EVALUATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF SOILS ALONG A TOPOSEQUENCE IN OKIGWE AREA OF IMO STATE, NIGERIA.

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Abstract
This study was carried out to evaluate the physical and chemical properties of the soils along a toposequence in Okigwe local government area of Imo State, Southeastern Nigeria. A transact was run down the slope, passing through three physiographic positions (summit, midslope and footslope) of the toposequence at an inter-pedon distance about 100cm. a pedon was sunk on each physiographic positions giving a total of three profile pits. The soil samples were collected according to FAO procedures and were subjected to standard laboratory analysis for selected physio-chemical properties. Soil data were analyzed statistically using analysis of variance (ANNOVA) and coefficient of variation. Correlation analysis was used to determine the relationship that exists among the soil parameters. Results of the findings revealed that the textural composition of the soil ranges from sandy loam to loamy sand and sandy clay loam. There is moderate variation of clay at the summit and mid slope but little variation at the foot slope with sand silt and clay showing no significance difference at ($p \leq 0.05$) across the topounits. Organic matter content was generally low, less than 1.08% in all the slope units, but has its highest mean value at the foot slope (0.99%.) the soils varied from low to moderate in exchangeable bases (Ca, Mg, K and Na), with low organic matter content, total nitrogen and available phosphorus. The pH in water varied from moderately acidic (pH 5.94) to slightly acidic (pH 6.14). Percentage base saturation of the area was generally high ranging from 64.9-84.5% and has little variation ($CV \leq 20$) across the topounits. Results of the finding also revealed that pH has a negative relationship with organic carbon, CEC, base saturation and phosphorus. The soils of the studied area were generally classified as Alfisols and suborder of Udalf prior to its high base saturation, low organic matter content and udic moisture regime. The trends of changes and difference in soil properties across the slope showed that soil properties differ at the three topounits. All the parameters studied were generally low having their highest mean values at the foot slope, indicating that landscape position, erosion and drainage significantly influenced variations in soil properties across the toposequence. Therefore, there is a need to adopt conservation measures like liming, mulching, organic and inorganic fertilizer along the toposequence for sustainable food production.

Keywords: physical, chemical, morphological properties; Toposequence; Soil Taxonomy; WRB Legend

1.0 INTRODUCTION

Soil is a collection of natural bodies occupying parts of the earth surface that is capable of supporting plant growth and that has properties resulting from the integrated effects of climate and living organism acting upon parent material as conditioned by topography over period of time (Brady and Weil, 2007).

Topography has a greater influence on spatial variation of soil properties through climate, parent materials, and vegetation. A sequence of related soils from the conditions but has differences in their characteristics due to variation in slope is known as toposequence (Brady and Weil, 2007). Toposquence can be classified into three classes according to slope gradient as upper slope [crest], mid slope and bottom slope.

Slope exhibit tremendous spatial variability in their physical and chemical properties along a toposequence. Ollinger *et al.*, [2002] reported that variation of soil properties is significantly influenced by some environmental factors such as climate, topography features [landscape position, topography, slope gradient and evolution], parent material, and vegetation.

The differences in soil properties as a result of slope position are associated to degree of detachment, transportation and deposition of soil materials. The toposequencial differentiation of soils is pivotal importance to the management of soils in different physiographic position in the landscape. Studies toposequencial differentiation of soils in the tropical rainforest of Nigeria concentrated on soil profile characteristics [Aweto and lyamah 1993]. Some researchers [Aweto and Enaruvbe, 2010; Osujieke, 2017] have reported on variation of soil properties along the toposequence soils of southern Nigeria.

The variation of soil properties should be mentioned and quantified to understand the effects of land use and management system on soils. Understanding soil properties and their variation along a toposequence is important for their sustainable utilization and proper management [Nuga *et al.* 2006].

Thus, evaluating land management practices require the knowledge of soil spatial variability and understanding the relationship among the soil properties. Spatial variability could allow prediction or estimation of values of un-sampled location within the region [Xuewe *et al.* 2001] and can also make a basis for defining different management zones on a field. Soil physical and chemical properties are necessary to define and evaluate soil types, slopes, existing land-use or natural cover under given condition of management. In the past, most toposequence are not subjected to intensive farming activity as it currently obtained now due to scarcity of arable land resulting from population boom. This practice could create serious degradation such as fertility decline, increased erosion if not properly managed.

Farmers in many tropical areas are beginning to crop on marginal lands including farming on slopes and this is the case of Okigwe area in Imo State. To this effect, there is used to evaluate soil properties along a toposequence in Okigwe area to ease communication and transfer of knowledge about such soil to inhabitants for maximum use of the area for both agricultural and non-agricultural purposes. It is important to know that different soil properties occur at different position on the landscape, and this various topographic differences can have effect on the yield of crops.

