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Variation in Soil Carbon Stock along Toposequences in Isiala Mbano, South Eastern Nigeria

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Abstract

This study was conducted to evaluate the variation in soil carbon stock along a toposequence in Isiala Mbano, Southeastern Nigeria. A profile pit was dug on each of the three physiographic positions, top slope, mid slope and foot slope. The profile pits were delineated according to horizons. Samples were collected from different horizons, together with undisturbed core samples using core samplers. Samples were subjected to routine analysis. Soil organic carbon sequestration was calculated and relationships between soil organic carbon sequestration and soil properties were obtained. Organic carbon decreased with depth and increased from top to bottom slopes. From the physicochemical properties, the mean sand content was highest at the top slope (714 g kg^{-1}), followed by the foot slope (694 g kg^{-1}) and finally the mid slope (682 g kg^{-1}). The mean silt and clay contents ranged from 106 to 120.0 and 168 to 200 g kg^{-1}. Sand content decreased while clay increased with soil depth. The average bulk density recorded 1.20-1.56 mgm^{-3} with the foot slope having the highest value (1.56 mgm^{-3}) the foot slope recorded the highest carbon sequestration (745.8 g.cm^2), while the mid slope sequestered the least carbon (40.8 g.cm^2). The mean total nitrogen was highest at the foot slope (0.12 %), while the least value was recorded at the top slope (0.04%). Also values of organic carbon were highest at a depth of 124-160cm at the foot slope (1.33%). Moisture content, total porosity, organic carbon, calcium, base saturation showed significant difference ($p \leq 0.05$) along the toposequence. The results obtained showed that different slopes on the toposequence sequester carbon differently. Therefore, farmers may periodically choose to adopt some farming practices such as mulching and cover cropping to build up organic matter, which will increase the organic carbon content.

Keywords: Soil variability, Toposequence, Carbon stock, Carbon sequestration, Soil fertility

1.0 Introduction

Carbon is one of the most crucial elements of the biosphere and is acknowledged as the second largest carbon reservoir in the ecosystem (Ogle and Paustian, 2005). Soils are the greatest carbon reservoirs in the terrestrial carbon cycle, holding twice as much carbon as the atmosphere and containing around three times as much carbon as the world's vegetation. According to Jha *et al*. (2003), soils are essential to the global carbon budget and greenhouse impacts, with the first 30 cm of soil holding 1500 pg of carbon. Anthropogenic emissions cause the atmospheric concentration of carbon dioxide CO_2 (IUPAC) to rise gradually, although the terrestrial biosphere causes significant interannual variability. Carbon can take many different forms, it is mostly found in soil organic matter, plant biomass, and atmospheric carbon dioxide (CO_2) (IUPAC).

The amount of carbon in a pool, which is a reservoir that has the capacity to store or release carbon, can be referred to as the soil carbon stock. Because of their increased organic matter content and ability to absorb CO_2 from the atmosphere, forest soils are one of the planet's main carbon sinks. Gains from plant and other organic inputs and losses from organic matter turnover determine the balance of soil organic carbon (SOC) in natural ecosystems (Smith *et al*, 2008). Thus, the equilibrium between carbon gains and losses determines how much organic carbon is stored in the soil. Predicting the effects of climate change is made easier with a thorough explanation of the distribution, variations, and elements of control of SOC (Albaladejo *et al*., 2013; Byrne *et al*., 2020). With over 2344 tons of organic carbon worldwide, we can thus conclude that SOC is the greatest carbon pool in the majority of terrestrial ecosystems (Lal, 2008; Stockman *et al*, 2013). Since forests are known for their exceptional conservation values and abundance of economically significant biodiversity, managing them may be a helpful strategy to raise soil carbon status because tree presence either directly or indirectly influences carbon dynamics. As a result, about 40% of the world's total SOC stock is found in forest ecosystems.

A toposequence is a geographical feature that preserves a flow connection between the foot slope and the top slope. The degree of transport and deposition of the soil's dissolved and particulate elements cause variations in the characteristics of the soil on a toposequence (Obasi *et al.*, 2011). A slight reduction in the SOC pool (stock) due to changes in land form, fertilization, cropping systems, farming practices, and soil erosion could greatly raise atmospheric CO_2 levels because soil carbon stocks are also heavily influenced by the climate, land form, and land cover. In particular, the land use pattern is changing quickly as a result of human activity; while on the other hand, soils can increase the existing SOC stock by sequestration of C from the atmosphere. Idiong *et al.*, (2024) carried out a research along slopes on a coastal plain sand of Akwa Ibom State and observed a variation in organic matter content as in upper slope (2.45%), Middle (2.31%) and lower slope 2.19% and also observed high infiltration rate at the middle slope.

