

ASSESSMENT OF SOIL PHYSICO-CHEMICAL PROPERTIES ON A TOPOSEQUENCE OF AN EROSION SITE IN IKEDURU, SOUTHEASTERN NIGERIA

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ABSTRACT

This study was carried out to assess soil properties of an erosion site in Ikeduru, Imo State. Three soil profiles were dug and described and samples collected for routine laboratory analysis. Data obtained were analyzed using Genstat Discovery, Edition 4 for a CRD experiment. The results revealed that the soils were deep, well drained, dark brown, brown, dark reddish brown, and red while moist in the Munsell colour notation. Significant means were separated using LSD at 5% probability level. Correlation analysis was carried out to explain relationships among selected physico-chemical properties of the studied soils. The particle size distribution indicated high sand content and low clay content in the three topounits with sandy clay loam (SCL) as dominating textural class. The bulk density was less than the critical level of 1.85g/cm^3 in all the soil profiles 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. Exchangeable bases, cation exchange capacity and organic matter contents of soils were low. Organic matter had significant positive correlations with Total Nitrogen ($r = 0.99^{***}$), Calcium (Ca) ($r = 0.85^{**}$), Magnesium ($r = 0.59^*$), potassium (K) ($r = 0.61^*$) and Effective Cation Exchange Capacity ($r = 0.74^{**}$). Available 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 %Base Saturation ($r = -0.98^{***}$). Land use patterns like arable farming, clean weeding, housing, road constructions, bush burning, tree felling, sand and stone quarrying were major factors that caused soil erosion in the study area. Keywords: soil erosion; soil properties; toposequence; topounits

Introduction

Soil erosion has been a challenging phenomenon in the southeastern part of Nigeria where vast land are being affected, causing displacement of the upper layer of soil, causing soil degradation. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year. Soil erosion may be a slow process that continues relatively

unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks (Morgan, 1991). Agricultural productivity, sustainability and management for food security/sustenance in this region has been undermined and greatly limited by the menace posed by soil erosion while the availability of farmlands for agricultural production and construction activities have been greatly reduced by losses caused by the attendant issues of soil erosion (Okorafor *et al.*, 2017). Soil erosion is considered to be a major environmental problem since it seriously threatens natural resources and the environment (Rahman *et al.*, 2009). Soil erosion diminishes soil quality and reduces the productivity of natural, agricultural and forest ecosystem (Pimentel, 2006).

Human activities have increased by 10–40 times the rate at which erosion is occurring globally. Excessive (or accelerated) erosion causes both "on-site" and "off-site" problems. On-site impacts include decreases in agricultural productivity and (on natural landscapes) ecological collapse, both because of loss of the nutrients-rich upper soil layers. In some cases, the eventual end result is desertification (Andrew *et al.*, 2002). Off-site effects include sedimentation of waterways and eutrophication of water bodies, as well as sediment-related damage to roads and houses. Water and wind erosion are the two primary causes of land degradation; combined, they are responsible for about 84% of the global extent of degraded land, making excessive erosion one of the most significant environmental problems worldwide (Mbagwu, 1996). Intensive agriculture, deforestation, roads, anthropogenic climate change and urban sprawl are amongst the most significant human activities in regard to their effect on stimulating erosion. However, there are many prevention and remediation practices that can curtail or limit erosion of vulnerable soils (Morgan, 1991).

Soil characterization is an essential part of the determination of the nature and extent of degradation of soils. Not only is it necessary to evaluate the actual distribution of erosion across a land surface, but the depth of degradation is also key to understanding how

erosion is distributed (Juo and Moorman, 2000). This investigation compares methods used by soil scientists to describe and map soils with two methods utilized in environmental investigations; a multiple point composite approach and a multiple increment approach (Akamigbo, 1999).

Soil degradation due to land mismanagement is a major concern that threatens economic and rural development, especially in third-world countries (El-Swaify, 1994). Soil quality is one of the most important factors in sustaining the global biosphere and developing agricultural practice (Wang and Gong, 1998).