The aim of this study is to evaluate the physical properties of the soil along a toposequence in Okigwe area, Imo state, Nigeria.

2.0 Materials and Methods

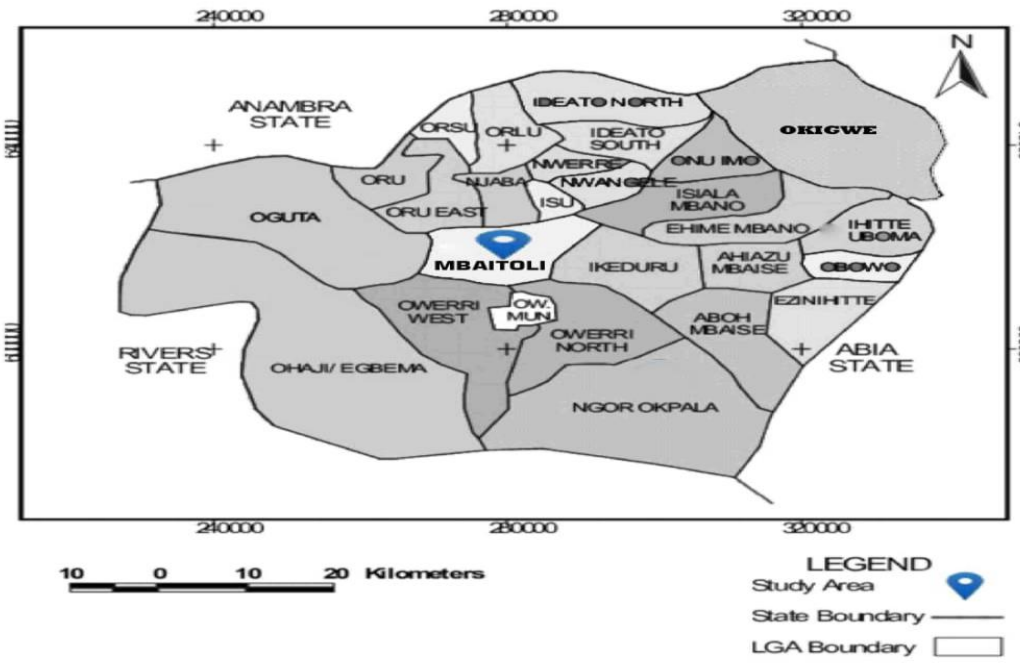
2.1 The study area

The study was conducted at Okigwe area of Imo state, Nigeria. Okigwe is one of the three zonal districts in Imo state, Nigeria. The area is situated between latitude 7^0 18'N to 5^0 54N and longitude 5^0 46'E and 7^0 2'E.

The climate is a humid tropical ecosystem. It falls within the rain forest belt of Nigeria, and has an average annual rainfall of about 1100mm a year (Iloeje 1981) . according to the author, the rainy season last from April to October with heavy down pour which results in heavy flooding and soil erosion. The wet season is associated with low temperature of around 30^0C and high humidity of around 90%.

The dry season which lasts from November to march is characterized by dry and dusty hamattan winds causing high evapouration rate. The dry season with humidity between 60-70%, Mananu (1995). The dominant vegetation is rainforest arranged in tier. It is characterized by multiple plant species ranging from shrub, herbs and trees.

Agriculture and farming are the major socio-economic activity of the area, about 70% of the total area is used as cultivated land. Slash and burn techniques have been the major method of land clearing where bush fallow is a soil fertility regeneration practice that has prevail over decades, whose length has been drastically reduced due to deaphic pressure on the land. (Onweremadu, 1994).



Map of Imo State, Nigeria, showing the study area

2.2. Field studies

A field reconnaissance visit was conducted to identify fields to be used, physiographic features of the study, and also familiarize with village heads, youth leaders, and necessary authorities for guarantee.

Soil sampling was done using the transect soil survey technique (Wang 1982). A transverse was cut to link the three identified physiographical land units, namely: the summit-slope, mid-slope and foot-slope and these topounits were aligned along the transverse.

A total of three profile pits were dug for the study with a pit in each physiographic land unit (summit slope, middle slope and foot slope). Soil samples were collected according to horizon differentiation as revealed by each of the profile pit. In addition, core sample were used to collect samples from each horizon for the evaluation of bulk density, moisture content and hydraulic conductivity respectively. The samples were taken to the laboratory for routine analysis.

