties of the studied soil. The particle size distribution indicated high sand content and low clay content in the three profiles selected with SCL as dominating textural class, except for 1.85 g cm^{-3} bulk density which was observed to be safe in all the profile pits examined, the silt – clay ratio was low (<1), except at the surface soil in the foot-slope (1.09). Soil pH (KCl) was moderately acidic at the summit. The organic matter had significant positive correlations with TN (r = 0.99***), Ca (r = 0.85**), Mg (r = 0.59*), K (r = 0.61*) and ECEC (r = 0.74**). Phosphorus maintained significant positive relationships with all basic cations with correlation coefficients that ranged from 0.51* for K to 0.59* for Ca. Total exchangeable acidity had a significant (P<0.001) negative relationship with %BS (r =-0.98***). It has been seen that the main causes of erosion are unprofessional land use forms.

RESEARCH ARTICLE

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INTRODUCTION

Soil erosion has been a challenging factor in the southeastern part of Nigeria where vast lands are being affected, causing transposition of topsoils, hence; causing the degrading of soil. Water and wind are found to be the major agents of soil erosion and land degradation; each contributes to a substantial extent of soil loss annually. The loss of topsoil from farmland could be reproduced in deficit crop production potential, lesser shallow water quality and spoiled drainage systems (Morgan, 1991). Agricultural production, sustenance and management aimed at food safety and sustenance have been greatly undermined in this section by the threat postured by soil destruction although the accessibility of agricultural farmlands for production and construction events has been significantly minimized by the losses initiated by the associated problems with soil erosion (Okorafor *et al.*, 2017).

The erosion of soils is seen as a major ecological difficulty as it utterly threatens and destroys natural resources as well as the environment (Rahman *et al.*, 2009). Soil erosion diminishes soil quality and reduces the productivity of natural, agricultural and forest ecosystems (Pimentel, 2006). Water and wind erosion are the two major constituents of land degradation: water and wind erosion cause 84% of te global magnitude of degraded land mass, excessive erosion, and most notable environmental defects (Mbagwu, 1996). Soil characterization is an essential part of the determination of the nature and extent of soils on a construction site or earth system in order to review subsurface conditions and ensure that the soil composition adhere to any lead down regulations. Soil contamination, soil or land pollution as part of land degradation is caused by the presence of human–made chemicals or other alteration in the natural soil environment (Wikipedia, 2022). Depth characterization also provides a key parameter in determining volumes of contaminated soil. Recently El- Swaify (1994) observed that the third world countries suffer from soil degradation incurred due to the maladministration of land; this has posed a main distress that threatens pastoral growth and economy. According to Wang and Gong (1998) one of the major factors that enhance the global biosphere and agricultural development practice is the quality of soil. To develop a workable soil management practice that will ensure the great productive potential of a soil, the knowledge of basic soil properties is required. The study is accurate of the temperate topsoil with intrinsic characteristics which include low (water holding capacity, cation exchange capacity, organic matter content) structural variability and flood hazard especially at foot slopes hence; it creates an uneven environment which envelops to soil erosion. Therefore, there is a need to characterize some of these problems on a toposequence and proffer solutions. The study's objectives are to compare soil physical-chemical properties of a toposequence in an erosion-prone environment, determine the effect of erosion on soil quality in the environment, and propose potential solutions to reduce the threat of soil erosion to agricultural productivity improvement.

MATERIALS and METHODS

Ikeduru Local Government region is situated in the western part of Imo State in Southeastern Nigeria. It is located on latitude 5° 56" 795' N, longitudes 7° 15" 338' E and with altitude of about 150 m (492 ft) and a monsoon climate. The area has mean annual rainfall ranging from 2000 mm to 2500 mm, a mean temperature of 27°C and humidity of between 70% and 80%. The climatic condition of the area favours the production of vegetables (pumpkin leaf) cassava, pineapple and plantains.

Geology of the workspace

The geological material from which the soils of the study area developed is coastal plain sand (Benin formation). The landform of the study area is dominated by gentle rolling relief which stretch towards a plain usually with streams that govern the hydrology of the area. The toposequence has a slope characterized by three identifiable units namely the upper-slope, mid- slope and foot-slope. The slope is 9% (upper-slope), 5% (mid-slope) and 2% (foot-slope). The slope was obtained using Abney level (Juo and Moorman, 2000). A humid tropical climate with an average annual rainfall of about 2156 mm and annual temperature of about 26°C and high relative humidity of 75% (Esu *et al.*, 2008).