Research has shown that if there is variation in soil characteristics, topography will change significantly, because percolating water prefers to flow laterally across a profile rather than vertically, soils on upper slopes show a notable change in characteristics from those on the summit. According to Wynn and Bird (2007); Saiz *et al.* (2012), biotic factors and management practices have a significant impact on the amount and quality of carbon inputs and decomposition processes at the local level, whereas topographic, edaphic, and climate-related factors primarily regulate the variation in SOC stock at the larger scale. Few investigations on soil carbon sequestration in relation to slope position have been conducted in South-Eastern Nigeria. In view of this, this study was designed to determine the quantity of carbon sequestered in each topographic unit. The major objective of this work was to determine the variation in soil carbon stocks along a toposequences in Isiala Mbano Southeastern Nigeria.

2.0 Materials and Methods

2.1 Description of Study Area

The study was conducted in the humid rainforest zone between latitudes 5^{o} 39^{1} and 5^{o} 43^{1}N and longitudes 7^{o} 09^{1} and 7^{o} 13^{1}E on a coastal plain sand parent material, at Umuoforocha, Umuorlu, Umunnuma in Okohia Isiala Mbano, Imo State, South Eastern Nigeria. According to NIMET (2015), its mean monthly temperature ranges from 25 ^{o}C to 30 ^{o}C, its mean annual rainfall ranges from 1700 mm to 2500 mm, and relative humidity ranges from 68.8 to 72.6%. The area is covered with rainforest vegetation, which includes palm trees, oil bean trees, elephant grasses, and orchids with lovely blossoms that are suited to draw a variety of forest insects. Others include rubber trees, strangler figs, pitcher plants, and Durian. The main economic activities of the area include farming, trading and civil service.

2.2 Field Study/Sample Collection and Preparation

Before the study was conducted, a reconnaissance visit was undertaken to the study area. For the investigation, a toposequence of roughly 1000 meters was used. Each of the three physiographic positions foot, mid, and up slope had a single profile pit excavated. The FAO process was followed in describing the three profile pits and defining them based on horizons (Adhikari *et al.* 2014). Samples from various horizons were collected. In order to determine the bulk density and moisture content, undisturbed core samples were also collected using core samplers. Samples were crushed, allowed to air dry at room temperature, and then sieved through a 2 mm sieve. Samples were further crushed and sieved through a 1 mm sieve in order to determine the amount of organic carbon.

2.2.1 Soil Profile Description

In soil profile description, the terms "A," "AB," “Ap” "E," "Bt1," and "Bt2" refer to specific layers or horizons within the soil.

A Horizon: The "A" horizon is the topsoil layer, typically rich in organic material (humus) and is crucial for plant growth. It is usually darker in color due to the high organic content and is often the most fertile layer in the soil profile.

AB Horizon: The "AB" horizon is a transitional layer between the "A" horizon (topsoil) and the "B" horizon (subsoil). It exhibits characteristics of both the "A" and "B" horizons, and the organic material content is usually lower than in the "A" horizon but higher than in the "B" horizon.

Ap Horizon: The Ap horizon is the plowed layer of the A horizon, typically found in agricultural soils. It shows evidence of human disturbance (e.g., tillage, hoeing, or other forms of cultivation.

E Horizon: The "E" horizon is the eluviation (leaching) layer, where minerals and nutrients are leached or washed out from the soil due to water movement. This layer is often lighter in color and may show signs of clay, iron, or organic matter depletion.

Bt1 Horizon: The "Bt1" horizon refers to a subsoil layer that is rich in clay, iron, or aluminum that has accumulated due to illuviation (the process of deposition of material leached from above). The number "1" indicates it is the first of two or more layers in the "B" horizon with similar characteristics, often showing evidence of clay illuviation.

Bt2 Horizon: The "Bt2" horizon is a second layer in the "B" horizon, with further accumulation of clay, iron, or other materials. The "2" indicates that it is the second layer within the "B" horizon that shows significant illuviation, often with more pronounced characteristics than the "Bt1" horizon.

2.3 Laboratory Analysis

Soil Physical Properties

Soil samples were analyzed for some physical properties following standard laboratory procedures as stated below; using sodium hexametaphosphate (Calgon) as a dispersant, the hydrometric method as outlined by Gee and Or (2002) was used to determine the particle size distribution. The bulk density was calculated using the core methods of Grossman and Reinch (2000), and the silt/clay ratio was obtained by calculating the ratio between silt and clay (Brady and Weil, 1999).

Total porosity (%) was calculated from the values gotten from bulk density with the formula:

$$\left[1 - \frac{Bd}{Pd}\right] x100 \quad \text{.......Equation 2.1}$$

Moisture content (%) was determined using the gravimetric method (Carter *et al.*, 1993)

$$\frac{W_2 - W_3}{W_3 - W_1} X \frac{100}{1} \quad \text{.......Equation 2.2}$$

Where:
W_1 = weight of can,
W_2 = weight of can + wet soil,
W_3 = weight of can + dry soil.

