Variability Evaluation of Selected Soil Properties in Three Locations in Oyo State, South West Nigeria

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Abstract

Studies were carried out on some soils derived from basement complex parent rocks in south-western Nigeria. The aim was to evaluate the variation in soil properties among the pedons on three locations as influenced by catenary position, the capability of the pedons and their limitations for arable crop production. A total of 14 soil types across three locations (Igbo-ora, Akinyele and Eruwa) all within the forest-savannah transition zone of south-western Nigeria were studied. Coefficient of variation was used to evaluate the levels of variability of the soil parameters while the influence of depth and physiography on the soil properties were determined by F-test ($P \leq 0.05$). Variations in clay, silt and sand were not significantly different among the locations. However, there was moderate to high variability in the soil chemical properties. Soil reaction was slightly or moderately acidic in all locations and the pH was the least variable (CV < 15%). Organic carbon showed high variability within and among the locations, Available P, Mg, K, and exchangeable acidity exhibited low to moderate variation. Total N and exchangeable acidity with CV values of 320% and 258% respectively were extremely variable. Physiographic position had significant effect on clay, sand and most of the soil chemical properties while soil depth significantly influenced clay, sand, gravel content, organic carbon and Mn. The high variability in the properties especially with physiographic positions suggests site specific management approach with careful consideration of catenary positions of individual fields for sustainable crop production.

Key words: Soil properties, Variability, Physiographic positions, Oyo state.

Introduction

Appropriate management and conservation of soil resources for now and posterity, is the central focus in sustainable land management. The dynamic processes in soils leading to degradation are the most limiting factors in soils of the humid and sub humid tropics. Tropical soils are experiencing a lot of pressure to meet the needs of the ever growing human population. Inappropriate land use could lead to an inefficient exploitation of its vast resources and may lead to degradation (Orimoloye, *et al*., 2007). It is estimated that nearly two billion ha of land worldwide – an area twice the size of China – are already seriously degraded, some irreversibly (TerrAfrica, 2005). Variability in soil properties has long been recognized especially in tropical soils due to variations in macro and micro flora and fauna (Jaiver *et al.,* 2010); differences in weathering rates, lithology, topographic differences and hydrological characteristics (Zebarth *et al.,* 2002) or variation in the human activities carried out on them (Akinbola *et al*., 2010). This has been identified as a challenge to accurate mapping and prediction of soils in terms of management and productive potentials (Ogunkunle, 1998; Ogunkunle, 2015). The spatial variation of soil properties can be significantly influenced by such factors as climate and landscape features including landscape position, topography, slope gradient, evolution, parent material, and vegetation (Ollinger *et al.,* 2002). Many studies have shown that topography influences local microclimates by changing the pattern of precipitation, temperature and relative humidity which in turn may significantly affect some soil parameters (Ata-Rezaei and Gilkes, 2005; Yimer *et al.,* 2006; Gonglanski *et al.,* 2008).Jing *et al.* (2014) noted that soil properties could exhibit variabilities with topographic pattern due to aspects of landscape position, difference in elevation and slope structure.

The basic detailed information on the spatial variability of soil properties in south western Nigeria (basement complex) and their properties are still largely lacking. Getting an adaptable package on appropriate land use and management has been difficult due to variation occurring in soils. A better understanding of the variability of soil properties and the influence of pedogenic factors such as physiographic position on soil properties enhance soil management practices and improved agricultural productivities. This will also promote sustainable land use and provide a valuable basis for decision on land use and management. This study was carried out therefore to evaluate the variations in the soil properties of some pedons in three locations on the basement complex of South west Nigeria, with special reference to their physical and chemical properties.