Field work and sample collection

Transect survey technique was employed in aligning soil profile pits along the slope. The collected samples were described according to FAO (2006). The location of the profile pits was done based on the accessible land usage as seen in the region, by way of augering along the topo-sequence the soil distribution as well as the topography of the area were determined. Three profile pits with designation: ECH/UK/01 (Summit), ECH/UK/02 (Middle slope), and ECH/UK/03 (Footslope) were placed end to end on the slope. Three samples of soil type were collected and characterized with respect to depth, 01: 0 – 30, 30 – 45, 45 – 65, 65 – 85, 85 – 110 cm, 02: 0 – 20, 20 – 40, 40 – 65. 65 – 85, 85 – 120 cm and 03: 0 – 15, 15 – 30, 30 – 45, 45 – 60, 60 – 100 cm. Samples collected were bagged, branded and conveyed to the laboratory for proper investigation.

Laboratory analysis

The samples of the soil were analyzed for certain selected soil properties that are necessary for proper scientific classification of the soils. The selected physical properties as determined includes particle size distribution, bulk density, moisture content and chemical properties including soil pH, exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}), exchangeable acidity (Al^{3+} and H^{+}), total nitrogen, available phosphorus and organic carbon.

The particle size distribution was determined through hydrometer method agreeing to the technique of Gee and Or (2002). Bulk density determined via core method (Grossman and Reinsch, 2002). Moisture content is determined gravimetrically by oven-drying saturated soil samples 105°C within 24 hours, as well as moisture percentage calculated (Obi, 1990). Thomas (1996), 1: 2.5 soil-liquid ration using pH meter was used to determine the soil pH.

Organic carbon was determined by wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro Kjeldahl distillation method (Bremmer and Mulvaney, 1982). Bray 11 method as described by Olsen and Sommers (1982) was used to determine the available phosphorus content. EDTA complexometric titration was used to obtain calcium and magnesium while an NH_4OA_C solution was used to extract the exchangeable basic cation. Exchangeable potassium and sodium were evaluated by means of flame photometry (Jackson, 1973).

According to McLean (1992) exchangeable acidity determination was carried out titrametrically through the extraction of exchangeable H^+ and Al^{3+} with in potassium chloride. The calculation of *ECEC* (Effective Cation Exchange Capacity) was done via summing up the value of the basic cations in cmol kg^{-1}. Percentage base saturation was calculated thus;

$$\%BS = \frac{TEB}{ECEC} \times \frac{100}{1} \tag{1}$$

Where,
BS: Base Saturation
TEB: Total Exchangeable Base cmol kg^{-1}
ECEC: Effective Cation Exchange Capacity

Aluminum saturation was calculated thus;

$$AL\ sat = \frac{AL^{3+} Cmol/\ kg\ sn^{1}}{ECEC\ Cmol/kg} \times \frac{100}{1} \tag{2}$$

Where,
Al sat: Aluminum Saturation
ECEC: Effective Cation Exchange Capacity
cmol: Centimole

Data and statistical analysis

Analysis of variance (ANOVA) for a CRD experiment was used in analyzing the data using SAS Package. Significant treatment means were separated using Least Significant Difference (LSD) at 5% probability level. Pearson correlation analysis was used to determine the relationships between measured variables.

RESULTS AND DISCUSSION

The soils morphological characteristics are shown in Table 1. The horizons were well-drained except for the horizons that shared boundary with the high water table at the footslope. This is due to the texture and structure of the soils geography of the study area. The trend of the particle size distribution down the profile was responsible for the loose and firm consistency of the soil both surface and sub-surface respectively. The structure and sandy nature of the soils explain why the soils were generally well drained and susceptible to leaching and erosion.

The various physiographic positions have different colour matrix range which are described as follows; at the summit it was observed that across the horizons the colour ranges from Brown (7.5YR $^4/_3$) when moist to Red (2.5YR $^4/_8$) when moist. The midslope recorded a colour range of Brown (7.5YR $^4/_2$) when moist to Red (2.5 YR $^4/_8$).