Chemical Characteristics of the Soil

Soil pH was measured in water and in I N KCl using the method of Thomas (1996). Soil organic carbon was determined using the method of Nelson and Sommers (1996) wet combustion, which involves oxidizing organic materials of wet potassium dichromate ($K_2 Cr_2 O_7$) and sulfuric acid ($H_2 SO_4$), to determine the organic carbon. The micro Kjeldahl method was used to calculate total N (Bremner and Mulvaney 1982). The Bray II method was used to determine the amount of phosphorus that was available (Olson and Sommers, 1982). Using I N neutral ammonium acetate (NH_4OAC) solution, exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+) were extracted. A flame photometer was used to detect the levels of K and Na in solution, while atomic absorption spectrophotometry was used to measure Ca and Mg. The sum of basic cations and exchangeable acidity was used to calculate effective cation exchange capacity, or ECEC. TEB/ECEC X 100 was the computation method used to determine the percentage base saturation. The titrimetric approach was used to estimate the exchangeable acidity (H+ and Al^{3+}) (Mclean 1996).

Soil Carbon Sequestration

Soil C sequestration was determined by the method of Batjes, 1996.
SOC stock = BD (Mgm^{-3}) X SOC (g/kg) X soil depth (cm), where BD = Bulk density, SOC = Soil organic carbon

2.4 Statistical Analysis

Data were analyzed statistically using the Analysis of Variance (ANOVA), correlation and coefficient of variation analyses. The results of coefficient of variation was ranked using the method of Wilding (1994) and the relationship between soil carbon sequestration and soil properties was determined using correlation.

3.0 Results and Discussion

3.1 The Physical Properties of Soils Toposequence

Tables 3.1 and 3.2, respectively, provide the physical properties of the toposequence's soils. The average amount of sand was between 682 and 714 g kg^{-1}. The three different geomorphic units' sand contents did not differ significantly ($p < 0.05$). At the upslope, the soil profile strata had sand contents ranging from 620 to 810 g kg^{-1}(Table 3.2). The distribution of sand along the profile pit varied little, suggesting that the horizon's sand fractions were homogeneous (Table 3.2). Parent material may be the cause of the study site's overall sandy nature (Ahukaemere, 2012). The upslope showed greater sand fraction values than the mid and foot slopes, but no discernible difference was found. According to Table 3.1, the average silt and clay concentrations varied between 106.0 and 120.0 and 168.0 and 200.0 g kg^{-1}, respectively. However, in the top slope, mid-slope, and foot-slope, the silt contents of the different horizons varied from 80.0 to 170.0, 80.0 to 140.0, and 60.0 to 140.0 g kg^{-1}, respectively. Additionally, the clay concentrations of the different strata varied from 150.0 to 310.0 g kg^{-1} at the foot slope, 70 to 330 g kg^{-1} at the mid slope, and 200 to 310.0 g kg^{-1} at the top slope.

In general, there was no variation in the amounts of sand, silt, and clay found in the soils along the toposequence. But according to Carter (1993), soil texture influences soil respiration and the microbial community, which in turn affects soil carbon sequestration. Soil management techniques, landforms, and land use types cannot readily alter the texture of soils, which are intrinsic soil characteristics. Sand content dropped and clay content rose with profile depth in all three physiographic positions. Clay eluviation as a result of leaching losses may be the cause of the increased clay content with depth (Enwezor *et al.*, 1990). There was moderate to high heterogeneity in the clay fraction distribution along the profile. This variability may be as a result of slope factors, soil structure and clay.

In general, the reported average bulk density values fell between 1.20 and 1.56 Mgm^{-3} (Table 3.1). In the up slope, mid slope, and foot slope, the bulk densities of distinct horizons varied from 0.57 to 1.61, 1.30 to 1.59, and 1.22 to 1.77 Mgm^{-3}, respectively. The study reveals that the three different land units did not significantly differ from one another. The results show moderate variance based on the coefficient of variation finding. Whereas the average moisture content ranged from 6.19 to 7.61% (Table 3.1), the moisture content of the soil horizon varied from 5.72 to 7.71 % at the top slope, 4.25 to 7.62 % at the mid slope, and 6.26 to 9.99 % at the foot slope (Table 3.2). There was a noticeable variation in the soils' moisture content, at the foot slope, mid slope, and top slope, the moisture content was rated as low to moderate.

While the total porosity of the soil profile varied from 39.2 to 79 % at the top slope, 40 to 59.2 % at the mid-slope, and 33.2 to 54 % at the foot slope, the mean total porosity obtained from the toposequence under study ranged from 41.14 to 54.32 %. At the foot slope, the silt-to -clay ratio (SCR) was 0.32 to 0.93, at the mid slope, 0.36 to 2.00, and at the up slope, 0.26 to 8.50. The three land units' SCRs varied greatly (CV > 35%). The soils had high average SCR: 2.36 for top slope, 0.85 for midslope, and 0.53 for foot slope.

An essential criterion for assessing clay migration, weathering stage, and source material and soil age is the SCR. The silt fraction decreases with increasing weathering of the soil. According to FAO (1990), an SCR below 0.20 denotes a low level of weathering. According to some reports, low values imply that the soils are pedogenetically ferrallitic if the SCR is less than unity (Essoka and Esu, 2002). Low values suggested extremely worn and pedologically matured soils (Ahn 1993). According to Nwaka and Kwari (2000), youthfulness of profiles and the coarseness of parent materials may be associated with high SCR. The range of the average bulk density values was 1.2 to 1.56 Mgm-^{3}. According to the findings, the bulk density values fell below the crucial threshold of 1.63 Mgm^{-3} needed for crop production (Noma *et al.*, 2005).

