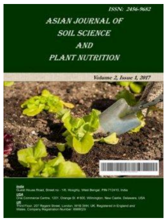

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Variation in Soil Physical and Chemical Properties as Affected by Three Slope Positions and Their Management Implications in Ganye, North-Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAG designed the study, carried out the field and laboratory work, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HJP and RIS managed the analyses of the study. Author EEO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Understanding topography or slopes, identifying physical and chemical properties of soils improves greatly informed management decisions for agricultural productivity. The study on variation of some physical and chemical properties of soils as affected by slope positions was aimed at providing critical fertility status of the soils. Farmers have complained of reduced output from their farm lands due to leaching activities and erosion hazards. Slope positions were delineated using the Geographic Information System (GIS) and 3 different slope positions were identified (SP1, SP2 and SP3), and each slope position was recognized as a unit. Three (3) profile pits were dug in each unit located at Kugon (SP3), Timdore (SP2) and Sammeri (SP1) respectively. Soil samples were collected in each identified soil horizon of the pits and soil samples were collected for

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laboratory analysis of some physical and chemical soil properties and One-way analysis of variance was carried out using GraphPad Prism (2007) software, version 5.0 at $p<0.05$. Soils were slightly acidic to neutral and predominantly sandy in nature (81.00%). The study revealed that slope position influenced water holding capacity and water retention in and were significantly different. Soil chemical properties were not significantly affected by slope positions. The soils were low in nitrogen (0-0.15%), organic carbon (<1%), while AV-P were generally rated medium (10-20), high Ca^{2+} (>5) at the Bt horizon, Mg^{2+} (>1) and %BS were rated medium to high (50-80, >80) regardless of slope position and are considered fertile with high potential to support agriculture. Good and improved management practices like use of organic material and integrated nutrient management (INM) practice will improve the soil texture and structure; reduce leaching activities and erosion hazards in the area.

Keywords: Horizon; slope position; erosion hazards; leaching; pedon.

1. INTRODUCTION

Soil is a natural body that exist in dynamic equilibrium with factors of soil formation and plays an important role in supplying plants with the essential nutrients required for crop's growth, development and yield. Therefore, it is expedient to determine soil physical and chemical properties for fertility analysis as influenced by factors and processes of soil formation. These factors and processes of soil formation at different developmental stages causes variations in soil physical and chemical properties as well as the thickness and composition of soil horizon at different slope position on a landscape. Soil properties are affected at different levels as parent materials are eroded from the upper slope leaving coarser sand and leaching activities. The lower slopes is influenced by deposition and accumulation of nutrient elements and water eroded due gradient. This action is continues and bring about variations in the soils over a period of time.

Farmers are beginning to crop on marginal lands including farming on slopes in many tropical countries. It is important to know that different soils occur at different positions on the landscape [1]. This various positions can have effect on yield of crops. Depending on the location on a slope, physical and chemical properties of soil will also vary either minimally or maximally. 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.

Slope gradient is the angle of inclination of the soil surface from the horizontal. It is expressed in percent, which is the number of feet rise or fall in 100 feet of horizontal distance. Erosion would normally be expected to increase with increase in slope length and slope steepness, as a result of respective increase in velocity and volume of surface runoff. The spatial variation of soil properties is significantly influenced by some environmental factors such as climate, landscape features, including landscape position, topography, slope gradient and evolution, parent material, and vegetation [2]. It is common knowledge that topography influences local microclimates by changing the pattern of precipitation, temperature and relative humidity [3] and significantly affects some soil parameters.

