PROPERTIES OF SOILS ON A HILLY TERRAIN ON A HUMID TROPICAL ENVIRONMENT OF NIGERIA.

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ABSTRACT
The study was conducted on a Hilly terrain using three physiographic units namely: Summit, Midslope and footslope. A transect of 100 m was established from the summit, to the midslope and footslope. A soil profile was dug on each physiographic unit. Each soil profile was dug and described using FAO procedure. Routine analysis was carried out using standard methods. The results indicated that soils at the summit had Dark brown colour $2.5YR^{2.5}/4$(moist) at the surface and Reddish grey $2.5YR^{4}/6$(moist) at the subsurface. At the midslope, the soil had brown colour to light brown. The soil at the footslope has greyish colour. The soil at the summit had weak fine granular to moderate subangular blocky structure. The midslope had coarse granular to moderate subangular blocky structure. while at the footslope the soil was massive. Soils were sandy. Moisture content varied moderately at the footslope (Mc=CV=30.6%) compared to moisture content at the upslope (Mc=CV=15.1%) and midslope (Mc=CV=12.8%). Bulk density (Bd) was moderate at the footslope (Bd=CV=24.0%) compared to Bd at the summit (Bd=CV=11.8%) and midslope (Bd=CV=8.5%). Total Porosity (Tp) was highest at the summit (TP=CV=80.7%) and low at the footslope (TP=CV=27.0%). Soils are acidic. Exchangeable bases (Ca and Mg) varied highly at the footslope (Ca=CV=41.8%; Mg=CV=83.2%) compared to Ca and Mg at the summit (Ca=CV=10.8%; Mg=CV=31.0%) and midslope (Ca=CV=5.8%; Mg=CV=39.5%). Exchangeable K had moderate variation at the summit (K=CV=32.3%) and high variation at the midslope (K=CV=43.3%). Base saturation (BS) was high at the footslope (BS=CV=39.1%) compared to BS at the summit (BS=CV=26.6%) and midslope (BS=CV=23.3%). Organic matter (OM) varied highly in all the physiographic units but was highest at the midslope (OM=CV=94.6%). Total Nitrogen (TN) was highest at the midslope (TN=CV=97.4%) and lowest at the summit (TN=CV=75.8%).
Keywords: Soil Properties, Hilly Terrain, Humid Tropical, Environment.

INTRODUCTION

Soil is one of the natural resources in the developing country like Nigeria. Soils in Nigeria are of poorer quality due to its increasing demand as a means to produce food (Fasina *et al,* 2007). Over the centuries, from the pre-colonial period till present, food production has been through the use of slash and burn system, multiple cropping, and cultivation especially in hilly areas. This has great influence on soil properties, which on the other hand affects food security as well as sustainable environment. With an increase in the demand for food as a result of increasing human population, most of the forested areas has been converted into non forested lands which are generally unproductive due to excessive cultivation (Achanya and Kafle, 2009). As a result, greater human pressure has been subjected to the hilly ecosystems or areas thus subjecting it to degradation and fragmentation into shrub/bush lands, loss of plant species, erosion resulting to washing away of top soils and soil nutrients (Muhaba,2018).

Understanding of soil properties and changes that takes place on it is important for sustainable crop production and proper soil management. Soil properties on a slope differ a result of the degree of detachment, transportation and deposition of materials downward (Maniyunda and Gwari, 2014) and such variation takes place in a systematic way due to landscape position, soil forming factors and soil management practice (Esu *et al*.,2008). Also, slope gradients, slope angle and length caused variation in the physicochemical properties of soil which may be atttributed to run off, drainage and erosion (Brubakar *et al.,* 1993). Ali *et al*. (2010) reported that changes in landscape and land use leads to heterogeneity in soil properties. Soil nutrients and their distribution were found to be higher on flat terrain that on steeper slopes (Fanuel, 2015). Smith and Montgomery (1962) in their study on a landscape reported the inherent characteristics of soil properties by pedological processes which act on the surfaces of the landscape. These processes differ because soils that are different are related to be due to differences in landscape. Ojo-Atere *et al*. (1988) reported that surface soils are developed from transported materials while the sub-surface soils are developed from the bedrock or underlying rock. Young and Hammer (2000) reported morphological changes in soil due to relief condition and such changes include colour, thickness and content of organic matter in the A horizon, degree of horizonation, depth of leaching and structural development.