Table 3.1: The physical properties of the soil along toposequence at Isiala Mbano

	Sand g kg^{-1}	**Silt** g kg^{-1}	**Clay** g kg^{-1}	**BD** **M**gm^{-3}	**MC** **%**	**TP** %	**SCR**
Top slope	714	118.0	168.0	1.20	7.04	54.32	2.36
Mid slope	682.0	120.0	198.0	1.50	6.19	47.04	0.85
Foot slope	694.0	106.0	200.0	1.56	7.61	41.14	0.57
$LSD_{P(0.05)}$	5.75	4.677	7.04	0.3445	1.31ns	12.9	3.001

NB: BD = Bulk density, MC= Moisture content, SCR = Silt clay ratio TP = Total porosity

3.2 The Chemical Properties of Soils along Toposequence

Tables 3.3 and 3.4 present the chemical characteristics of the toposequence's soils. At the up slope, the pH in water ranged from 5.03 to 5.43, 5.53 to 4.38 at the mid slope, and 4.92 to 5.67 at the foot slope, while the pH in KCl ranged from 4.18 to 4.94, 3.40 to 4.55, and 3.50 to 4.96 at the up, mid, and foot slopes, respectively. The results indicated that the pH in both water and KCl showed significant differences among the various land units of the toposequence under study. The toposequence's soils were generally acidic, which may have been caused by the leaching of basic cations (Uzoho *et al*, 2007) and management practices like fertilizer application.

According to (Vesterdal *et al.*, 2008), the pH of soil decreases when fertilizers like urea $(CoNH_2)_2$ and ammonium sulphate $(NH_4)_2$ SO4 are continuously applied to increase soil fertility without the use of lime. The average organic carbon content varied between 0.42 and 1.33 g kg^{-1}, with the greatest value (1.33 g kg^{-1}) found in the soils at the top slope. On the other hand, the mid slope yielded the lowest value (Table 3.3). The range of organic carbon (OC) at the various units was 0.86 to 2.65 g kg^{-1} at the foot slope, 0.06 to 2.55 at the top slope, and 0.06 to 0.78 at the mid-slope.

However, it was found that the surface horizons had the highest values for each physiographic unit in the distribution of OC along the soil profile. The deposition of organic compounds on the surface horizon may be the cause of this. There are substantial differences ($P < 0.05$) in the OC concentration of the soils at the foot slope, mid-slope, and top slope. Vegetation cover, runoff velocity, slope, soil texture, and material deposition from the top slope to the summit could all contribute to the difference in OC. This is consistent with Igwe's (2001) report. Along the toposequence, the mean values for total nitrogen and the C:N ratio varied from 0.036 to 0.115 g kg^{-1}(Table 3.4) and 11.580 to 11.708 g kg^{-1} (Table 3.3).

Table 3.2: Vertical distribution of soil physical properties along a toposequence at Isiala Mbano

Horizon	depth (cm)	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Tex. class	Bd Mgm^{-3}	MC (%)	TP (%)	SCR
		TOP SLOPE							
A	0 – 18	810.00	170.00	20.00	Sand	0.57	7.48	79.00	8.50
AE	18 – 32	790.00	140.00	70.00	Sand	0.83	7.63	67.00	2.00
E	32 – 73	740.00	110.00	150.00	Sand	1.61	6.65	39.20	0.73
Bt_1	73 – 115	610.00	80.00	310.00	SL	1.40	5.72	47.20	0.26
Bt_2	115– 140	620.00	90.00	290.00	SL	1.61	7.71	39.20	0.31
	Mean	714.00	118.00	168.00		1.20	7.04	54.32	2.36
	SDV	9.396	3.701	12.93		0.477	0.849	17.87	3.503
	CV (%)	13.20	31.40	76.90		31.618	12.1	32.90	>100
	Rank	L	M	H		M	L	M	L
		MID SLOPE							
AP	0 – 15	810.00	80.00	110.00	Sand	1.30	6.59	51.00	0.72
AB	15 -31	790.00	140.00	70.00	Sand	1.57	5.84	59.20	2.00
Bt_1	31 – 77	670.00	140.00	190.00	LS	1.48	6.63	44.20	0.74
Bt_2	77 – 100	590.00	120.00	290.00	SL	1.59	7.62	40.00	0.41
Bt_3	100 – 122	550.00	120.00	330.00	SCL	1.57	4.25	40.80	0.36
	Mean	682.00	120.00	198.00		1.50	6.19	47.04	0.85
	SDV	11.626	2.449	11.189		0.121	1.253	8.06	0.668
	CV (%)	17.047	20.408	56.510		8.067	20.242	17.149	78.588
	Rank	M	M	H		L	M	M	H
		FOOT SLOPE							
AP	0 – 17	790.00	60.00	150.00	LS	1.22	9.99	54.00	0.40
AB	17 – 37	700.00	130.00	170.00	LS	1.68	8.12	36.60	0.76
Bt_1	37 – 80	710.00	140.00	150.00	LS	1.77	6.26	33.20	0.93
Bt_2	80 – 124	680.00	100.00	220.00	SL	1.55	6.87	41.50	0.45
Bt_3	124 – 160	590.00	100.00	310.00	SL	1.58	6.80	40.40	0.32
	Mean	694.00	106.00	200.00		1.56	7.61	41.14	0.53
	SDV	7.162	3.131	6.782		0.209	1.496	7.901	0.261
	CV (%)	10.319	29.538	33.91		13.397	19.658	19.224	49.245
	Rank	L	M	M		L	M	M	H