2.3 Laboratory analysis

The soil samples collected were sent to the laboratory for routine analysis on the selected physical and chemical properties. The physical properties that were analyzed include: particle size distribution, bulk density, while the chemical properties determined includes: total nitrogen, available phosphorus, organic carbon, soil pH, organic matter, exchangeable cations, and base saturation. The methods for analyzing the soil properties include:

Particle size distribution was determined by hydrometer method according to the procedure of Gee and Or (2002).

Bulk density was determined by undisturbed core sampling method after drying the soil samples in an oven at 105^0C to constant weights (Grossman and Reinsch 2002).

Soil pH was determined using a glass electrode pH meter and in KCl at 1:2:5 soil water ratio. (Udo et al., 2009).

Organic carbon was determined using Walkley and Black wet digestion method. (Udo et al., 2009).

Total nitrogen was determined by Micro Kjeldah Digestion and distillation method described by Udo et al., (2009).

Exchangeable cation was determined by the method described by (Udo et al., 2009), the amount of potassium (K) and sodium (Na) were determined using flame photometer with appropriate fillers while magnesium (Mg) and calcium (Ca) were determined by atomic absorption spectrometer (AAS).

Percentage Base saturation was determined as a sum of exchangeable cations divided by CEC and multiplied by 100. (Udo et al., 2009).

Available phosphorus was determined by Bray P-1 extracted and P in the extract will be determined using Murphy and Riley methods as described by (Udo et al., 2009).

2.4 Data analysis and presentation

The statistical tool used were: Descriptive statistics, analysis of variance (ANOVA) at $p \leq 0.05$ and coefficient of variation, while the degree of relationship was done using correlation analysis (r). statistical analysis was done using IBM-SPSS statistics 21 software.

Data were presented on tables. Analysis of variance (ANOVA) was used to determine the variations between the soil properties at 5% level of probability and the relationship among soil properties was estimated using coefficient of correlation.

Coefficient of variation (CV) was used to determine the degree of variability existing among soil properties at different horizon and across the toposequence.

Table 1: Ranking of variability (Adopted from Aweto 1982)

Level (%)	Ranking
C.V <20	Little variation
C.V 20-50	Moderate variation
C.V >50	High variation

3.0 RESULTS AND DISCUSSION

3.1 Morphological Characteristics Of The Study Area

The morphological characteristics of the soils in the studied site are shown in table 2. The entire horizons were well drained.

The soil depth was very deep (0-134cm) at the upper slope and mid slope (0-136cm) and moderately deep at the foot slope (0-54cm).

The various topounits have different soil color matrix ranges. It was observed that across the horizons, the soil color ranges from reddish brown (5YR5/3) to pink (7.5YR7/3) (moist) at the summit slope, very dark grey (7.5YR3/1) to reddish yellow (5YR7/6) (moist) at the mid slope, and dark brown (7.7YR3/2) to reddish yellow (5YR6/8) at the foot slope. The drainage condition and physiological position may have influence the observable color in the topounits which agrees with Gerrard (1981) and Esu et al., (2008).

The parent materials and environmental factors (humidity, rainfall and temperature) may have contributed to the soil color variation of each horizon. Also the amount of eluviations and or illuviations that have occurred within these toposequence may equally contribute to the soil color matrix on each topographic unit. The reddish color is due to the ferrous iron (Fe) compound indicating that the soil is well aerated. According to Nuhu (1983) the brownish tinges in most of the horizons of the profile were due to the presence of organic matter which is the main coloring agent in the top soil.

At the summit, the texture of the first two horizons (0-23cm and 23-64cm) was dominated by sandy loam while last two horizon (64-103cm and 103-134cm) were dominated by sandy clay loam. The mid and foot slope were generally loamy sand and sandy loam with sandy clay loam dominating only at the last horizon (100-130cm) of the mid slope.

Sub angular structures dominated in the soil across the toposequence. The soils were firm except the mid slope and foot slope that have friable and very friable consistency.

Few fine roots or no roots were observed from the second horizons (endopedons) to the last horizons of all topounits, while the first horizons (epipedons) have many fine roots, the boundaries were generally smooth and clear except from the horizons where gravel was observed.