Soil of an area which is the most important natural resources has great influence in agricultural productivity. Therefore understanding soil properties and their effect on crop production (Ogunkunle, 2005) will be beneficial to mankind especially in the areas of food security and environmental sustainability (Oluwatosin *et al.,* 2001; Amanze *et al*., 2016).

Mbano is a rural community in Imo State with known diversity of landforms including different sloping and flat lands. With the expanding population, most of the land and forest resources in the area have been subjected to intensive use to meet the demands for food as well as fuel wood. In the process farmers now move down to the hilly areas for cultivation thus putting it under pressure and by so doing causing the degradation of the area in the form of erosion and topsoil loss. Such degradation has lead to changes in the nature of the slope, soil properties, parent materials, flora and fauna activities and loss of soil nutrients.

There has been limited information on the proper use of soil resources especially in areas of agriculture in Mbano, Imo State, Nigeria. This information will be needed for effective planning and implementation. This study aimed to generate information on soil properties which will help to evaluate the soils of the area for their suitability for specific purposes. Therefore, this study was conducted to investigate soils on a hilly terrain in a humid tropical environment of Nigeria.

MATERIALS AND METHODS

Study Area: The study was conducted in a hilly terrain at Okohia in Mbano Area of Imo State, Nigeria. The area lies between Latitudes 5^{o}38’ and 5^{o} 44’ N and longitudes 7^{o} 11’ and 7^{o} 18’E with the elevation of 124 m above sea level (Fig 1). The soils of the study area are derived from Coastal Plain Sand (Benin Formation). The area has a humid tropical climate with an average annual rainfall of about 2500 mm with a mean annual temperature that ranges from 26 to 31^{o}C, and a high relative humidity above 80 % during rainy season (Ofomata, 1975). The vegetation of the area is rainforest which is characterized by multi-storey plant structures and the common crops and plants found there include oil palm (*Elaeis guineesis*), bamboo plants (*Phyllostachy saureosulcata*), cocoyam (*Colocasia Spp*), yam (*Dioscorea species*), cassava (*Manihot esculentus*), Plantain(*Musa paradisiaca*), Banana(*Musa sapientum*).

Grasses found there include *Sida acuta*, *Chromolena odorata*, *Panicum maximum*, *Pennisetum purpureum.* The original rainforest vegetation has been altered by land clearing, cultivation and building. Farming is the major socio-economic activity of the area.