CV≤ 15%=Low Variation (L), CV>15≤35%= Moderate Variation (M), CV> 35%=High Variation (H), SL = Sandy loam, LS = Loamy sand, Bd = Bulk density, Mc = Moisture content, SCR = Silt clay ratio, Tp = Total porosity, A, AB, AE, E, Bt, AP = different soil profile horizons.

Higher levels of organic carbon are crucial in tropical soils, nevertheless, as they serve as the standard by which the characteristics of forest soils are measured. It was found that organic carbon rose with nitrogen because it also improves agricultural productivity and appropriateness and plays a significant influence in soil quality.

Along the toposequence, total exchangeable acidity (TEA) varied significantly ($p < 0.05$), with mean values ranging from 2.08 to 2.72 $cmol^{+}kg^{-1}$. The top slope had a TEA of 1.84 to 2.48, the mid-slope had a TEA of 1.00 to 2.88, and the foot slope had a TEA of 2.12 to 3.40 $cmol^{+}$ kg^{-1}. According to Uzoho *et al.* (2007), soils with ECEC values < 16 cmol kg^{-1} also showed low clay activity. The mean value of available phosphorus ranged from 3.05 to 3.82 mg kg^{-1}, which was extremely low. At various horizon depths, it was discovered that the amount of available phosphorus was declining.

3.3 Carbon Sequestration Capacity of Soils of the Toposequence at Isiala Mbano

Carbon sequestration at the top slope varied from 24.2 in Bt_1 to 514.9 gcm^2 in Bt_3 (Figure. 3.1). But at the mid-slope, the AB horizon had the maximum carbon sequestration (196.9 gcm^2), whereas Bt_1 had the lowest (40.8 gcm^2). Soil carbon sequestration at the foot slope had the highest mean value (569.84 gcm^2), with the Bt_1 horizon showing the highest value (745.8), followed by Bt2 (654.7 gcm^2), and the AB horizon showing the lowest value (409.9 gcm^2) (Figure 3.3). There was no consistent pattern in the way carbon was distributed throughout any soil profile. This finding did not conform with the report of Vesterdal, *et al* (2008) who stated that soil organic carbon sequestration decreased with depth. The average amount of carbon sequestered at various slope positions was, on average, between 123.4 gcm^2 at the mid-slope and 569.84 gcm^2 at the foot slope (Figure 3.4). The carbon sequestration capabilities of the three slope sites varied significantly ($p < 0.05$).

Additionally, the findings showed that slope position had an impact on soil carbon sequestration and other soil parameters (De Wit *et al*, 1999). It was found that the carbon sequestration capacity varied considerably despite the samples being taken on the same time sequence, with the same climate conditions, and under the same management techniques. The quick deposition of materials from the top slope to the foot slope via runoff may be the cause of the foot slope's greatest carbon content. Decompositions and the quantity of SOC stored in an ecosystem and released into the atmosphere are significantly influenced by temperature and precipitation. There is still an urgent need to address the rate of carbon cycling in various land units and at varying depths within a toposequence.

3.4 Correlation of Soil Properties

Results shows that the silt and sand fraction at the top slope exhibited a positive correlation ($P \leq 0.05$), but the clay and sand fraction showed a negative correlation ($P > 0.01$). The findings also indicated that organic carbon had a negative correlation ($P < 0.05$) with clay, a positive correlation ($P \leq 0.05$) with sand, and a negative correlation ($P \geq 0.01$) with silt. There was a negative correlation between total nitrogen and sand ($P \geq 0.05$) and a positive correlation with organic carbon ($P \leq 0.01$), suggesting that the sequestration of organic carbon in soil rises as total nitrogen increases. Results, on the available phosphorus demonstrated a strong positive correction with organic carbon and total nitrogen ($P \leq 0.05$), suggesting that available phosphorus rises with organic carbon. ECEC also exhibited strong positive correlation at ($P \leq 0.05$) with TEB, meaning that as ECEC increases, TEB also increases. Carbon sequestration showed no significant relationship at the top slope. At the mid-slope, there was a negative association between clay and sand ($P \geq 0.01$), suggesting that sand reduces as clay content increases. There was a significant positive correlation ($P \leq 0.01$) between total nitrogen and organic carbon, OC rises with an increase in total nitrogen. There was a negative correlation ($P \geq 0.05$) between available phosphorus and bulk density. At ($P \geq 0.01$), ECEC and TEA demonstrated a high