TABLE 2: MORPHOLOGICAL CHARACTERISTICS OF THE SOILS IN THE STUDY AREA

Horizon	Depth(cm)	Colour (moist)	Texture	Structure	Consistency (moist)	Drainage	Roots	Horizon boundary
Summit slope								
AP	0-37	Reddish brown (5YR5/3)	SL	Weak medium crumb	Fr	Wd	Mfr	clear
AB	37-64	Light brown (7.5YR6/4)	SL	2Sbk	Firm	Wd	Nr	Diffused
Bt1	64-103	Pink (7.5YR6/4)	SCL	2Sbk	Firm	Wd	Nr	Clear
BC	103-134	Pink (7.5YR6/4)	SCL	3Sbk	Firm	Wd	nr	Clear
Mid slope								
Ap	0-30	Very dark grey (7.5YR3/1)	SL	Weak medium granular	Fr	Wd	Mfr	Clear
AB	30-48	Reddish yellow (7.5YR6/6)	LS	2Ssbk	Fr	Wd	Ffr	Diffused
Bt1	48-75	Reddish yellow (7.5YR7/6)	LS	3Sbk	Fr	Wd	Nr	Diffused
Bt2	74-100	Reddish yellow (5YR6/6)	SL	Weak medium granular	Fr	Wd	Nr	Clear
Bct	100-130	Reddish yellow (5YR7/6)	SCL	Weak granular	Fr	Wd	Nr	clear
Foot slope								
AP	0-20	Dark brown (7.5YR3/2)	LS	Granular	Fr	Wd	Mfr	Clear
AB	20-30	Brown (7.5YR5/4)	LS	Weak medium granular	Vfr	Wd	Ffr	Clear
Bt1	30-36	Reddish yellow (5YR6/6)	SL	Weak medium granular	Fr	Wd	Ffr	Clear
Bt2	36-40	Yellowish red (5YR5/6)	SL	Spheroidal granular	Firm	Wd	Ffr	Clear
Bt3	40-45	Reddish brown (5YR5/4)	LS	Prismatic and angular blocky	Fr	Wd	Nr	Diffused
Bt4	45-54	Reddish yellow (5YR6/8)	LS	Weak medium granular	Fr	Wd	Nr	Clear

KEY: SL= Sandy loam, LS= Loam sand, SCL=Sandy clay loam, SBK= Subangular blocky, ISBK= Weak subangular blocky, 2SBK= Medium subangular blocky, 3SBK= Strong subangular blocky, Fr= Friable, Wd= Well drained, Mfr=Many fine roots, Ffr= Few fine roots, Nr= No root.

3.2 SOIL PHYSICAL PROPERTIES

The result of the physical properties of the soils along a toposequence is shown in table 3. The sand content decreases as depth increases at the summit and mid-slope, but did not have a stable decrease or increase at the foot slope. It ranges from 556.00-656.00g kg^{-1} at the summit, 656.00-796. 00g kg^{-1} at the mid-slope and 736 00-856.00g kg^{-1} at the foot-slope, with the mean values of 596.00, 740.00, and 799.30g kg^{-1} respectively. Sand fraction occurred highest at the foot-slope compared to those of summit and mid-slope. The highest proportion of sand observed at the foot-slope could be as a result deposition, (Ahukaemere et al., 2012), or as a result of their higher erodibility, characterized by their light weight. Hence they tend to be found near the base of the toposequence (Irvin, 1996). Sand fraction shows little variation across the three topounits (Table 3).

Silt fraction did not have a stable increase with depth. It ranges from 172.00-232. 00g kg^{-1} at the summit, 52.00-132. 00g kg^{-1} at the mid-slope, and 52.00-112. 00g kg^{-1} at the foot-slope with mean values of 192.00, 108.00 and 75.40g kg^{-1} respectively. Silt content occurred highest at the summit with the mean value of 192.00g kg^{-1} followed by the mid-slope of 108. 00g kg^{-1} and the least fraction occurred at the foot-slope (75.30g kg^{-1}). Coefficient of variation (CV) showed moderate variation at the mid-slope and foot-slope, while summit has little variation. (table 3).

Clay content ranges from 172.00-272.00g kg^{-1} at the summit, 112.00-212.00g kg^{-1} at the mid-slope and 92.00-152.00g kg^{-1} at the foot slope. Clay content did not have a stable increase or decrease with depth. The relative proportion of clay was higher at the summit with mean value of 212. 00g kg^{-1} followed by mid-slope (152. 00g $kg^{-1)}$ and the least mean value which occurred at the foot slope (125.30g kg^{-1}). Summit and mid-slope showed moderate variation, while foot-slope has low variation.

Analysis of variance (ANOVA) of sand, silt and clay showed significance differences across the three topounits at ($P \leq 0.05$) (table 3).