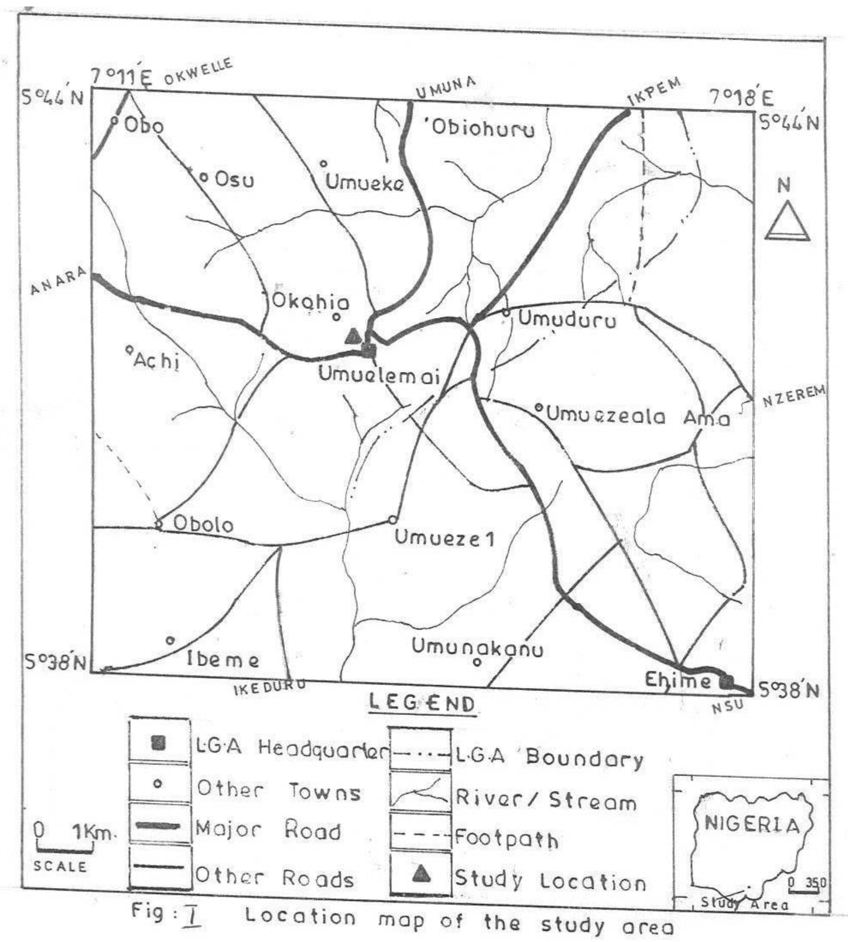

Fig : I Location map of the study area

Field Studies

Three physiographic units were selected for the study namely; Summit, midslope and footslope. A transit was established 100 m from the summit, midslope and footslope. A profile pit was dug on each of the physiographic unit at the study sites and a total of three profile pits were sampled. The profile pits were geo-referenced using a handheld Global Positioning System (GPS). The soil depths increased at both the summit and midslope except at the footslope where depth restriction occurred due to the presence of water which was encountered at the depth of 50 cm. The digging of the profiles, their description and sampling were done according to the procedure of Soil Survey Staff, 2006, and FAO, 2003. Additionally, core samplers were used to collect soil sample for bulk density determination. The collected soil samples were air-dried and sieved using a 2 mm sieve preparatory for laboratory analysis.

Laboratory Studies

Particle size distribution was determined by using the hydrometer method according to Gee and Or (2002). The soil moisture content was determined by the gravimetric method. Bulk density was determined according to the procedure of Grossman and Reinsch (2002) and was calculated as the ratio of oven dry soil weight to the volume of core sampler. The total porosity was calculated from the result of the bulk density and particle density where the particle density is assumed to be 2.65 gcm^{-3}. Soil pH was measured in a soil water ratio of 1:2.5 using a glass –electrode pH meter. Exchangeable bases (Ca, Mg, K, Na) were extracted using normal ammonium acetate (NH_4OA_C). Exchangeable Ca and Mg were determined using atomic absorption spectrophotometer. Exchangeable K and Na were determined using flame photometer. Exchangeable acidity (Al and H) was determined by leaching the soil with IN KCl and titrating with 0.05 N NAOH (Mclean, 1965). Effective cation exchange capacity (ECEC) was obtained by the summation of the exchangeable Ca, Mg, K, Na and exchangeable acidity (Al and H). Base saturation was determined by dividing the total exchangeable bases with effective cation exchange capacity (ECEC) expressed as a parentage. Organic carbon was determined by walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982). Total Nitrogen was determined using the micro-Kjeldhal method according to the procedure of Bremner and Mulvaney (1982). Available phosphorus was determined using Bray No 2 method.

Statistical Analysis

Soil data collected were subjected to statistical Analysis using the PROC Mix-model of SAS (2003.) The statistical analysis system was used to calculate for mean and coefficient of variation. The coefficient of variation was ranked according to the procedure of (wilding *et al.*, 1994) where CV; 0-15 % as varying low, 15-35 % as varying moderately 35 % and above as varying highly.