Materials and Methods

Description of the study sites

This study was carried out at three different sites within the forest savannah transition zone of south western Nigeria (Figure 1) between April 2012 and July 2014. Igbo-ora (Site I)is located at the out skirts of Igbo-Ora town in Ibarapa Central Local Government Area of Oyo State, 96 km west of Ibadan. Igbo-Ora has an area of 43.605 ha, defined between latitudes 7^{o} 26'43.9"N and 7^{o}27'15.0"N and longitudes 3^{o} 16' 20.3"E and 3^{0} 17' 09.4"E. Akinyele site (site II) is located in latitude 7^{0} 30' 30"N and longitude 3^{o}45'0"E and is within the surveyed area of the Ibadan North- East sheet 261 of the Federal surveyed topographic map of 1964 (Jones, 1964). The site is located in Akinyele L.G.A, Oyo state, Nigeria and covers an area of approximately 20 ha.The Eruwa study site (Site III) covering approximately 207 hectares, is located along Eruwa – Ibadan road in Ido Local Government Area of Oyo State. It is at latitudes 7^{o} 30'32"N and longitudes 3^{o} 30'35"E.

Climate of the study area

The rainfall distribution is bimodal, with the peak periods in May/June and September/October. The mean annual rainfall is between 1190 mm and 1342 mm (IITA, 2008). The mean daily maximum and mean daily minimum temperature of 32°C and 21°C respectively at the study area. Usually, afternoon temperatures fall as the rains advance, to 29°C or less by July and rises again towards the end of the year. Night temperature drops to 18°C in December and absolute minimum temperatures to 9°C. The cool weather around December – January is mainly associated with the effect of cold North East wind from the Sahara desert blowing across the country at the time of the year.

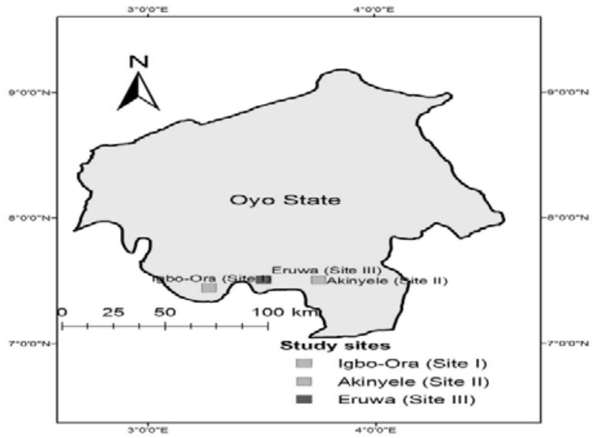

Figure 1: Map of Oyo State showing the study sites

Geology and physiography of the study area

The study area lies within the agro-ecological zone classified as Zone N described asvery humid Oyo-Ibadan-Ondo-Oka Plains (Ojanuga, 2006). The area is generally low lying with elevations in the three study sites ranging approximately between 110-250 m above the sea level. The sites have slightly to moderately undulating topography. The geology is made up of crystalline Basement Complex rocks. Many parts of the area could be classified as the Guinea slope category of the Niger-Guinea watershed (Ojanuga, 2006).

Field Survey and mapping of the sites

Soil samples used in this study were obtained when detailed soil survey was conducted at the three sites. Soil survey methods, soil descriptions and classification of the soils has been were done as described by Akinbola(1998) and Akinbola and Okafor (2012). The soil samples were obtained from genetic horizons of soil profiles at the upper slope middle slope and lower slope positions in the landscape. The soil samples were appropriately labelled and conveyed to the laboratory for treatment and analysis of the physical and chemical properties of the soils.

Laboratory analysis

The soil samples were air dried, crushed and sieved through a 2mm aperture size sieve. The gravel content (portion with particle size greater than 2mm in diameter), was calculated as a percentage of the total air-dried soil. The particle size fractions were determined by the modified Bouyoucos hydrometer method (Anderson and Ingram, 1993). The soil pH was determined in 1:1 soil:water ratio and by KCl using glass electrode pH meter with calomel electrode. Organic carbon was determined by Dichromate wet oxidation method of Walkley and Black (1934). Total nitrogen was obtained using the micro Kjeldahl method (Jackson, 1962). Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945); while exchangeable cations (Ca, Mg, K and Na) were extracted with neutral NH_4OAC. Potassium (K) and Sodium (Na) were measured through flame photometer, while Calcium (Ca) and Nagnesium (Mg) was determined by Atomic Absorption spectrophotometer (AAS). Exchangeable acidity was determined by 1N KCl extraction and titrated with 0.05N NaOH solution (Black, 1975). Effective Cation Exchange Capacity (ECEC) was calculated as the summation of the values of exchangeable cations and exchangeable acidity. The micro nutrients (Fe, Mn, Cu and Zn) were determined in 1N HCl and evaluated using the AAS (Jackson, 1962).