Furthermore, the footslope had colour matrix range, Brown (7.5 YR $^4/_2$) when moist, when moist and Red (7.5 YR $^4/4$) when moist. The drainage condition and physiographic position may have influenced the observable changes in the soil colour matrix in topographic units.

However, the textural class of the toposequence ranges from sandy loam to sandy clay loam. The slope showed a textural range of sandy loam (SL) at the A horizon, and sandy clay loam (SCL) was observed at other horizons for the summit. The midslope shows a textural range of A, B1 & B2 horizons and sandy clay loam (SCL) at the B_3 and C horizon. The footslope was observed to have a textural range of sandy loam (SL) at A and B_1 horizon.

Table 1. Morphological characteristics of soils of the study site.

Slope Gradient	Depth (cm)	Matrix colour (moist)	Texture	Structure	Consistency	Drainage	Root
Summit							
	0-30	Brown (7.5YR $^4/_3$)	SL	Granular	Loose	Wd	Mf
	30-45	Dark Reddish Brown (2.5 YR $^3/_3$)	SCL	Sbk	Firm	Wd	Mf
	45-65	Reddish Brown (2.5R $^4/_4$)	SCL	Sbk	Firm	Wd	Mf
	65-85	Reddish Brown (2.5R $^4/_4$)	SCL	Sbk	Firm	Wd	Cf
	85-110	Red (2.5 $^4/_8$)	SCL	Sbk	Firm	Wd	Cf
Midslope							
	0-20	Brown (7.5YR $^4/_2$)	SL	Granular	Loose	Wd	Mf
	20-40	Dark Reddish Brown (5YR $^3/_2$)	SL	Sbk	Firm	Wd	Mf
	40-63	Dark Reddish Brown (2.5YR $^3/_4$)	SL	Sbk	Firm	Wd	Mf
	63-80	Dark Reddish Brown (2.5YR $^3/_6$)	SCL	Sbk	Firm	Wd	Cf
	80-120	Red Brown (2.5YR $^4/_8$)	SCL	Sbk	Firm	Wd	Fine
Footslope							
	0-15	Dark Brown (5YR ¾)	SL	Crumb	Loose	Wd	Mf
	15-30	Reddish Brown (5YR $^4/_4$)	SL	Sbk	Firm	Wd	Mf
	30-45	Reddish Brown (2.5YR $^4/_4$)	SCL	Sbk	Firm	Wd	Cf
	45-60	Dark Brown (5YR $^4/_6$)	SCL	Sbk	Firm	Wd	Cf
	60-100	Dusky red (7.5YR $^4/_4$)	SCL	Sbk	Firm	Pd	Fine

YR = Yellow-red, SL = Sandy loam, SCL = Sandy clay loam, Sbk = Subangular blocky, Wd = Well drained, Pd = Poorly drained, Mf = Many fine, Cf = Common fine, F = Fine

Soil physical properties

Tables 2 and 3 posits the soil results of the physic-chemical properties and are stated as Pedons Summit via Mid-slope plus Foot-slope, hence the distinctions in the physical and chemical properties in different soil profile depths (Summit), (Midslope), and (Footslope), while Table 4 shows the mean variation value of physico-chemical properties in varying toposequence.

Particle size distribution of soil texture

The comparative percentage of the different soil such as sand, silt, and clay which makeup the classes of soil (Gee and Or, 2002). Hence, the outcome shows that the content of the sand in all the samples was actual high and it ranges from 66.8 - 80.8%, while Summit and Foot-slope obtained 85% which is the maximum outcome and Mid-slope (67 %) which is the least.

Low silt content was recorded in all the profiles in the pedons ranging from 2.0 – 10.0. Low to medium ranged of 2.0-6.2% was observed in the clay contents. Summit and foot-slope recorded maximum values, however displays no convincing development. The clay movement with other finer materials results from top amid shows 8.2 – 27.2% that fluctuates among the depths of all soils by an overland flow, the results was in line with Akamigbo (1999) and Adekayode and Akomolafe (2011). As posit by Medugu *et al.* (2008) the issue could be resolved by tree planting to protect the soil from being eroded.

Bulk density

Gee and Or (2002) defines bulk density as dry weight (mass) of the soil over unit of bulk volume of soil. The bulk densities of soil samples are usually moderate, ranging between 1.50 and 1.70 g cm^{-3}. According to De Geus (1973), bulk densities greater than 1.75 g cm^{-3} for sands limit root penetration in soils.