RESULTS AND DISCUSSION

Soil morphological properties presented in Table 1 indicated that the summit varied in colour from Dark brown 2.5YR$^{2.5}$/4(moist) at the surface to Reddish grey 2.5 yrs ^{5}/6(moist) at the subsurface soil. The dark brown colour at the surface of the summit indicated that the soils are well drained and productive. This may be due to the position of this soil at the landscape. Fasina *et al.* (2005) reported that soils of the humid formed at the upper part of the slope are well drained. However, the reddish grey colour at the subsurface soils showed the presence of mottles indicating that the subsurface soil was imperfectly drained. Also, at the midslope, the surface horizon had brown colour indicating good drainage while at the subsurface horizon, the soil colour was light brown. However, at the footslope, soil had greyish colour within the depth of 50 cm. At this depth, the soils are saturated with water as a result of high water table (Akpan-Idiok, *et al.*, 2006; Abua, 2012) and influence of topography where excessive run off and erosion caused the movement of materials from the summit down to the footslope (Ibanga, 2006). The gray colour indicated the presence of mottles reflecting poor damage conditions of the profile.

The soil texture at the summit ranged from Sandy-Loam to Sandy Clay Loam while the soil texture at both the midslope and footslope were Sandy Loam. The soil structure at the summit ranged from weak fine granular at the soil surface to moderate subangular blocky at subsurface horizon of the profile. Also, the soils of the midslope had coarse granular structure at the surface and moderate subangular blocky at the subsurface horizon. However, the soil structure at the footslope tends to be different. It was mostly massive that is structureless indicating poor drainage. The lack of structure in soils at the footslope may be attributed to the flooding of the profile and the effect of groundwork table (Udo *et al*, 1993).

In terms of consistency, the soils at the summit were friable at the surface and firm at the sub-surface under moist condition. More also at the midslope the soils ranged from very loose to friable under moist condition. However, at the footslope, the soils were sticky under wet condition.

Furthermore, soils at the summit had many fibrous root at the surface and coarse tap root at the sub-surface horizon. Additionally, both the midslope and the footslope had many fine to few medium fibrous root at the sub-surface horizon while absence of root was observed at the sub-surface of the midslope. Faunal activities were present in all the soils studied but was absent at the 90-160 cm and 50-130 cm depths of the summit and midslope.

Table 1 Morphological Properties of the studied soils

Horizon	Deptus cm	Colour (Moist)	Texture	Structure	Consistency (Moist)	Consistency wet	Drainage	Mottles (Moist)	Root Abundance	Faunal Activity	Boundary
					Summit						
Ap	0-15	Dark brown 2.5 YR 2.5/4	SL	Weak fine granular	Friable	None	Well drained	-	Many fine fibrous root.	Prominent	Smooth
AB	15-40	Light brown 2.5YR 4/4	SCL	Medium granular	Very friable	None	Well drained	-	Few fine fibrous root.	Minimal	Wavy
Bt_1	40-90	Dark Reddish Brown 2.5YR 4/8	SCL	Strong sbk	Firm	None	Imperfectly drained	-	Common coarse tap root.	Nil	Wavy
Bt_2	90-160	Reddish grey 2.5YR 4/6	SCL	Moderate sbk	Firm	None	Imperfectly drained	Medium Red 2.5YR 4/6	None	Nil	Wavy
					Mid slope						
Ap	0-10	Brown 7.5YR 4/4	SL	Coarse granular	Very loose	None	Well drained	-	Many fine fibrous root	Prominent	Smooth
AB	10-50	Light reddish Brown 5YR 4/6	SCL	Moderate sbk	loose	None	Imperfectly drained	-	Few medium fibrous root	Minimal	Wavy
Bt_1	50-130	Light brown 5YR 6/6	SL	Moderate sbk	Friable	None	Imperfectly drained	-	None	Nil	Irregular
					Footslope						
Ap	0-10	Grayish brown 7.5YR 4/4	SL	Massive	None	Sticky	Poorly drained	Med. 7.5YR4/4	Many fine fibrous root	Nil	Irregular
Bg1	10-50	Very dark grey 10YR 5/4	SL	Massive (structureless)	None	Sticky	Very poorly drained	Distinct 10YR 5/4 Dark grayish Mottles.	Many fine fibrous root	Nil	Irregular