Statistical analysis

The soil analytical data obtained were subjected to statistical analysis using descriptive statistics to calculate the means, standard deviation, minimum and maximum (range). The standard deviation was used to calculate the coefficient of variation (CV %). The CV% was used to determine the extent of variation among the pedons. The level of variation was grouped into three (3) according to the standard set by Wilding and Drees (1983) which are least variable (CV< 15%), moderately variable (CV = 15 – 34%) and highly variable (CV> 35%). Two way analysis of variance (ANOVA) for soil properties among physiographic locations and soil depth was carried out while significant means were compared using LSD at α = 0.05using the Genstat 12 software (version2.0) (VSNI, 2010)

Results

The influence of physiography and soil depth on soil properties

Table 1 shows the influence of physiography and soil depth on soil physical properties. The particle size distribution analysis indicates significant difference (P< 0.05) in clay content at the physiographic position with highest clay content of 312.0 g kg^{-1} and245.0 g kg^{-1}occurring at the upper slope and the middle slope respectively, and lowest clay content was observed at valley bottom (212.0 g kg^{-1}). Significant difference also occurred in sand content at the physiographic positions with highest amount of sand content being observed at the middle slope followed by the valley bottom while the upper slope has the least value. Sampling depths significantly influenced the clay contents. The highest clay content occurred at the 60-90 cm depth, while the lowest was at 0-30 cm soil sampling depth. Sand and gravel were significantly affected by depth with highest point of accumulation occurring at 0-30 cm and 30-60 cm respectively while the lowest values occurred at depths of 60-90 cm and 90-120 cm respectively, silt content was not significantly influenced by depth. Interaction between physiography and soil depth were significant with respect to soil particle size distribution.

The soil chemical properties of total nitrogen and exchangeable acidity were not significantly influenced by physiographic position while pH, Organic Carbon, Available P, Na, Mg, Ca, K, ECEC, Fe, Mn, Cu, and Zn were significantly affected by physiography (Table 1). With respect to depth, organic carbon and Mn accumulation occurred mostly at the surface within the depth of 0 - 30 cm while the lowest values of 5.40 g kg^{-1} and 60 mg kg^{-1} were found to occur at depths of 60-90 cm and 90-120 cm respectively. Apart from organic carbon and Mn which were significant, other parameters such as pH, Total N, Available P, Na, Mg, Ca, K, Exchangeable Acidity, ECEC, Fe, Cu and Zn were not significant with depth (Table 1).

Table 1: Influence of physiography and soil depth on soil physical and chemical properties.