At the summit, bulk density ranges from 1.29-1.57g/cm^3, 1.10-1.63g/cm^3 at the mid-slope and 1.25-1.77g/cm3 at the foot-slope. The highest mean value of bulk density occurred at the foot-slope (1.46g/cm3) followed by the summit (1.40g/cm3) and the least occurred at the mid-slope (1.34g/cm3). Base on the critical value of 1.6g/cm -3 (McKenzie et al., 2004), the surface and subsurface horizons of the topounits had low bulk density ranging ranging from 1.10-1.40g/cm-3 which can support optimum movement of water and air and also ease root penetration. Bulk density showed little variation across the topounits. Analysis of variance (ANOVA) showed non significance different at ($P \leq 0.05$). The textural class of the toposequences ranges from sandy loam, sandy clay loam and loamy sand with loamy sand dominating at the foot-slope.

TABLE 3: SOIL PHYSICAL PROPERTIES OF THE TOPOSEQUENCE

HORIZON	DEPTH	SAND (g/kg^{-1})	SILT (g/kg^{-1})	CLAY (g/kg^{-1})	TC	B.D (g/cm^{-3})
			SUMMIT SLOPE			
AP	0-37	656.00	172.00	172.00	SL	1.35
AB	37-64	616.00	192.00	192.00	SL	1.40
Bt1	64-103	556.00	232.00	212.00	SCL	1.57
Bt2	103-134	556.00	172.00	272.00	SCL	1.29
MEAN		596.00	192.00	212.00		1.40
STD		4.90	2.83	4.32		0.12
CV(%)		8.22	14.74	20.38		8.57
			MID SOLPE			
AP	0-30	796.00	52.00	152.00	SL	1.25
AB	30-43	776.00	112.00	112.00	LS	1.10
Bt1	43-75	776.00	112.00	112.00	LS	1.63
Bt2	75-100	696.00	132.00	172.00	SL	1.60
Bt3	100-130	656.00	132.00	212.00	SCL	1.10
MEAN		740.00	108.00	152.00		1.34
STD		6.07	3.29	4.24		0.26
CV(%)		8.20	30.46	27.89		19.40
			FOOT SLOPE			
AP	0-20	816.00	72.00	112.00	LS	1.25

AB	20-30	796.00	72.00	112.00	LS	1.30
Bt1	30-36	756.00	92.00	152.00	SL	1.54
Bt1	36-40	736.00	112.00	152.00	SL	1.44
Bt3	40-45	856.00	52.00	92.00	LS	1.77
Bct	45-54	836.00	52.00	112.00	LS	1.47
MEAN		799.30	75.30	125.30		1.46
STD		4.63	2.34	2.42		0.19
CV(%)		5.79	31.08	19.31		13.01

3.3 CHEMICAL PROPERTIES

Table 4 shows the chemical properties of the soils of the study area with their mean, standard deviation and coefficient of variation values. The mean values of the pH in water (H_2O) of the soils across the three topounits are summit (pH 5.94),mid slope (pH 6.14), and foot slope (pH 5.95) respectively. pH of the soils in water were moderately acidic at the summit and foot –slope but slightly acidic at the mid-slope which could be attributed to the kaolinitic nature of the soil (Juo and Katherine, 2003). It could also be as a result of leading of the exchangeable basic cations or runoff down the slope. The three topounits were observed to have low variation (CV<20) respectively. Soil pH shows non significant difference across the three topounits at (P<0.05).

ORGANIC CARBON: organic carbon ranges from 0.31-0.64% at the summit, 0.27-1.08% at the mid-slope and 0.62-1.17% at the foot-slope, with mean values of 0.50,0.63 and 1.00% respectively. The highest mean value of organic carbon occurred at the foot-slope (1.23%) which could be attributed to runoff from the summit to foot-slope (London, 1991). It may also be due to more litter materials and deposition down the slope. The organic carbon generally decreases with depth at all the slope units. According to the rating standard (FDALR, 1990), the organic carbon of the studied area was generally low ranging from 0.27-1.08% in all the topounits. Analysis of variance (ANOVA) of organic carbon across the slope unit showed non significant difference at (P<0.05). Coefficient variation (CV) was moderate at the summit and foot-slope, but high at the mid-slope.