Table 2 shows the physical properties of the soils of the studied sites. Sand dominated the particle size fraction of the studied soils probably due to the influence of the parent material Coastal Plain Sand. The sand content varied moderately at the summit (CV=Sand= 30.0 %) compared to the sand content at the midslope(CV=Sand=26.2 %) and footslope (CV=Sand=13.3 %). The moderate variation of sand at the summit may be attributed to the influence of erosion and run off where the finer materials were washed down the slope leaving the larger grains. High sand content shows high infiltration rate and leaching (Osujieke *et al.*, 2017). However, the silt content varied highly at the footslope (Silt=CV=57.3 %) compared to the silt content at both the summit (Silt=CV=5.7 %) and midslope (Silt=CV=17.0 %) which had low variation. The high variation of silt content at the footslope may be attributed to the transportation of finer materials by the influence of erosion and runoff where finer materials are washed downwards into flatter area (Soil Survey Division Staff, 1993). The finer soils are able to travel further from the base of the slope to flatter areas. Clay content varied moderately at the summit (Clay=CV= 32.3%) and decreased down to the midslope and footslope (midslope=Clay=CV =31.8%; footslope=Clay=CV =17.8%). The moderate variation of clay at the summit could be due to the concentration of the clay minerals at the summit that had less weathering. Silt/Clay ratio had higher variation at the footslope (Silt/Clay=CV=73.5 %) compared to the silt/clay ratio at the summit (Silt/Clay=CV=42.1%) and midslope (Silt/Clay=CV=16.9%) possibly due to deposition of finer materials at the footslope. Moisture content (MC) at the footslope varied moderately (MC=CV=30.6%) when compared to moisture content at the summit and midslope with low variation of (MC=CV=upslope =15.1%; midslope=MC=CV= 12.8 %) probably due to the influence of topography. The footslope often receives sediments that are washed from the summit and midslope above.

The bulk density varied moderately at the footslope (BD=CV=24.0%) possibly due to the influence of land use. While at the summit and midslope, BD varied low (summit=BD=CV=11.8%), midslope (BD=CV=8.5 %). The lowest BD at the footslope shows that the soils were not compacted. Total porosity varied highly at the summit (TP= CV= 80.7%) compared to the footslope (TP= CV= 27.0%) possibly due to the dominance of sand grains at the summit. Sand gains in coarse textured soil contain dominance of macropores which allows rapid movement of air and water through such soil. This is also indicative of the lower bulk density at the summit.

Table 2: Physical properties of the studied location

	Horizon	Depth	Sand g/kg	Silt g/kg	Clay g/kg	Silt/Clay	MC g/kg	BD g/cm^3	TP %
Summit									
	Ap	0-15	691.2	217.6	91.2	1.30	98.0	1.48	44.0
	AB	15-40	439.2	217.6	343.2	0.60	104.9	1.73	35.0
	Bt1	40-90	399.2	244.6	356.2	0.70	121.6	1.30	51.0
	Bt2	90-160	385.2	230.6	384.2	0.60	399.6	1.48	45.0
	Mean		**478.70**	**227.60**	**293.70**	**0.80**	**181.03**	**1.50**	**43.75**
	CV		30.0	5.7	32.2	42.1	15.1	11.8	80.7
Mid slope	Ap	0-10	599.20	234.60	166.20	1.40	734.00	1.47	44.00
	Bt1	10-50	439.20	320.60	240.20	1.30	271.40	1.59	40.00
	Bt2	50-130	359.20	320.60	320.20	1.00	296.00	1.74	34.00
	Mean		**465.87**	**291.93**	**242.20**	**1.23**	**433.80**	**1.60**	**39.33**
	CV		26.2	17.0	31.8	16.9	12.8	8.5	60.0
Foot slope	Ap	0-10	699.20	117.60	183.20	0.60	111.20	1.76	34.00
	Bg1	10-50	579.20	277.60	143.20	1.90	163.70	1.25	52.80
	Mean		**639.20**	**197.60**	**163.20**	**1.25**	**137.45**	**1.51**	**43.40**
	CV		13.3	57.3	17.8	73.5	30.6	24.0	27.0