Table 2. Soil physical properties of erosion prone toposequence

Slope Gradient	Horizon depth (cm)	Sand (%)	Silt (%)	Clay (%)	Silt/Clay ratio	TP (%)	Bd (g cm^{-3})	Texture
Summit	0 – 30	80.8	2.0	17.2	0.12	43.40	1.50	SL
	30 – 45	70.8	2.0	27.2	0.07	43.40	1.50	SCL
	45 – 65	70.8	2.0	27.2	0.07	43.40	1.50	SCL
	65 – 85	66.8	2.0	31.2	0.06	43.40	1.50	SCL
	85 – 110	68.8	2.0	29.2	0.07	43.40	1.50	SCL
Mean		**71.6**	**2.0**	**26.4**	**0.08**	**43.40**	**1.50**	
Mid slope	0 – 20	76.8	4.0	19.2	0.21	44.15	1.48	SL
	20 – 40	89.8	2.0	8.2	0.24	43.40	1.50	SL
	40 – 63	76.8	4.0	19.2	0.21	39.62	1.60	SL
	63 – 80	76.8	2.0	21.2	0.09	43.40	1.56	SCL
	80 – 120	72.8	2.0	25.2	0.08	43.40	1.60	SCL
Mean		**78.6**	**2.8**	**18.6**	**0.17**	**41.58**	**1.55**	
Foot slope	0 – 15	80.8	10.0	9.2	1.09	43.40	1.50	SL
	15 – 30	78.8	8.0	13.2	0.61	43.40	1.50	SL
	30 – 45	68.8	5.0	26.2	0.19	41.51	1.55	SCL
	45 – 60	78.8	4.0	17.2	0.23	39.62	1.60	SCL
	60 – 85	70.8	4.0	25.2	0.16	39.62	1.60	SCL
Mean		**75.6**	**6.2**	**18.2**	**0.46**	**41.51**	**1.56**	
LSD (0.05)		**NS**	**2.2****	**7.1***	**NS**	**NS**	**NS**	

*, ** = Significant at 5 and 1% probability levels, respectively; NS = Not significant at 5% probability level.
SL = Sandy loam; SCL = Sandy clay loam.

Silt / Clay ratio

A silt / clay ratio at the topsoil level is a soil index used to assess flood risk. Where the ratio is <1, it suggests absence of flood hazard in the environment. However, when the ratio is >1, it suggests presence of flood incidence/hazard. Results obtained from this study showed that Silt/clay ratio at 0-30 cm soil depth at the summit and at 0-20 cm at mid-slope were <1 (0.12, and 0.21, respectively) (Table 2), hence; it agrees with Nwosu *et al.* (2011) who noted that such soils are old and highly weathered. Silt /clay ratio at the foot-slope was greater than 1, suggesting flood hazard at 0 – 15 cm soil depth at the foot-slope.

Soil chemical properties

The outcomes of toposequence of an erosion prone area on soil chemical properties are as shown in Table 3.

Soil pH

The pH of the soil indicates strongly acidic in the absence of potassium chloride; while the pH of the soil alternates between 4.08 and 4.66, this indicates high level acidity content; however, in one horizon of the mid-slope, the range falls within 4.9, indicating that the acidic response is very strong as shown in (Table 3). The pH value a times increases with the depth as noted by Yakubu and Ojanuga (2011) and Sharu *et al.* (2013) who reported that the average pH values of the soils are 7.7, 7.1 and 7.0 which indicates acidity of the soil around humid regions. While, Akamigbo and Igwe (1990) who noted that low acidity result are observed in soils around humid regions due to soil erosion that is liable for the low to high calcium and magnesium contents of the soil.

Soil organic carbon (OC) and soil organic matter (OM)

The summit has an OM range of 0.38 1.17%, the mid-slope has an OM range 0.14 1.10% and foot-slope and organic matter alternate between 0.10 and 0.93%. According to Morgan (1991) the outcomes are consistent hence it is in line with the organic (matter and carbon) in tropical soils as they are mostly low owing to leaching activities and terrible sheet erosion, accompanied by the burial of top soils via tillage operation with mineralization of organic matter via increased warmth.