	Ph	Total N	OC	Available P	Exchangeable Cations						Extractable Micronutrients				Particle Size			
					Na	Mg	Ca	K	EA	ECEC	Fe	Mn	Cu	Zn	Clay	Silt	Sand	Gravel
	(H_20)	g kg^{-1}		mg kg^{-1}	cmol kg^{-1}						mg kg^{-1}				g kg^{-1}			
Physiography (P)																		
Upper slope	6.3	6.6	17.0	26.4	0.8	3.3	9.2	1.1	3.0	14.6	103.0	135.0	4.0	9.0	312.0	156.3	530.0	441.0
Middle slope	6.1	0.6	6.3	3.7	0.8	2.5	4.5	0.7	5.5	8.8	86.0	83.0	2.0	5.0	245.0	108.8	646.0	422.0
Valley bottom	6.9	0.8	8.2	5.2	1.7	4.0	5.3	0.7	0.3	11.8	153.0	65.0	2.0	4.0	212.0	143.0	645.0	263.0
LSD	0.7	Ns	6.5	18.6	0.7	0.8	4.1	0.2	ns	4.6	50.0	59.0	1.0	3.0	83.7	ns	110.7	ns
Depth (D)																		
0-30	6.4	1.6	19.0	14.4	0.8	3.3	8.5	0.8	3.3	13.7	149.0	149.0	3.0	7.0	140.0	162.4	698.0	291.0
30-60	6.4	1.1	11.0	14.1	1.0	2.9	5.6	0.8	2.1	10.6	111.0	94.0	3.0	6.0	257.0	125.8	618.0	495.0
60-90	6.2	6.1	5.4	4.4	1.2	3.3	6.0	0.9	5.2	11.7	99.0	74.0	2.0	6.0	344.0	118.0	535.0	440.0
90-120	6.7	1.8	6.6	14.2	1.4	3.4	5.1	0.8	1.1	10.9	97.0	60.0	3.0	6.0	283.0	138.0	579.0	274.0
LSD	Ns	Ns	7.5	Ns	ns	ns	ns	Ns	ns	Ns	ns	69.0	Ns	Ns	96.7	ns	127.9	210.0
D x P	Ns	Ns	ns	Ns	ns	1.6	ns	0.5	ns	9.1	99.9	Ns	2.4	Ns	167.4	95.65	221.5	363.7

D- Depth, P- Physiography x- interaction, Na –Nitrogen, Mg-Magnesium, Ca- calcium, K-potassium, EA- Exchangeable Acidity, ECEC- Effective Exchangeable Cation Capacity, P-phosphorous, N- nitrogen, OC - organic carbon, Fe- Iron, Mn- Manganese, cu- Copper , ns- not significant.

Descriptive statistics of soil properties of the three locations

Table 2 shows the summary of descriptive statistics of soil properties across the three locations. When all the pedons were pooled to know the level of variability within the soil properties across the three sites, soil pH (15.6) was the least variable when compared with others soil parameters. Sand had moderate variation while clay (50.3%), silt (52.3%), organic carbon (95.5%), available P (198.7%) had high variation, Exchangeable cations (Ca, Mg, K) and Exchangeable Acidity (EA) showed moderate to high variability but total nitrogen (320%) was extremely variable.

Table 2: General descriptive statistics of soil properties at the three soil locations

Parameters	Range	Mean ±SD	CV%
Particle Size (g kg^{-1})			
Clay	34.0–554.0	256.1±128.7	50.3
Silt	20.0–300.0	136.1±71.7	52.3
Sand	352.0–912.0	607.3±137.6	22.7
pH (H_2O)	3.9–8.7	6.4±1.0	15.6
Organic Carbon	0.8–43.6	10.5±10.0	95.5
Avail. P (mg kg^{-1})	0.7–92.5	11.8±23.4	198.7
Exchangeable Cations (cmol kg^{-1})			
Ca	0.1–25.0	6.3±6.4	101.6
Mg	0.5–8.1	3.2±2.6	79.6
K	0.1–2.1	0.8±0.7	90.2
Na	0.3–4.8	1.1±0.9	77.9
EA	0.1–32.9	2.9±7.6	258.6
Total N (g kg^{-1})	0.1–50.4	2.6±8.4	320.0

SD- Standard deviation, CV- coefficient of variation, Na -Nitrogen, Mg-Magnesium, Ca-calcium, K-potassium, EA- Exchangeable Acidity, P-phosphorous, N- nitrogen

Variability of soil properties in the three locations

The descriptive statistics of the soil properties at Igbo-ora, Akinyele and Eruwa are shown in Table 3. At Igbo-Ora, clay and silt fractions were 261.5 and 109.0 g kg^{-1}respectively. Sandcontent hadthe highest mean of 627.8 g kg^{-1} at Igbo-ora and the lowest mean 590.3 g kg^{-1} at Eruwa. Bases (Ca, Mg, K and Na) also showed high variation at Igbo-Ora with the CVs of140.8, 71.9, 110.5 and 102.9% respectively. The soil textural parameters such as sand, silt and clay across the three locations showed moderate to high variations with CV ranging from 20.5% to 66.7%. Generally, higher variations are exhibited by clay while the sand fractions tended to be more homogenous. Also, Eruwa site showed higher variability in soil textural properties than Igbo-Ora and Akinyele sites. Soil pH was generally less variable inall locations