MC = Moisture content, BD = Bulk density, TP = Total porosity.
CV = Coefficient of variation, 0-15% low variation; 15-35% moderate variation 35% and above high variation (Wilding *et al.* 1994)

The chemical properties of the studied soils are presented in Table 3. Soils are strongly acidic. Exchangeable Ca and Mg varied highly at the footslope (CV= Ca=41.8%; CV=Mg= 83.2%) compared to Ca and Mg at the summit (Ca=CV=10.8%; Mg=CV=31.0%) and midslope (Ca=CV=5.8%; Mg=CV=39.5%) with low variation. The high variation of exchangeable Ca and Mg may be attributed to the movement of material along the slope downwards. Exchangeable Na had low variation in all the physiographic unit while exchange K had moderate variation at the summit (K= CV=32.3%), high variation at the midslope (K=CV=43.3%) probably due to the movement of materials from the summit to the midslope, application of inorganic fertilizers and other farming practices especially at the midslope (Miller and Donahue, 1995). However, at the footslope, exchangeable K was not detectable. Total Exchangeable Acidity (TEA) varied highly at the summit (TEA = CV = 51.3 %), moderately at the midslope (TEA= CV= 32.4 %) while at the footslope, total exchangeable acidity (TEA) had low variation (TEA=CV=7.9 %). The high variation of TEA at the summit may be attributed to intensive leaching of the exchangeable bases due to heavy rainfall prevalent in the area. The exchangeable bases must have been leached away from the exchange sites leaving the exchangeable H and Al ions (Miller and Donahue, 1995; Brady and weil, 2002). Base saturation (BS) varied highly at the footslope (BS= CV= 39.1 %) compared to the base saturation at both the summit (BS= CV= 26.6 %) and midslope (BS=CV=23.3 %). The high base saturation at the footslope was as a result of most of the basic nutrients moving down from the summit to the footslope in available form in the soil solution. Organic matter (OM) varied highly in all the soils studied but was higher at the midslope (OM=CV=94.6 %) compared to OM at the footslope (OM= CV= 50.3 %). The low concentration of OM at the footslope may be attributed to poor drainage condition at the footslope which may have lead to slow decomposition of organic materials at the footslope. Also, continous cultivation of soil at the footslope may have resulted to the decline of soil organic matter to lower equilibrium (Woldeamlak and Stroosnijder, 2003). However, the high OM at the midslope could be due to the use of inorganic fertilizer and transportation of nutrients from the summit to midslope. The total N (TN) varied highly in all the soils studied but was highest at the midslope (TN=CV=97.4%). The lowest value of TN was obtained at the summit probably due to the climatic condition resulting to leaching, continuous cultivation and high mineralization of organic substrates from crop resides added during intensive activation (Mc Donagh *et al.,* 2001).