Total nitrogen

The outcomes of the total nitrogen content in the three Summit, Mid-slope and Foot-slope indicates values alternate amid 0.02-0.12 %, 0.01-0.06 %, 0.01-0.05% separately. There was a decrease in nitrogen values of the soil with increased depth, caused by the erosion of nitrates on the top soils. This is in line with Noma *et al.* (2011) who noted that Total Nitrogen values of the soils in the area changed irregularly with depth which could be attributed to influence of continuous land use and degradation in the area. Esu (1991) the Total Nitrogen in the soils remained low when compared to the evaluations.

Available Phosphorus (AvP)

The result of the available phosphorus content of the soil (0.25-2.65 cmol kg^{-1}) hence, pedon 01 has values from 1.1-1.25 cmol kg^{-1}, mid-slope varied between 0.28-0.50 cmol kg^{-1} and Foot-slope varied between 1.00-2.25 cmol kg^{-1}. The values are comparable with the values reported by Ohaeri and Eshett (2011). The loss of phosphorus is commonly owing to its elimination by the crops as posit by (Enwezor *et al.*, 1990). Phosphorus react in acidic soils to produce an insoluble compounds such as Fe^{3+}, Al^{3+}, and Mg^{2+}

Exchangeable bases

The results of the exchangeable bases show that sodium (Na^{+}) has 0.11-0.16 cmol kg^{-1}, potassium (K^{+}) 0.12-0.17 cmol kg^{-1}, magnesium (Mg^{2+}) 0.18-1.48 cmol kg^{-1} and calcium (Ca^{++}) has 1.22-1.86 cmol kg^{-1} in pedon 01. As noted by Esu et al (2008) the results show values from low to medium in all pedon. The result of the study was supported by Noma *et al.* (2004) who noted that the exchangeable bases are generally low, showing it was inconsistent. This was in accordance Mbagwu (1996) who stated that the leaching of Ca and Mn is principally liable in the growth of acidity in the soil through high precipitation via permeable layer of the soil texture in addition to the parent constituents.

Total Exchangeable Acidity (TEA)

The results of the total exchangeable acidity (0.3-1.1 cmol kg^{-1}) show that total exchangeable acidity falls in the middle of low and medium with higher values noted in the Summit and Mid-slope, as well as the Foot-slope which has the poorest outcome. Note that TEA is the measurement of the quantity of cation exchange capacity content in the soil which is occupied by acidic cations.

Effective Cation Exchangeable Capacity (ECEC)

The results of ECEC obtained in Table 3; indicate an observation of low to medium values which falls between 3.50 and 3.87 cmol kg^{-1}. The highest value was found in Summit, while the lowest in Foot-slope. It will be noted that due to the activities of clay mineral content (kaolinite) the value of ECEC turned low.

Base Saturation (BS)

The BS results as obtained were very high going from 71.87-90.00%, the highest value was observed in Summit in the lowest horizon, while the Mid-slope observed the lowest outcome in the upper horizon. The figure obtained is in consonance with Akamigbo and Asadu (1986), who posit that parent constituents may have a sturdy control on the total exchangeable bases as well as the total acidity of a soil; which may be due to erosion of soil by precipitation.

Table 3. Soil chemical properties of an erosion prone toposequence.