According to Tulu (2002), the global store of arable and grazing land continues to decline through urbanization, unsustainable agricultural practices and deforestation. An understanding of the basic soil properties is essential for developing soil management practices that will maintain the productive potential of a soil. This is particularly true of the tropical soils with inherent properties of low cation exchange capacity, low organic matter content, low water holding capacity, structural instability and flood hazard especially at foot slopes which make them vulnerable to soil erosion. Hence the need to characterize some of these problems on a toposequence and proffer solutions. The objectives of the study were to compare soil physico-chemical properties of a toposequence on an erosion-prone environment, ascertain effect of erosion on soil quality of the environment and suggest possible remedies to minimize soil erosion menace to enhance agricultural productivity.

Materials and Methods

Study Area

Ikeduru Local Government Area is located in the western part of Imo State in south eastern Nigeria. It lies on Latitude $5^{\circ} 56' 0.795''$ N and Longitude $7^{\circ} 15' 0.338''$ E. Ikeduru Local Government Area is made up of 16 communities which share common culture and market days together (Emeka, 2000). The people of Ikeduru Local Government Area are mainly subsistence farmers but in recent times, most dwellers engage in business enterprises including trading. Arable land farming is done using the traditional farming methods.

Geology and Geomorphology

The geological material from which the soils of the study area developed is coastal plain sands (Benin formation). The land form 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).

Climate

The study area has 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 about 80 %. The hottest period in the area is between January and March while the highest rainfall intensity occurs between July and September. However, the study area is characterized by a bimodal rainfall distribution pattern with two peaks in July and September (Esu *et al.*, 2008).

Vegetation

The area is characterized by a variety of vegetal forms although dominated by trees and shrubs, with rain forest as the natural agroecology. Some of the plants growing in the area include mango (*Magnifera indica*), avocado (*Persea americana*), kola (*Kola nitida*), oil palm (*Elacis quineensis*), bread fruit (*Treculia africana*), coconut palm (*Cocos nicifera*) and various species of herbs and grasses. Cultivated crops in the area include maize (*Zea mays*), yam (*Dioscorea spp*), cassava (*Manihot spp*), cocoyam (*Colocasia and Xanthosoma spp*), and pumpkin (*Telferia occidentalis*).

Field Work and Sample Collection

Transect survey technique was employed in aligning soil profile pits along the slope. The collected samples were described following the guideline of FAO (2006). Soil profiles were sited based on available topounits of the area. Three soil profile were sited along the slope to include the designation: ECH/UK/01 (Summit), ECH/UK/02 (Middle slope), and ECH/UK/03 (Footslope). Soil samples were collected from the three types of soils categorized according to depth. Sample collected was based on horizon differentiation. Soil macromorphological properties were observed and recorded *in situ*. These soil samples were bagged, labeled and transported to the Soil Science Laboratory for analysis.

Laboratory Analysis

The soil samples were analyzed for certain selected soil properties that are necessary for proper scientific classification of the soils. Some of these selected properties include physical properties such as particle size distribution, bulk density and moisture content and chemical properties such as 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 properties were determined as follows;

Particle size distribution was determined by hydrometer method according to the procedure of Gee and Or (2002). Bulk density was determined by core method (Grossman and Reinsch, 2002). Moisture content was determined gravimetrically by oven-drying saturated soil samples for 24 hours (Obi, 1990) and amount of moisture calculated in percentage. Soil

pH was determined in 1:2.5 soil-liquid ration using pH meter (Thomas, 1996).

Organic carbon was determined by wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro Kjeldahl distillation method (Bremner and Mulvaney, 1982). Available phosphorus was determined using Bray 11 method as described by Olsen and Sommers (1982). Exchangeable basic cations were extracted with IN NH_4OAc solution, with exchangeable calcium and magnesium obtained by EDTA complexometric titration. Exchangeable potassium and sodium were estimated by flame photometry (Jackson, 1962).

Exchangeable acidity was determined titrimetrically after extraction of exchangeable H^+ and Al^{3+} with IN KCL (Maclean, 1982).