Table 3: Chemical properties of the studied location

Physiographic Unit	Horizon	pH (KCl)	Ca	Mg	Na	K	TEB	TEA	ECEC	BS	OM	TN	Av. **P**
			cmol/kg							**%**	**g/kg**		**mg/kg**
Summit	Ap	4.76	2.08	0.81	0.073	0.01	2.98	0.88	3.86	77.2	28.96	1.20	7.63
	AB	4.46	1.80	1.58	0.082	0.02	3.48	2.80	6.28	55.4	9.96	0.50	4.20
	Bt1	4.19	1.84	1.24	0.108	0.01	3.20	4.12	7.32	43.7	8.24	0.31	3.99
	Bt2	4.84	1.60	1.76	0.104	0.01	3.47	3.80	7.27	47.8	7.89	0.27	2.66
	Mean	**4.56**	**1.83**	**1.35**	**0.09**	**0.01**	**3.28**	**2.90**	**6.18**	**56.03**	**13.76**	**0.57**	**4.62**
	CV	6.6	10.8	31.0	18.5	32.3	7.4	51.3	26.2	26.6	73.9	75.8	45.9
Midslope	Ap	4.73	1.40	1.04	0.09	0.02	2.55	2.32	4.87	52.40	23.72	1.12	6.30
	Bt1	4.23	1.52	0.84	0.10	0.01	2.47	4.52	6.99	35.30	5.50	0.20	1.05
	Bt2	4.82	1.36	0.44	0.10	0.01	1.91	3.36	5.27	36.20	4.80	0.18	0.56
	Mean	**4.59**	**1.43**	**0.77**	**0.10**	**0.01**	**2.31**	**3.40**	**5.71**	**41.30**	**11.34**	**0.50**	**2.64**
	CV	6.9	5.8	39.5	6.0	43.3	15.1	32.4	19.7	23.3	94.6	97.4	60.3
Footslope	Ap	4.74	1.00	0.28	0.09	0.00	1.38	3.80	5.18	26.60	13.75	1.09	1.89
	Bg1	4.82	1.84	1.08	0.09	0.00	3.01	3.40	6.41	46.90	6.53	0.32	1.12
	Mean	**4.78**	**1.42**	**0.68**	**0.09**	**0.00**	**2.19**	**3.60**	**5.79**	**36.75**	**10.14**	**0.71**	**1.51**
	CV	1.2	41.8	83.2	12.3	0.0	52.5	7.9	15.0	39.1	50.3	77.2	36.2

OM = Organic Matter, TN = Total Nitrogen, TEA = Total Exchangeable Acidity, TEB = Total Exchangeable Bases,
ECEC = Effective Cation Exchangeable Capacity, BS = Bases Saturation, Avail.p = Available phosphorus.
CV = Coefficient of Variation, 0-15% low variability; 15-35% moderate variation 35% and above high variation (Wilding, *et.al* 1994)

Available phosphorus (AP) was high in all the soils but was more at the midslope (AP=CV=60.2 %). The high available P at the midslope may be attributed to erosion which may have transported the clay and OM fractions of the soil which are rich in P fractions from the summit to the midslope thus, increasing the available P at the midslope. Also, the weathering of soil minerals, decomposition and rapid mineralization of soil OM, and commercial fertilizers may have increased the available phosphorus at both the summit and midslope. However the values of available P was lower at the footslope (AP =CV= 36.2%) possibly due to high P fixation capacity. This result is in line with Eshett (1987) who reported low phosphorus in most Nigerian soils due to high fixation of P.

CONCLUSION

The morphological characteristics of soils of the study area indicated that the soils were different in depths, colour, texture, structure, consistence. The soils of the footslope had poor drainage condition because of the presence of water within 50 cm of soil depth, massive structure. The physical and chemical properties were different in all the physiographic unit studied. Bulk density was moderate at the footslope, TP was highest at the summit, exchangeable bases (Ca and Mg) were high at the footslope. Exchangeable K had moderate variation at the summit, high variation at the midslope. Base saturation was high at the footslope and moderate at the summit and midslope. The use of organic manure as soil amendment, agroforestry, crop rotation and intercropping with legumes will be helpful in soils of the study area especially with the soils at the footslope which is characterized with poor nutrients due to poor drainage condition of the area.

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