Table 3: Descriptive statistics of the soil properties at the three study sites

Parameters	Statistics	Locations		
		Igbo-ora	Akinyele	Eruwa
Particle Size (g kg^{-1})				
Clay	Means	261.5	208.8	298.0
	SD	128.1	88.7	155.1
	CV%	49.0	42.5	52.0
Silt	Means	109.0	187.5	111.7
	SD	47.4	64.9	74.4
	CV%	43.5	34.6	66.7
Sand	Means	627.8	603.7	590.3
	SD	129.0	130.4	160.7
	CV%	20.5	21.6	27.2
pH (H_2O)	Means	6.9	6.6	5.83
	SD	1.2	0.3	1.01
	CV%	17.5	4.7	17.3
Organic Carbon (g kg^{-1})	Means	13.4	10.7	7.42
	SD	14.4	8.6	4.34
	CV%	107.5	80.3	58.5
Available P (mg kg^{-1})	Means	24.4	2.5	8.46
	SD	38.1	2.9	1.07
	CV%	156.0	117.0	12.64
Exchangeable Cations (cmol kg^{-1})				
Ca	Mean	5.5	1.6	11.8
	SD	7.7	2.4	2.6
	CV%	140.8	149.1	22.1
Mg	Mean	1.9	1.3	6.5
	SD	1.4	0.8	0.9
	CV%	72.0	63.6	13.9
K	Mean	0.4	0.3	1.8
	SD	0.4	0.2	0.2
	CV%	110.5	75.0	11.2
Na	Mean	1.4	1.1	0.8
	SD	1.4	0.2	0.1
	CV%	102.9	19.3	17.3
EA	Mean	8.2	0.4	0.2
	SD	11.7	0.2	0.1
	CV%	143.1	36.6	0.4
Total N (g kg^{-1})	Mean	6.3	0.9	0.8
	SD	14.3	0.5	0.1
	CV%	226.3	52.9	17.3

SD- Standard deviation, CV- coefficient of variation, Na –Nitrogen, Mg-Magnesium, Ca-calcium, K-potassium, EA- Exchangeable Acidity, P-phosphorous, N- nitrogen.

than other soilchemical parameters. Variability of organic carbon was higher at Igbo-Ora (CV = 107.5%) and Akinyele (CV = 80.3%) but least in the Eruwa site (CV = 58.5%). Available P showed very high variations with CV >100% at Igbo-ora and Akinyele sites but have moderate variability at Eruwa. Exchangeable cations and total nitrogen showed very similar trends of variability in the study locations as the available P. The contents of Na, Exchangeable acidity (EA representing the summation of H+ and Al^{3+}) and total nitrogen also varied significantly with the three soil locations.

Discussion

Medium to high degree of vertical and horizontal variations in the properties of the pedons were observed in all the sites studied. The observed variations in the soil properties within and among the pedons can be attributed to structural factors such as rock weathering, soil type, parent materials, topography and micro-relief (Jing *et al*., 2014; Wilson *et al*., 2016).

Generally, the coefficient of variation (CVs) for all the variables in the sites were different and non-uniform, thus the assumption that soils derived from same parent material within relatively close proximities are uniform in their properties, which informs the use of blanket fertilizer recommendation, is invalid. Collins (2014) stated that variability within a single field can be large. This has implications for crop production since soil variability will lead to variation in crop performance. The variations in soil pH were moderate whileclay, silt, organic carbon, available P, Exchangeable cations (Ca, Mg, K Na) and exchangeable acidity were moderate to high in variation, but total nitrogen was extremely variable.