EXCHANGEABLE CATIONS: the mean values of Ca^{2+}, Mg^{2+} and K^{+}, showed an increasing order, from the summit to the foot-slope, with foot-slope having the highest mean value of the basic cations. According to the rating standard (FDALR, 1990), result of the findings revealed that the basic cations varied from low to moderate at the studied area with the ranges of 1.12-1.89 $Cmolkg^{-1}$ for Ca,0.94-1.19 $Cmolkg^{-1}$ for Mg, and 0.19-0.23 $Cmolkg^{-1}$ for K respectively. Analysis of variance (ANOVA) showed significance different at Ca and non-significance difference at Mg and K at (P<0.05). Coefficient of variation (CV) showed moderate variation at Ca and Mg but little variation at K in each topounit respectively. Na has the mean values of 0.11 $Cmolkg^{-1}$ at the summit, 0.10 $Cmolkg^{-1}$ at the mid-slope and 0.13 $Cmol/kg^{-1}$ at the foot-slope respectively. The highest mean value of Na^{+} occurred at the foot-slope (0.13$Cmolkg^{-1}$) and the least mean value occurring at the mid-slope (0.10 $Cmolkg^{-1}$). Na^{+} is generally very low ranging from 0.10-0.13 $Cmolkg^{-1}$ at the studied area according to rating standard (FDALR, 1990). Analysis of variance (ANOVA) showed non significant difference with moderate variation in each of the slope units. The high mean values of exchangeable cations observed at the foot-slope may be as a result of dominance of grass vegetation at the foot-slope which restricts leaching or volatilization of exchangeable cations. This finding does not agree with Miller and Donahue (1992) which reported that exchangeable cations decreases from summit slope to the foot-slope.

Percentage base saturation of the soils ahs the highest mean value at the foot-slope (76.78%) and the least occurring at the mid-slope (70.24%). Analysis of variance (ANOVA) showed non-significant difference with little variation (CV<20) across the three topounits. Base saturation of the study area is generally high ranging from 64.9-84.5% according to (FDALR,1990) rating standard.

Available phosphorus has the highest mean value at the foot-slope (3.34 mg/kg^{-1}) and the least at the mid-slope (2.05 mg/kg^{-1}). Results of the finding revealed that available phosphorus of the studied area is very low, regarding the rating standard (FDALR,1990). Analysis of variance (ANOVA) showed non-significant difference at (P<0.05) and coefficient of variation showed high variation (CV>50) across the three slope units. The general low value of phosphorus across the three slope units may be as a result of low organic matter, high mineralization and acidic nature of the soil.

TABLE 4: SELECTED SOIL CHEMICAL PROPERTIES OF THE STUDIED AREA

HORIZON	DEPTH(cm)	pH(H2O)	O.C(%)	O.M(%) →	TEA	AL^{3+} Cmolkg^{-1}	H+	T.N(%)	Ca^{2+}	Mg^{2+}	K^{+}	Na+	CEC	B(%)	P(mgkg^{-1})
SUMMIT SLOPE															
AP	0-37	5.84	0.64	1.07	1.20	0.90	0.30	0.07	1.80	1.20	0.27	0.14	4.31	79.1	4.74
AB	37-64	6.12	0.59	1.03	1.30	0.80	0.50	0.06	1.40	1.00	0.21	0.11	4.02	67.6	2.69
BT1	64-103	5.60	0.47	0.89	1.10	0.60	0.50	0.04	1.20	0.80	0.18	0.13	3.41	67.7	1.59
BT2	103-134	6.18	0.31	0.55	1.00	0.80	0.20	0.027	1.00	0.75	0.18	0.07	3.00	66.6	0.94
MEAN		5.94	0.50	0.89	1.15	0.78	0.38	0.05	1.35	0.94	0.21	0.11	3.69	70.25	2.49
STD		0.27	0.24	0.43	0.13	0.13	0.15	0.02	0.34	0.21	0.04	0.03	0.59	5.92	1.66
CV(%)		4.55	48.00	48.31	11.30	16.67	39.47	40.00	25.19	22.34	19.05	27.27	15.99	8.43	66.67
MID SLOPE															
AP	0-30	5.97	1.08	1.08	0.90	0.60	0.30	0.09	1.40	1.00	0.20	0.12	3.62	75.1	3.64
AB	30-43	6.25	0.79	1.04	0.85	0.40	0.45	0.06	1.20	1.20	0.23	0.14	3.60	76.3	2.76
BT1	43-75	6.30	0.56	0.85	1.00	0.60	0.40	0.042	0.80	1.80	0.17	0.10	2.87	65.1	1.55
BT2	75-100	5.89	0.47	0.65	0.90	0.60	0.30	0.032	1.20	0.60	0.21	0.07	2.99	69.8	1.47
BT3	100-130	6.28	0.27	0.48	1.20	0.80	0.40	0.024	1.00	0.95	0.16	0.09	3.40	64.9	0.82
MEAN		6.14	0.63	0.82	0.97	0.60	0.37	0.05	1.12	1.11	0.19	0.10	3.29	70.24	2.05
STD		0.19	0.43	0.55	0.14	0.14	0.07	0.03	0.23	0.44	0.03	0.03	0.35	5.37	1.13
CV(%)		3.09	68.25	67.07	14.43	23.23	18.92	60.00	20.54	39.64	15.79	30.00	10.64	7.65	55.12
FOOT SLOPE															
AP	0-20	6.10	1.07	1.17	0.80	0.60	0.20	0.18	2.50	1.45	0.26	0.16	5.17	84.5	7.36
AB	20-30	6.04	1.02	1.13	1.20	0.90	0.30	0.13	2.20	1.60	0.27	0.14	5.41	77.8	5.13
BT1	30-36	6.10	1.01	1.10	0.90	0.50	0.40	0.09	2.40	1.00	0.31	0.18	4.79	81.2	3.36
BT2	36-40	6.25	0.74	1.03	1.10	0.70	0.40	0.09	1.80	1.20	0.22	0.10	4.42	75.1	1.90
BT3	40-45	5.91	0.67	0.86	0.80	0.60	0.20	0.06	1.00	0.90	0.17	0.09	2.96	72.9	1.44
BCT	45-54	5.29	0.52	0.62	1.20	0.90	0.30	0.06	1.45	1.00	016	0.09	3.90	69.2	0.86
MEAN		5.95	1.00	0.99	1.00	0.70	0.30	0.10	1.89	1.19	0.23	0.13	4.44	7678	3.34
STD		0.34	0.56	0.59	0.19	0.17	0.09	0.05	0.59	0.28	0.06	0.04	0.90	5.58	2.49
CV(%)		5.71	56.00	59.60	19.00	24.29	30.00	50.00	31.22	23.53	26.09	30.77	20.70	7.27	74.55