Table 3.3: The chemical properties of soils along toposequence at Isiala Mbano

	pH H_2O	**pH** KCl	**OC** %	**TN** %	**C/N**	**Av.P** $mgkg^{-1}$	**Ca**	**Mg**	**K**	**Na**	**TEB**	**TEA**	**ECEC**	**BS (%)**
							←			$Cmolkg^{-1}$			→	
Top slope	5.19	4.58	1.03	0.09	11.70	3.05	2.80	0.98	0.530	0.53	5.20	2.29	7.10	67.1
Mid slope	5.00	4.01	0.42	0.04	11.71	3.36	5.76	2.96	0.226	0.478	9.40	2.08	11.50	81.40
Foot slope	5.18	0.749	1.33	0.12	11.58	3.82	4.40	2.38	0.396	0.488	7.70	2.72	10.40	68.60
$LSD_{(0.05)}$	0.61^{NS}	0.75	0.654	0.07^{NS}	0.25	0.95^{NS}	2.865	3.10^{NS}	0.36^{NS}	0.06^{NS}	5.93^{NS}	0.648^{NS}	5.91^{NS}	12.17

pH = Soil pH, OC = Organic carbon, TN = Total nitrogen, C/N = Carbon: nitrogen ratio, Av. P= Available phosphorus, Ca = Calcium, Mg = Magnesium, K = Potasium, Na = Sodium, TEB = Total exchangeable bases, TEA = Total exchangeable acidity, ECEC = Effective cation exchange capacity, BS = Base saturation, NS=Not significant.

Table 3.4: Vertical distribution of soil chemical properties of the toposequence at Isiala Mbano

Horizon	Depth	pH H_2O	pH kcl	OC gkg^{-1}	TN gkg^{-1}	C/N	Av P mg/kg	Ca	Mg	K	Na	TEB	TEA	ECEC	BS%
								←			Cmolkg^{-1}			→	
							TOP SLOPE								
A	0 – 18	5.10	4.94	2.55	0.219	11.64	5.69	2.60	1.00	0.22	0.57	4.39	2.48	6.87	63.90
AE	18 – 32	5.08	4.86	1.38	0.119	11.59	2.84	3.40	1.60	0.74	0.52	6.26	1.92	8.18	76.53
E	32 – 73	5.33	4.52	0.78	0.067	11.64	2.53	2.00	0	0.27	0.52	2.79	1.84	4.63	60.26
Bt_1	73 – 115	5.43	4.40	0.36	0.031	11.61	2.35	3.00	1.30	0.80	0.56	5.66	2.20	8.26	68.52
Bt_2	115 – 140	5.03	4.18	0.06	0.005	12.00	1.86	3.00	1.00	0.62	0.48	5.10	2.20	7.70	66.23
	Mean	5.19	4.58	1.03	0.088	11.69	3.05	2.80	0.98	0.53	0.53	4.84	2.29	7.13	67.09
	SDV	0.18	0.318	0.986	0.085	0.171	1.516	0.529	0.60	0.269	0.036	1.846	3.376	1.502	6.08
	CV (%)	3.37	6.943	95.73	96.59	1.460	49.71	18.89	61.5	50.75	6.79	35.5	16.42	2.12	9.06
	Rank	L	L	H	H	L	H	M	H	H	L	H	M	L	L
							MID SLOPE								
AP	0 – 15	5.43	4.40	0.46	0.039	11.79	5.72	4.00	0.50	0.19	0.48	5.17	1.01	6.17	83.79
AB	15 -31	5.53	4.55	0.78	0.067	11.64	3.63	8.00	5.50	0.24	0.48	14.22	1.24	15.46	91.98
Bt_1	31 – 77	4.52	3.54	0.06	0.005	12.00	3.46	5.30	3.30	0.30	0.43	9.33	2.44	11.77	79.27
Bt_2	77 – 100	5.13	4.15	0.36	0.031	11.61	2.04	5.00	2.00	0.16	0.52	7.68	2.88	10.56	72.73
Bt_3	100 – 122	4.38	3.40	0.46	0.040	11.50	1.96	6.50	3.50	0.24	0.48	10.72	2.84	13.56	79.06
	Mean	4.99	4.01	0.42	0.036	11.71	3.36	5.66	2.96	0.23	0.48	9.40	2.08	11.50	81.37
	SDV	0.52	0.514	0.258	0.022	0.171	1.529	1.537	1.86	0.054	0.032	3.385	0.8971	3.510	7.121
	CV (%)	10.5	12.818	61.43	61.11	1.46	45.44	26.68	62.8	23.81	6.70	36.01	43.13	30.51	8.75
	Rank	L	L	H	H	L	H	M	H	M	L	H	H	M	L
							FOOT SLOPE								
AP	0 – 17	4.92	3.58	2.65	0.229	11.57	6.82	2.80	0.60	0.74		0.48	2.12	6.74	68.55
AB	17 – 37	5.37	4.96	1.22	0.105	11.62	5.20	2.30	0.40	0.68		0.42	2.40	6.20	61.29
Bt_1	37 – 80	4.93	3.64	0.98	0.085	11.53	3.72	2.30	0.30	0.22		0.56	2.60	5.98	56.52
Bt_2	80 – 124	4.99	3.50	0.96	0.083	11.56	2.16	4.60	2.70	0.19		0.52	3.08	11.09	72.23
	124 – 160	5.67	4.82	0.86	0.074	11.62	1.19	10.00	7.90	0.15		0.46	3.40	21.91	84.48
	Mean	5.18	4.10	1.33	0.115	11.705	3.82	4.40	2.38	0.39		0.49	2.72	10.40	68.61
	SDV	0.333	0.725	0.748	0.065	0.065	2.269	3.27	3.239	0.289		0.054	0.517	6.774	10.77
	CV (%)	6.429	17.68	56.52	56.52	1.65	59.40	74.32	>100	72.98		11.07	19.00	65.14	15.71
	Rank	L	M	H	H	L	H	H	H	H		L	M	H	M