Effective cation exchange capacity was calculated by summing up the value of the basic cations in Cmol/kg . Percentage base saturation was calculated thus;

$$\frac{\text{TEB}}{\%BS} = \frac{x}{\text{ECEC}} \times 100 \quad \text{----- (1)}$$

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

Aluminum saturation was calculated thus;

$$\text{Al sat} = \frac{\text{Al}^{3+} \text{Cmol} / \text{kg sn}^{-1}}{\text{ECEC Cmol} / \text{kg}} \times 100 \quad \text{---- (2)}$$

Where Al sat = Aluminum Saturation
ECEC = Effective Cation Exchange Capacity
Cmol = Centimole

Statistical Analysis

Analysis of variance (ANOVA) for a CRD experiment was used in analyzing the data using SAS (1985) 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

Morphological Characteristics

The morphological characteristics of the soils in the study site are as shown in Table 1. All 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 topography of the study area, texture and structure of the soils. The trend of the particle size distribution down the profile was responsible for the loose and firm consistency of soil both surface and sub-surface soils, respectively. Texture was generally sandy while structure was weak and granular particularly at the epipedons. 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 (Upper part of the slope). it was observed that across the horizons the colour ranges from Brown ($7.5\text{YR}^{4/3}$) when moist to Red ($2.5\text{YR}^{4/8}$) when moist. The midslope recorded a colour range of Brown ($7.5\text{YR}^{4/2}$) when moist to Red ($2.5\text{YR}^{4/8}$).

Furthermore, the footslope had colour matrix range, Brown ($7.5\text{YR}^{4/2}$) to somewhat gray colours when moist, and Red mottles ($7.5\text{YR}^{4/4}$) 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 sandy clay loam (SCL) at the B₃ and C horizons. The footslope was observed to have a textural range of sandy loam (SL) at A and B₁ horizon.

Table 1: Morphological Characteristics of Soils of the Study Site

Slope Gradient	Dept (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 ³ / ₄)	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

The results of the physical and chemical properties of the soils studied are presented in Table 2 and 3 are expressed as pedons Summit through Mid-slope and Foot-slope, Variations of Physico-chemical Properties in various Depths of Soil Profile (Summit), (Midslope), and (Footslope), while table 4ows variations of Mean Values of Physico-chemical Properties in Different Toposequence. The effects of toposequence of an erosion prone area on soil physical properties are as shown in Table 2.

Particle Size Distribution of Soil texture

This is the relative proportion of the various soil separates sand, silt, and clay that make up the soil classes (Gee and Or, 2002).

From the results, the sand content of all the samples are generally very high ranging between 66.8 – 80.8%, with Summit and Foot-slope having the highest value of 85% and the lowest being Mid-slope with 67%.

The silt contents in all the profiles are low ranging between 2.0 – 10.0 in the pedons. The clay contents ranged between 2.0 – 6.2% which shows low to medium. The highest value was recorded in Summit and Foot-slope, but shows no definite trend. This is as the result of the movement of clay and other finer materials from the top between 8.2 – 27.2 % that fluctuates among the depths of all soils by an overland flow. This result was supported by Akamigbo (1999) and Adekayode and Akomolafe (2011). The problem could be remedied by planting trees to protect the soil from being eroded easily (Moffat and Boswell 1990; Medugu *et al*, 2010).

Bulk Density

This is the dry mass (weight) of soil per unit of bulk volume of soil (Gee and Or, 2002). From the results, the bulk density of soil samples are generally moderate, ranging between 1.50 – 1.70 g/cm³. Mostly, the bulk densities increased with depth. This may be due to recent weathering and deposition of eroded materials in Summit. Bulk densities above 1.75g/cm³ for sands are quoted by de Geus (1973) as causing hindrance to root penetration in the soil.

Table 2: Soil Physical Properties of an 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

Silt /clay ratio at the topsoil is a soil index used to measure flood hazard. 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). Silt/clay ratio at the foot-slope was greater than 1, suggesting flood hazard at 0 – 15 cm soil depth at the foot-slope (Moorman, 1981).

Soil chemical properties

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

Soil pH

The soils are generally strongly acidic for pH in Kcl. The pH of the soils ranged between 4.08 and 4.66, indicating extreme acidity, except in one horizon which falls within the range of 4.9 in Mid-slope which indicates very strong acidic reaction (Table 3). In most cases, the pH values increased with depth. The results are in tuned with the findings of Akamigbo and Igwe (1990) who observed that low acidity values are recorded in humid soils due soil erosion which is responsible for low to high calcium and magnesium content of the soils.