Sig ($p \leq 0.05$)	0.27(N/S)	0.06(N/S)	0.05(S)	0.25(/S)	0.25(N/S)	0.43(N/S)	0.05(S)	0.03(S)	0.51(N/S)	0.43(N/S)	0.54(N/S)	0.05(S)	0.13(N/S)	0.54(N/S)

O.C= Organic carbon, O.M= Oorganic matter, TEA= total exchangeable acidity, T.N=total nitrogen, CEC= cation exchange capacity, BS= Base saturation

Relationship among selected soil properties

Soils of the study area were correlated to check the types and degree of relationship existing between soil chemical properties in the studied. The results are shown below in table 5.

Soil cation exchange capacity (CEC) had a moderate positive relationship with organic carbon (0.852), Ca (0.950), Mg (0.446), K (0.786), Na (0.730), base saturation (0.846) and phosphorus (0.902). this type of relationship is an indication of the fact that as cation exchange capacity increases or decreases, there is also a corresponding increase or decrease in the proportion of the positively correlated soil properties.

Soil pH correlated with soil organic carbon (-0.157), CEC (-0.153), base saturation (-0.233) and phosphorus (-0.160). this shows that increase or decrease in the soil pH in the studied area did not cause a corresponding increase or decrease of the correlated properties.

Table 5: correlation matrixes of the soil chemical properties across the topounits.

	pH	O.C	O.M	TEA	$AL.^{3+}$	H.	Ca^{2+}..	Mg^{2+}..	K^{+}.	Na^{+}.	CEC	BS(%)	P(PPM)	
pH	**1**													
O.C	**-0157**	**1**												
O.M	**0.187**	**0.999****	**1**											
TEA	**0.113**	**0.230**	**0.228**	**1**										
AL^{3+}.	**0.162**	**0.069**	**0.060**	**0.803****	**1**									
H.	**0.433**	**0.272**	**0.283**	**0.414**	**0.210**	**1**								
T.N	**0.201**	**0.997**	**0.998**	**0.226**	**0.036**	**0.317**	**1**							
C.a**	**0.152**	**0.865**	**0.867**	**0.032**	**0.067**	**0.156**	**0.857**	**1**						
Mg**	**0.249**	**0.516**	**0.521**	**0.062**	**0.049**	**0.027**	**0.530**	**0.316**	**1**					
K*	**0.196**	**0.667**	**0.669**	**0.125**	**0.122**	**0.018**	**0.642**	**0.857**	**0.285**	**1**				
Na2**	**0.128**	**0.707**	**0.699**	**0.157**	**0.297**	**0.196**	**0.664**	**0.759**	**0.407**	**0.807**	**1**			
CEC	**0.153**	**0.852**	**0.855**	**0.184**	**0.224**	**0.040**	**0.846**	**0.950**	**0.446**	**0.786**	**0.730**	**1**		
BS(%)	**0.233**	**0.846**	**0.848**	**0.387**	**0.220**	**0.300**	**0.837**	**0.859**	**0.309**	**0.848**	**0.780**	**0.767**	**1**	
P(PPM)	**0.160**	**0.902**	**0.901**	**0.174**	**0.019**	**0.257**	**0.892**	**0.800**	**0.506**	**0.754**	**0.752**	**0.784**	**0.841**	**1**