CV ≤15%= Low Variation (L); CV>15≤35%=Moderate Variation (M); CV>35%= High Variation(H);.pHw=pH in water; pHkcl= pH in kcl; OC=organic carbon; TN=Total nitrogen; CN= Carbon nitrogen ratio; AvP=Available phosphorus; Ca= calcium; Mg= magnesium; Na= sodium; TEB=Total Exchangeable Base; TEA=Total Exchangeable Acidity; ECEC= Effective Cation Exchange Capacity; BS=Base saturation; K= potassium; A, AB, AE, E, Bt, AP = different soil profile horizons.

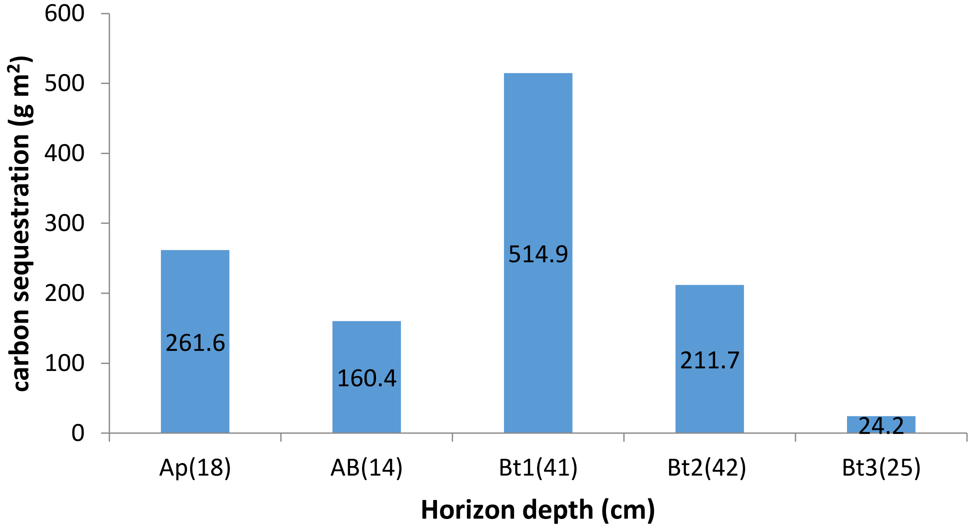

Figure 3.1: Carbon sequestration of soils of the top slope at Isiala Mbano

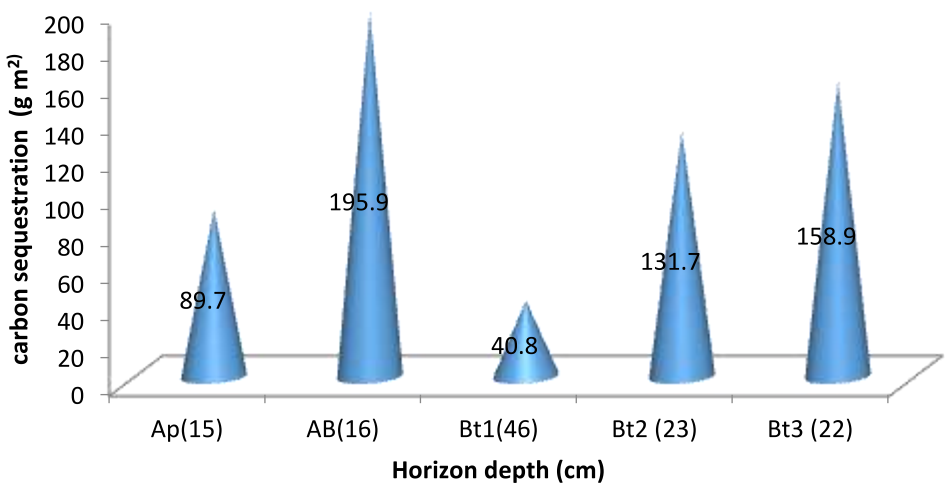

Figure 3.2: Carbon sequestration of soil in the mid slope

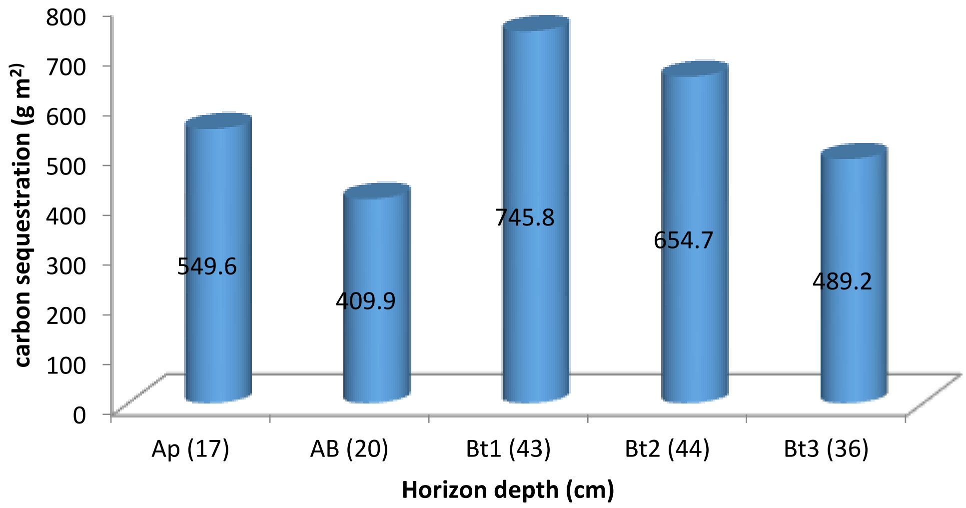

Figure 3.3: Carbon sequestration of soils in the foot slope at Isiala Mbano

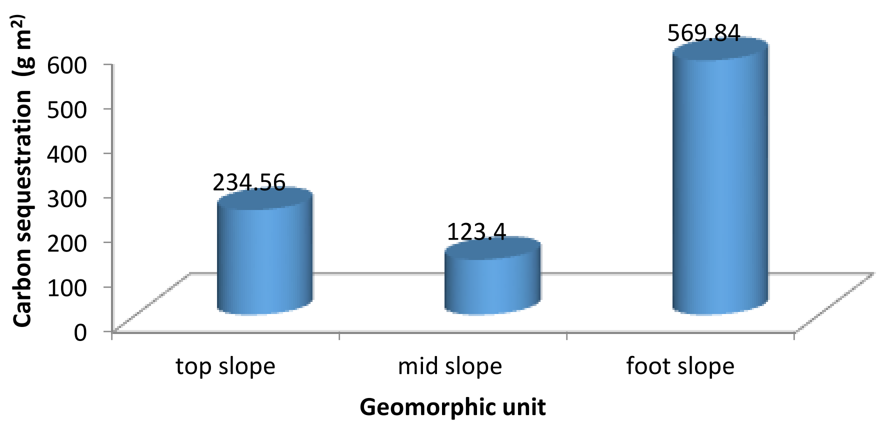

Figure 3.4: Average carbon sequestration capacity of three varying geomorphic units

positive correlation, suggesting that TEA is rising with ECEC on the mid slope. There was a substantial positive association between carbon sequestration and both organic carbon and total nitrogen $P<0.05$ ($r = 0.891, 0.898$; $p<0.05$).

Bulk density and silt had a substantial positive correlation at the foot slope ($P<0.01$). In other words, silt is growing along with bulk density. Organic carbon and moisture content have a substantial positive correlation whereas clay and sand have a negative correlation. Organic carbon, moisture content, and total nitrogen all showed positive correlations at $P < 0.05$ and 0.01 respectively. There is a negative correlation between available phosphorus and sand at ($P<0.05$). In contrast to base saturation, clay, and ECEC, which all showed positive correlations, ECEC demonstrated a significant positive connection at P0.01. This suggests that base saturation rises, with clay and ECEC content. There was a substantial association between carbon sequestration and CN at ($r = -0.952$, $p = 0.05$).

4.0 Conclusion

According to the physicochemical characteristics, the top slope had the highest sand content, followed by the foot slope and the mid-slope; as profile depth increased with clay content and decrease with sand content. The mid-slope sequestered the least amount of carbon, whereas the foot slope recorded the largest amount. The findings demonstrated that carbon is sequestered differentially on distinct toposequence slopes. This suggests that the amount of carbon sequestered decreases with increasing depth. The carbon content of the soil increased down the slope, according to the study of the soil carbon sequestration at various slope levels along the toposequence. Therefore, in order to build up organic matter and raise the amount of organic carbon on the toposequence, farmers may implement certain farming techniques like mulching, erosion control measures, cover crops, etc.

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