Toposequence	Horizon depth (cm)	pH (H_2O)	pH (KCl)	OM (%)	TN (%)	Av. P (mg kg^{-1})	TEA	Ca^{2+}	Mg^{2+}	K^+	Na^+	ECEC	%BS
							→		cmol kg^{-1}	←			
Summit	0 – 30	5.10	4.42	2.31	0.12	1.1	0.4	1.86	1.42	0.17	0.15	4	90.00
Summit	30 – 45	4.66	4.32	1.17	0.06	1.25	1.0	1.67	1.44	0.15	0.13	4.39	77.22
Summit	45 – 65	4.93	4.35	0.59	0.03	1.15	1.1	1.28	1.26	0.14	0.13	3.91	71.87
Summit	65 – 85	5.19	4.60	0.55	0.03	0.00	0.9	1.26	1.20	0.12	0.11	3.59	74.93
Summit	85 – 110	4.98	4.31	0.38	0.02	0.00	0.7	1.22	1.28	0.13	0.14	3.47	79.83
Summit mean		**4.97**	**4.40**	**1.00**	**0.05**	**0.70**	**0.82**	**1.46**	**1.32**	**0.142**	**0.132**	**3.87**	**78.77**
Mid slope	0 – 20	4.37	4.10	1.10	0.06	0.5	1.1	1.4	1.36	0.14	0.13	4.13	73.37
Mid slope	20 – 40	4.86	4.08	1.00	0.05	0.45	1.0	1.45	1.23	0.14	0.15	3.97	74.81
Mid slope	40 – 63	5.09	4.45	0.14	0.01	0.00	0.7	1.36	1.28	0.15	0.12	3.61	80.61
Mid slope	63 – 80	5.17	4.66	0.00	0.00	0.00	0.5	1.29	1.22	0.13	0.13	3.27	84.71
Mid slope	80 – 120	4.48	4.17	0.00	0.00	0.45	0.8	1.27	1.24	0.14	0.12	3.57	77.59
Mid slope mean		**4.79**	**4.29**	**0.45**	**0.02**	**0.28**	**0.82**	**1.35**	**1.27**	**0.140**	**0.130**	**3.71**	**78.22**
Foot slope	0 – 15	5.22	4.61	0.93	0.05	2.65	0.3	1.6	1.48	0.16	0.15	3.69	91.87
Foot slope	15 – 30	4.98	4.15	0.34	0.02	1.00	0.6	1.43	1.3	0.14	0.16	3.63	83.47
Foot slope	30 – 45	5.09	4.52	0.10	0.01	1.00	0.5	1.38	1.18	0.15	0.14	3.35	85.07
Foot slope	45 – 60	4.43	4.56	0.17	0.01	1.15	0.6	1.24	1.34	0.12	0.15	3.45	82.61
Foot slope	60 – 85	4.87	4.60	0.34	0.02	0.00	0.4	1.32	1.38	0.14	0.13	3.37	88.13
Foot slope mean		**4.92**	**4.49**	**0.38**	**0.02**	**1.16**	**0.48**	**1.39**	**1.34**	**0.140**	**0.150**	**3.50**	**86.23**
Toposequence LSD (0.05)		NS	NS	0.45*	0,02*	NS	NS	NS	NS	NS	NS	0.27*	NS

* = Significant at 5% probability level; NS = Not significant at 5% probability level.
OC =organic content, OM= organic matter, TN= total nitrogen, TEA=total exchangeable acidity, AL= aluminum, H= hydrogen,
Ca= calcium, Mg= magnesium, potassium, Na= sodium, TEB= total exchangeable base, CEC= cation exchangeable capacity, BS=base saturation,
Avl. P = available phosphorus

Variation of selected soil properties within profile depths

Table 4 shows the level of variability of some selected properties within profile depths. There was low variation of soil pH (KCl) within the profile irrespective of physiographic position on the toposequence. Other parameters with low variation within the profile at all the physiographic units on the toposequence include sand, potassium, calcium, total exchangeable acidity and base saturation. This agrees with Ogunkunle (1993) that soil pH and porosity (sand) are the least variable soil properties.

Clay varied moderately at the summit but only slightly at the mid-slope and foot-slope. Effective cation exchange capacity showed differential variations across the toposequence, being high, moderate and low at summit, mid-slope and foot-slope, respectively. This could be attributed to the impact of erosion along the toposequence. At the summit, the percent silt showed no variation. However, there was moderate variation at mid-slope and foot-slope. This could be attributed to alluvium and colluvium deposition at these physiographic units.

There was high variation of organic matter within the profile in all the physiographic position on the toposequence. This can be ascribed to the differential loss of organic matter caused by erosion commencing from the summit to the foot-slope.

Table 4. Selected soil properties within profile depth with rankings.

Soil properties	Summit		Mid-slope		Foot-slope	
	Means/Std	Ranking*	Means/Std	Ranking	Means/Std	Ranking
Sand	71.6±5.4	Lv	78.6±6.5	Lv	75.6±5.4	Lv
Silt	2.0±0.0	Nv	2.8±1.1	Mv	6.2±2.7	Mv
Clay	26.4±5.4	Mv	18.6±6.3	Lv	18.2±7.4	Lv
BD	1.5±0.00	Nv	1.55±0.06	Lv	1.56±0.05	Lv
TP	43.40±0.00	Nv	41.58±2.11	Lv	41.51±1.89	Lv
pH(KCl)	4.40±0.12	Lv	4.29±0.29	Lv	4.49±0.19	Lv
K	0.142±0.02	Lv	0.140±0.01	Lv	0.140±0.01	Lv
Ca	1.46±0.29	Lv	1.35±0.08	Lv	1.39±0.14	Lv
TEA	0.82±0.28	Lv	0.82±0.24	Lv	0.48±0.13	Lv
ECEC	3.87±0.36	Hv	3.71±0.34	Mv	3.50±0.15	Lv
OM	1.00±0.79	Hv	0.45±0.55	Hv	0.38±0.33	Hv
BS	78.77±6.93	Lv	78.22±4.57	Lv	86.23±3.79	Lv

Ranking*: Hv= High variation; Mv = Medium variation; Lv = Low variation; and Nv = No variation.