** Correlation is significant at 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed)

O.C: Organic Carbon, O.M: Organic Matter, TEA: Total exchangeable Acidity, T.N: Total Nitrogen, CEC: Cation Exchange Capacity, BS: Base

3.5 CLASSIFICATION OF THE SOILS OF THE STUDIED AREA

The soils of the studied area were classified using USDA soil taxonomy (soil survey staff 2010) and correlated with the World Reference base (FAO, 2006) soil nclassification system. The studied location falls under isohyperthermic temperature and Udic moisture regimes. The pedons have high base saturation (>60%) and low organic matter content which qualifies them as Alfisol. It falls under the suborder of udalf because of its udic moisture regime and it is located under humid climate and has been forested at some point.

The surface horizons are classified as mollic epipedon as been brown, friable and strongly acidic. The subsurface horizon is classified as kandic horizon at the foot-slope and agrillic horizon with kaoilinite-like clay at the summit and mid-slope. The soils falls under the great group of hapludalf and subgroup of typic hapludalf at the summit and mid-slope, because they are well drained, have loamy and clayey textural classes, high base saturation with moderate to deep depth. Hence, foot-slope fall under the subgroup of psammentic hapludalf because of its loamy and sandy textural composition. Correlating the soil under World Reference Base (FAO, 2006) soil classification system, it is classified as chromic Luvisols (Lc) having strong brown to red B horizon with hue of 7.5YR and a chroma of more than four ($) or hue that is redder than 7.5YR.

TABLE 6: CLASSIFICATION OF THE SOILS OF THE STUDY AREA USING USDA SOIL TAXONOMY AND CORRELATING WITH WRB CLASSIFICATION SYSTEM

Topouints	USDA SOIL TAXONOMY						WRB		FEATUERS OBSERVED
	Order	Sub order	Great group	Sub group	family	series	soil class	Soil unit	
summit	Alfisol	Udalf	Hapludalf	Typic hapludalf	Fine clayey, mixed, active, isohypertermic, shallow.	Quebrada or juncal	Luvisol	Chromic luvisol	High base saturation (>60), Udic moisture regime, simple agrillic horizon, well drained, low OM that decreases with depth, loamy or clayey texture, deep depth.
Mid-slope	Alfisol	Udalf	Hapludalf	Typic hapludalf	Fine clayey, mixed, active ,isohypertermic, shallow.	Quebrada or juncal	Luvisol	Chromic luvisol	High base saturation, Udic moisture regime, simple agrillic horizon, well drained, low OM that decreases with depth, loamy or clayey texture, deep depth.

Foot-slope	Alfisol	Udalf	Hapludalf	psammentic hapludalf	Fine loamy, over sandy or sandy-skeletal, mixed superactive, messic	Gardenvale	Luvisol	Chromic luvisol	High base saturation, Udic moisture regime, simple kandic horizon, Loamy and sandy texture, low OM that decreases with depth, moderately deep.

4.0 CONCLUSION

The result of the study showed that nutrient status of the soils of the study area were generally low and that basic cations, organic matter and available phosphorus have their highest mean values at the foot-slope as a result of transportation and deposition of soil mater.

The soils could have differed as a result of erosion, transport and deposition of surface materials as well as leaching, translocation and deposition of chemicals and particulate constituents in the soil. Topography plays a major role in these processes and thereby influences the development and characteristics of the soils along the toposequences. Most of the important soil quality indicators such as bulk density, structure, OC, soil pH, CEC, total N, available P, exchangeable bases, and available micronutrients were influenced by the different landscape positions, particularly at the surface horizon. Continuous intensive cultivation without appropriate soil management practices has contributed to the degradation of the important soil quality indicators.

The study area is susceptible to the forces of degradation and therefore, requires the following conservation measures for sustainability, Since the soil exhibits moderate and slightly acidity, lime application will be need to increase the pH of the soil. The overall nutrient status of the soil in the studied area is low; therefore mulching, organic and inorganic fertilizers application should be practiced, Mixed cropping and the use of vegetative barriers to create neutral terraces should be adopted to mitigate runoff, Agro-forestry system should be adopted on the landscape of the toposequence to minimize degradation. Further research on the erodibility of the study area would be of great importance.

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