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

Soil fertility is closely linked to soil organic matter, whose status depends on biomass input and management, mineralization, leaching and erosion (Roose and Barthes, 2001; Nandwa, 2001). It is well recognized that soil organic matter increases structure stability, resistance to rainfall impact, rate of infiltration and fauna activities (Roose and Barthes, 2001). In the Summit, OM ranged between 0.38 - 1.17% respectively. In Mid-slope OM ranged between 0.14- 1.10 % and Foot-slope and OM ranged between 0.10 - 0.93% respectively. The results are consistent with the finding of Morgan (1981) who reported that the organic matter and organic carbon in humid soils are generally low due to leaching and severe sheet erosion, burial of top soils by tillage and mineralization of organic matter by high temperature.

Total nitrogen

The total nitrogen status of any soil is closely associated with the soil organic matter (Graham, 2010). The results of Total nitrogen in the three Summit, Mid-slope and Foot-slope indicated that the values ranged between 0.02 - 0.12%, 0.01 - 0.06% and 0.01 - 0.05% respectively. The values of Nitrogen of the soils were found to decrease with an increased depth, which was observed to be due to erosion of nitrates on the top soils. This result is consistent with the finding of Graham (2010) in the savannah zone of Nigeria. And the Total Nitrogen in the soils was also as very low compared to the ratings of Esu (1991). The reduced microbial activities caused by low pH can affect Nitrogen availability in the soil (London, 1991).

Available Phosphorus

The available phosphorus content of the soils varied between low to medium, with values ranging between 0.25 - 2.65 cmol/kg, with pedon 01 having values that varied between 1.1 - 1.25 cmol/kg, mid-slope varied between 0.28 - 0.50 cmol/kg and Foot-slope varied between 1.00 - 2.25 cmol/kg. Losses of phosphorus are usually due to the removal by crops (Enwezor, 1981). In acidic soils, much of the P become fixed up by reaction with iron (Fe^{3+}), aluminum (Al^{3+}), and manganese to form insoluble compounds.

Exchangeable bases

Exchangeable bases in the soils include Na^+ , K^+ , Mg^{++} and Ca^{++} . The values of sodium (Na^+) in pedon 01 ranged between 0.11 - 0.16 cmol/kg, potassium (K^+) ranged between 0.12 - 0.17 cmol/kg, magnesium (Mg^{2+}) ranged between 0.18 - 1.48 cmol/kg, and

Calcium (Ca^{++}) ranged between 1.22 - 1.86 cmol/kg. The results showed that the value of exchangeable based ranged between low to medium values in all the pedon (Esu, 2008). The results of all the exchangeable bases such as sodium, potassium, magnesium and calcium decreased with depths. The results are inconsistent with the finding of Akamigbo (1983) who observed low Ca / Mg ratio in the soils of Ukpok. Also, exchangeable bases have been observed as inherently low on the eroded soils of south eastern Nigeria (Enwezor, 1986; 1987). The low exchangeable bases in the soils show heavy leaching of soil nutrients. According to Enwezor (1981) pointed out that leaching of calcium and magnesium are largely responsible for the development of acidity in the soil due to high rainfall with porous nature of the soil texture and the parent materials. This was supported by Mbagwu (1996).

Total Exchangeable Acidity (TEA)

Total exchangeable acidity is a measure of the amount of a soil's cation exchange capacity (CEC) that is occupied by acidic cations. By acidic cations, it is generally mean H^+ and Al^{3+} , but it can also include Fe and Mn cations. Aluminum and iron cations will combine with OH^- ions and take it out of solution, forming an insoluble compound. From the results, it is observed that total exchangeable acidity ranged between low and medium (0.3 - 1.1 cmol/kg), with higher values recorded in the Summit and Mid-slope, and the Foot-slope having the lowest value.

Effective Cation Exchangeable capacity (ECEC)

From the results, the values of ECEC ranged from low to medium, with values between 3.50 and 3.87 cmol/kg (Table 3). The highest value was found in Summit, while Foot-slope recorded the lowest value. The low ECEC is suspected due to the low activity clay mineral type (kaolinite clay) present in the soil.