Relationship among soil properties

Pearson correlation analysis was carried out to obtain relationships that exist between selected soil properties of a toposequence of erosion area. The results are as shown in Table 5. Percent sand recorded a very significant negative correlation with percentage clay (r = 0.98***). This is as expected as an increase in sand content will bring about a decrease in clay content of the soil. Silt had a non-significant positive or negative correlation with all measured soil parameters, with correlation coefficients that ranged from 0.06^{ns}-0.27^{ns}. A rise in the soil's clay content decreased the soil sodium content studied (r =-0.67**). This relationship reinforces the opposite roles of clay and sodium as flocculating and deflocculating agents in soil management, respectively. However, an increase in sand content maintained a positive and significant ($p<0.01$) increase in soil sodium (r =-0.67**).

Bulk density had a significant inverse relationship with OM (-0.62*), TN (-0.62*) and ECEC (-0.61*). Low soil OM increases soil compaction which increases soil BD. This relationship may be linked with the role of OM in increasing soil TN and ECEC with increase in OM.

Soil reaction (pH) in KCl had a negative and significant ($P<0.05$) correlation with TEA and ECEC (r = 0.62* and r = 0.55*, respectively and a positive and significant ($P<0.05$) correlation with percent base saturation (%BS) (r = 0.56*). Organic matter had significant positive correlations with TN (r = 0.99***), Ca (r = 0.85**), Mg (r = 0.59*), K (r = 0.61*) and ECEC (r = 0.74**). This relationship of OM with TN, basic cations and ECEC underscores the importance of OM as an index of soil fertility management. Similar effects were recorded in the relationships between soil TN and Ca (0.86***), Mg (r = 0.60*), K (r = 0.63* and ECEC (r = 0.73**). These, support the assertion that a degraded Ultisol with low TN will most likely be low in Ca, Mg, K and ECEC. Calcium content in the studied soils accounted for 84% and 66% soil exchangeable K and Mg contents of the soils, respectively (r = 0.84*** and r = 0.66**, respectively).

Phosphorus maintained significant positive relationships with all basic cations with correlation coefficients that ranged from 0.51* for K to 0.59* for Ca. This suggests that an improvement in soil P of the studied soil will equally improve basic cations in the soil. Total exchangeable acidity had a significant ($P<0.001$) negative relationship with %BS (r =-0.98***). This is as expected in an acidic soil, where an increase in TEA will bring about a decrease in %BS.

Table 5. Pearson correlation analysis of selected soil properties of a toposequence