The pattern in Igbo-ora, showed that clay and silt had high variation maybe as a result of removal, transportation and deposition of these fine weathered materials down the slope. However,the moderate variation observed in sand fraction could be due to higher mass and size of the sand fractions that made them less eroded than clay and silt (Loescher *et al.,* 2014). Soil pH and sand were the least variable whereas, organic carbon and available P were highly variable. This may be due to land management or differential accumulation of nutrient resulting from application ofphosphate fertilizers. Ghuman and Sur (2001) reported that conventional tillage under arable farming enhances rapid mineralization of organic materials. This may have resulted in the high variations observed in organic carbon, available P, Ca, Mg, K, Na, Exchangeable Acidity and total nitrogen. The influence of topography and land use could affect the availability and distribution of soil pH which in turn could result in high nutrient variability in soils. Ndukwu *et al.* (2013) observed increase in exchangeable bases in soils as a result of animal manure accumulation on the soil surface.

Differences in land use and catenary formations at Igbo-ora, Eruwa and Akinyele might have influenced the pattern of variability in soil properties in these locations.Soil pH and sand had moderate variation while other parameters showed higher variation with total nitrogen being extremely variable.At Akinyele with a more undulating terrain; clay, silt and sand had moderate to high variations.The reasons could be attributed to the rate of removal, transportation and deposition of fine materials down the slope by agents of denudation.Loescher *et al.* (2014)

confirmed the influence of topography on soil physical properties. Soil pH ranged from levels indicating moderate to near neutral and showed the least variation across the three locations. Organic carbon, available P, exchangeable Ca, Mg, K,acidity and total nitrogen were highly variable in the pedons and this could be associated with differences in soil types, parent materials, land use, accumulation of materials (Ye *et al*., 2016).While silt, Na, and sand showed moderate variation at Akinyele, Ca was extremely variable. This could be attributed to the presence of mineral nutrients in the soil probably as a result of closer relationship to its feldspar rich parent rock materials. This suggests that soil in Akinyele is constantly supplied by basic cations.Base saturation is consistently high in the soils suggesting that basic cations dominated the exchange complex (Orimoloye, *et al*., 2007) and also it indicates presence of high colloidal materials in the soil.

The pattern of variation in soil particle fractions (clay, silt and sand), organic carbon and Exchangeable Acidity at Eruwa showed that the soil has high variation as a result exogenous factors such as weathering of the parent materials and topography, High organic matter accumulation, rainfall (acid), and tillage perhaps predisposed the soil to erosion (Sanchez *et al*., 2003). The soil pH ranged from strongly acidic to strongly alkaline with moderate variation, this has both direct and indirect influences on the chemical properties of the soils. Such variation in soil reactions can be attributed to differences in location, hydrological regimes, lithological origins and climatic conditions (Akamigbo, 2001). The consequence of this is that, they could be very rich or very poor in plant nutrients (Jaiver*etal*., 2010). Soil pH, Ca, Na and Total Nitrogen were moderate in variation while Available P, Mg and K were the least variable, probably induced by tillage, non-uniform management practices, geology and climate (Zhang *et al.*, 2006).

There was a remarkable change in variation pattern when the pedons on each of the sites were grouped together compared to the trend in variability when one site is considered separately. It was observed that pH, organic carbon, Ca, Mg, k, Na and Exchangeable Acidity were the least variable in each site, while Available P was between low to moderate in variation but clay, silt, and sand exhibited high variation in each of the sites. This variation could be due to original composition of the parent materials as observed by Akamigbo (2001). Obi and Akinbola (2009) also noted that differences in lithology (parent materials), topography and Landuse management practices could lead to wide variations in soil properties. This buttresses the differences in soil properties and the existences of soils of different taxonomic classes occurring from the crest to the valley bottom of toposequences in South Western Nigeria (Ogunkunle, 2015; Olatunji and Ewetola, 2015).