Base saturation (BS)

The results shows that the values of BS were very high ranging between 71.87 - 90.00 %, with Summit recorded the highest value in the lowest horizon, while the lowest value was found in the upper horizon of Mid-slope. These results could be due to properties inherited from the parent materials due to soil erosion by rainwater. This was confirmed by Akamigbo and Asadu (1986) who reported that parent materials have a strong influence on total exchangeable bases and total acidity of soils.

Table.3. Soil Chemical Properties of an Erosion Prone Toposequence

Toposequence	Horizon depth (cm)	pH(H ₂ O)	pH(KCl)	OM (%)	TN (%)	Av. P (mg/kg)	TEA	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	ECEC	%BS
							----- Cmol/kg -----						
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

pH=pondus hydrogenium, OM=organic matter, TN=total nitrogen, Av. P=available phosphorus, Ca²⁺ =exchangeable calcium, Mg²⁺=exchangeable magnesium, K⁺= exchangeable potassium, Na⁺= exchangeable sodium.=TEA=total exchangeable Acidity
ECEC=effective cation exchange capacity, BS=base saturation

* = Significant at 5% probability level; NS = Not significant at 5%, probability level.

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 had low variations at both 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. Percent silt did not show any variation at the summit. However, there was moderate variation at mid-slope and foot-slope. This may be attributed to deposition of alluviums/colluviums at these physiographic units.

There was high variation of organic matter within the profile in all the physiographic position on the toposequence. This could be attributed to the differential loss of organic matter due to erosion 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

BD= bulk density, TP=total porosity, pH= pondus hydrogenium, OM=organic matter, TN=total nitrogen, Av.

P=available phosphorus, TEA=total exchangeable Acidity

ECEC=effective cation exchange capacity, BS=base saturation

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 percent 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} to 0.27^{ns} . An increase in clay content of the soil decreased the sodium content of the studied soil ($r = -0.67^{**}$). 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 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 gcm 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.

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The study was conducted to assess soil properties of a toposequence in Ikeduru. The toposequence is located at Ugwumba Umuocha Umuomi in Uzoagba Eziamma autonomous community in Ikeduru L.G.A of Imo state South-East Nigeria. A transect survey techniques was used to align soil profile pit along the toposequence. Three profile pits were dug and described and samples collected for routine laboratory analysis for selected physiochemical properties using ANOVA for a CRD experiment. Significant means of the toposequence were separated using LSD at 5% probability level. A correlation analysis was carried out to explain relationships among selected physiochemical properties of the studied soils. The result of the physiochemical properties of the toposequence varied with depth. The particle size distribution indicated high sand content and low clay content in the three gradients with SCL as dominating textural class. The bulk density was less than the critical level of 1.85g/cm^3 in all the profile pits examined on the toposequence. The silt-clay ratio was low (less than 1) in all the slope gradient, expect at the surface soil in the Foot-slope indicating advance stage of weathering and flood hazard at the Foot-slope. Soil pH (KCl) was moderately acidic in all the summit, exchangeable bases, CEC and organic matter contents of the soils are very low due to leaching and intensive agricultural activities that lead to eroding of the soil. Generally the soil differed in both physical and chemical properties yet the variability in depth of some properties such as sand, bulk density, total exchangeable base and total exchangeable acidity had moderate variation. Organic matter was significant with depth and down the slope. 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, 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. Bulk density had significant inverse relationship with OM (-0.62^*), TN (-0.62^*) and ECEC (-0.61^*). 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 increased in TEA and decreased % BS.

Also from the mean values of the physico-chemical properties in different topo-sequence, it was observed that higher values of soil properties were found in the lower slope than the upper and middle slope due to soil erosion. Land use patterns like arable farming,

clean weeding, housing, road constructions, bush burning, tree feeling, sand and stone quarrying are major factors that causes of soil erosion in the study area.

Conclusion

It was concluded that the soils of Ikeduru Local Government Area of Imo State are predominantly sandy loam in texture with low levels of soil nutritional values such as organic matter, total N, available P and exchangeable cation and CEC. The soils were also strongly acidic. It was recommended that conservation agriculture and liming practices should be practiced on the toposequence for for sustainable soil management and increased food production.

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