Soil property	Sand %	Silt %	Clay %	BD g cm^{-3}	TP %	pH (KCl)	OM %	TN %	Ca cmol kg^{-1}	Mg cmol kg^{-1}	K cmol kg^{-1}	Na cmol kg^{-1}	TEA cmol kg^{-1}	ECEC cmol kg^{-1}	BS %	P mg kg^{-1}
Sand	1															
Silt	-0.08^{ns}	1														
Clay	-0.98***	-0.12^{ns}	1													
BD	-0.13^{ns}	0.29^{ns}	0.08^{ns}	1												
TP	0.13^{ns}	-0.29^{ns}	-0.08^{ns}	-1.0***	1											
pH (KCl)	-0.29^{ns}	0.11^{ns}	0.27^{ns}	0.37^{ns}	-0.37^{ns}	1										
OM	0.34^{ns}	-0.27^{ns}	-0.28^{ns}	-0.62*	0.62*	-0.21^{ns}	1									
TN	0.33^{ns}	-0.23^{ns}	-0.28^{ns}	-0.62*	0.62*	-0.20^{ns}	0.99***	1								
Ca	0.42^{ns}	-0.17^{ns}	-0.38^{ns}	-0.42^{ns}	0.42^{ns}	-0.09^{ns}	0.85***	0.86***	1							
Mg	0.24^{ns}	-0.25^{ns}	-0.19^{ns}	-0.19^{ns}	0.19^{ns}	0.07^{ns}	0.59*	0.60*	0.66*	1						
K	0.32^{ns}	0.03^{ns}	-0.33^{ns}	-0.20^{ns}	0.20^{ns}	-0.08^{ns}	0.61*	0.63*	0.84***	0.53*	1					
Na	0.67**	0.00^{ns}	-0.67**	-0.27^{ns}	0.27^{ns}	-0.19^{ns}	0.30^{ns}	0.30^{ns}	0.40^{ns}	0.34^{ns}	0.29^{ns}	1				
TEA	-0.16^{ns}	-0.06^{ns}	0.17^{ns}	-0.36^{ns}	0.36^{ns}	-0.62*	0.06^{ns}	0.04^{ns}	-0.22^{ns}	-0.27^{ns}	-0.32^{ns}	-0.39^{ns}	1			
ECEC	0.21^{ns}	-0.21^{ns}	-0.17^{ns}	-0.61*	0.61*	-0.55*	0.74**	0.73**	0.62*	0.47^{ns}	0.41^{ns}	0.05^{ns}	0.60*	1		
BS	0.24^{ns}	0.03^{ns}	-0.24^{ns}	0.26^{ns}	-0.26^{ns}	0.56*	0.11^{ns}	0.13^{ns}	0.41^{ns}	0.44^{ns}	0.47^{ns}	0.46^{ns}	-0.98***	-0.41^{ns}	1	
P	0.35^{ns}	0.01^{ns}	-0.35^{ns}	-0.31^{ns}	0.31^{ns}	0.07^{ns}	0.36^{ns}	0.37^{ns}	0.54*	0.59*	0.51*	0.55*	-0.24^{ns}	0.32^{ns}	0.36^{ns}	1

*; **; *** = Significant at 5, 1 and 0.1% probability levels, respectively; NS = Not significant at 5% probability level.
OC =organic content, OM= organic matter, TN= total nitrogen, TEA=total exchangeable acidity, AL= luminum, H= hydrogen,
Ca= calcium, Mg= magnesium, potassium, Na= sodium, TEB= total exchangeable base, CEC= cation exchangeable capacity, BS=base saturation, Avl. P = available phosphorus

CONCLUSION

This research was carried out in Ikeduru to assess soil properties of a toposequence. A transect survey technique was used to align soil profile pit along the toposequence. Three profile pits were dug, described and samples collected for repetitive laboratory analysis for selected physiochemical properties using ANOVA for a CRD experiment. LSD at 5% probability level was utilized to separate the toposequence significantly. A correlation investigation carried out was used to explain relationships among selected physiochemical properties of the studied soils. The result of the physiochemical properties of the toposequence varied with depth. The physico-chemical properties of the soil in the various topo-sequence with respect to their mean values were found to have a higher value, though lower slope than the upper as well as middle slopes. It was observed that erosion experienced in the study area includes sheet, rill and gully erosions, though rill erosion was observed to be more rampant within the area. It could be established that some of the mineral content of the soil was lost through leaching in the area. The soil of the area was found to have high acidic content caused by the continuous tiring and destruction of the top soils through erosion by sheet and later to gully erosion enhanced by human and animal actions. The climatic and environmental factors are contributory to the erosion hazards due to the undulating and irregular land form. Also, the rate at which land is made use of becomes a major factor that causes soil erosion, such includes, building of houses, road constructions, burning of bushes, stone quarrying are contributory factors that causes the erosion of soils in the research region. This study will go a long way to supporting researchers, farmers and agriculturist who will want to embark on massive agricultural production in different countries of the world that have similar land terrain and it can be expanded to accommodate other regions of the country and the world at large.

DECLARATION OF COMPETING INTEREST

We authors hereby affirm that there is no conflicting of interest whatsoever.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors hereby declare that the contributions given are correct.
Patricia Akunna Oriaku: Review and methodology,
Christopher Ikechi Obineche: Writing original draft and investigation,
Nkechi Udochukwu Ezechike: Validation of results,
Patience Chinasa Ezema: Statistical and data review.

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This article does not require any ethical committee decision.

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