Studies have shown that soil variability is likely to increase the number of samples within a given area (Loescher *et al*., 2014). So, when all the pedons in the three sites were pooled together to estimate the degree of variation of the soil properties across the threesites, it shows that there was high degree of variation across the sites with some properties more variable than others. The high level of variation observed could be attributed to soil management practice employed in the different sites. Zebarth *et al.* (2002) noted that human-induced changes in soil can fundamentally alter the natural pattern of soil distribution in landscape even over relative short time scales. Although variation was observed in the three sites, the observed differences were significant among some mapping units and not significant in others when the means of the soil properties in each pedons were compared with one another at ($p<0.05\%$).Across the sites, clay, silt, sand, pH, organic carbon, Mg, K and Na were not significantly different from each other but Ca, Available P, Exchangeable Acidity, Total N showed significant differences in their means within the pedons.

The influence of physiography and soil depth on soil physical properties indicates significant difference in clay and sand content due to physiographic positions with highest accumulation occurring at the upper and middle slope respectively. This can be attributed to the removal, transfer and deposition of finer materials (clay illuviation) down the slope by subsurface drainage and surface runoff (Foth, 1990). There were no significant differences in silt and gravel content with physiography reason may be as a result of inherently low silt formation in the weathering process due to the original composition of the lithology or parent materials (Akamigbo, 2001). Clay, sand and gravel contents were all significantly influenced by depth while silt was not. This is probably due to pedogenic factors of illuviation, transformations and movement within the soil column. Interactions between physiography and depth were significant with respect to soil particle size fractions. Soil genesis, anthropogenic influences, farming activities, erosion and parent materials may be contributing factors.

The influence of physiographic position and soil depth on soil chemical properties revealed that there is significant difference in pH, organic carbon, Available P., Na, Mg, Ca, K, ECEC, Fe, Mn, Cu, and Zn due to physiography. Organic matter accumulation due to leaf litter, cropping pattern and land management history could have influenced the distribution of soil chemical properties (Ollinger *et al.,* 2002; Macedo *et al*., 2008; Otite, 2014). Physiography did not significantly influence total Nitrogen and Exchangeable Acidity probably because many nutrients are subject to leaching as a result of management practices, geology and climate irrespective of topographic positions (Zhang *etal.*, 2006).There were significant differences in organic carbon and Mn as affected by soil depth but pH, Total Nitrogen, Available P, Na, Mg, Ca, K, Exchangeable Acidity, ECEC, Fe, Cu and Zn were not significant with depth. Significant interactions between depth and physiography were observed in Mg, K, Fe and Cu possibly as a result of leaching of materials, continuous cropping, anthropogenic factors, erosion and land management. According to Katyal *et al.*(2001), a decline in organic matter leads to a significant decrease in the availability ofmicro-nutrients such as Zn, Cu, Mn and Fe. Long-term fertilizer experiments had established positive relationships between soil organic matter and availability of micronutrients (Macedo*et al.*,2008). Certain land use patterns with the management of organic residues can lead to build-up or depletion of micronutrients and general soil fertility indices (Ye *et al*.,2014).

Conclusion and Recommendations

Variability of the soil properties in the pedons located in the three sites studied showed that the soil properties vary both as a result of topographic position and the depths. Soil pH was the least variable while sand was moderately variable but clay, silt, organic carbon, Available P, Ca, Ma, K, Na, Exchangeable Acidity and total N were highly variable. Total N and Exchangeable Acidity were not significantly affected by physiographic position while soil depth significantly affected Organic Carbon and Mn; but soil depth and physiography interaction significantly affected pH, Mg, K, ECEC, Fe and Cu. The soils have the capability for profitable crop production under proper management. To achieve optimum crop production, the use of each soil type and its resources according to their capabilities should be encouraged while site specific measures should be adapted in managing the soils. The following measures could be recommended for soils of these area:

i. Shallow rooted crops should be cultivated around the upper slopes where soil depth is limiting.
ii. Since surface textures of the soils tend to be sandy and/ or loamy sands, soil conservation measures such as mulching, cover cropping and contour ploughing/ridging should be adopted to check erosion and siltation of dams/water bodies.
iii. In addition to site specific soil fertility management, the use of organic fertilizers that can improve both physical and chemical properties of the soils would be most appropriate in this area.

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