In the course of soil formation the chemical composition of a soil-forming rock changes. Some substances are carried (washed) out of its thickness, included into (enveloped with) a soil formation, while others are accumulated. In the course of soil formation, accumulation of a substance is accounted for by inflow of organic substance of plant and animal residues into a soil as well as from the hydrosphere (easily soluble salts, gyps, carbonates of alkaline and alkali-earth metals, compounds of iron, earth silicon, coming from groundwater) and the atmosphere (dust particles of different sizes and composition, compounds, being contained in the atmospheric precipitation). Outflow of substance from soil can take place with downward and lateral water flows in the soil, removal of soil particles from its surface with water and wind flows. A ratio between the substance accumulation and removal determines the balance of soil formation [4].

On the earth's surface, a soil-forming process takes its course under the influence of a great diversity of combinations of the soil-forming factors that result in a diversity of the soil formation types and respective soils. At the same time, the same processes are repeated in different soils, and they are essentially of the same quality, but different by their intensities and in details of their manifestation. As an example of such processes can be accumulation of humus, occurring in all soils, though at different qualitative and quantitative levels. Another example can be the process of desalting, that is; an outflow of easily soluble salts with downward water flows from the profile of an initially salted soil. It is important to underline that these processes are specific soil processes.

Such processes, common for different types of soil formation, are termed as elementary soil-forming processes (ESP). These processes are complicated in their nature, and the notion “elementary” should not be interpreted as ‘simple’. At present, the list of these processes cannot be considered a final one as well as the methodology and criteria for separation of the soil-forming processes. At present, several tens of elementary soil-forming processes are identified. All their variety is divided into several groups according to the balance of substances, determined by these processes, and to qualitative composition of compounds, which are results of manifestation of these processes [5].

Farmers in the study area are experiencing reduction in productivity of the soils in terms of yields, nutrient decline and losses over the years; and this is not unconnected to erosion hazards. Furthermore, increase in leaching activities might have resulted in lower yields due to heavy rains. This study evaluates some physical and chemical properties of soils of the study area, aimed at improving soil condition and performance in terms of yields for the farmers and generates data on the soils which will inform best agronomic practices for sustainable agricultural production. This is crucial due to its importance in reducing environmental degradation and help use land resource in an eco-friendly manner.

2. MATERIALS AND METHODS

2.1 Location and Extent

The study was carried out in Ganye Local Government Area, Southern Part of Adamawa State, Northeast Nigeria. The study area is located between Longitude 11° 50’0”E and Latitude 8° 20’ 0”N to Longitude 12° 10’ 0”E and Latitude 8° 30’ 0”N, covering a total area of 7, 452.58 hectares (Fig. 1). The study area is within the northern guinea savannah zone which is characterized by tall grasses with few trees and many shrubs. Temperature in this region is high throughout the year because of the high radiation influx which is relatively, evenly distributed throughout the year. Seasonal change in temperature occurs in this region. There is a gradual increase in temperature from February to May, the maximum usually occur in April/May and drops at onset of rains due to cloudiness. Maximum temperature in the state can reach 40°C with the mean monthly range of 26.70°C in the north eastern part [6].

2.1.1 Field work and sample collection

Slope positions were delineated using the Geographic Information System (GIS) where 3 different slope positions were identified (SP1, SP2 and SP3) and each slope position was recognized as a unit. Three (3) profile pits were dug in each unit located at Kugon (SP3), Timdore (SP2) and Sammeri (SP1) respectively. Soil samples were collected in each of the identified soil horizon of the pits dug, placed in well labelled polythene bags as described by the Soil Survey Field and Laboratory Methods Manual [7].

2.1.2 Preparation of soil samples

Soil samples collected from the field were air-dried at room temperature, crushed and passed through a 2mm sieve after a carful removal of plant parts and other unwanted materials for some soil physical and chemical analysis in the laboratory as described by the Soil Survey Field and Laboratory Methods Manual [7].

2.1.3 Laboratory analysis

Bouyoucos hydrometer method was used to determined particle size distribution in the Laboratory by as described by [8]. Soil Textural Class was determined using USDA textural triangle [9], bulk density was determined using the cylindrical metal core sampler method according to the [10], Particle density was determined by the use of graduated cylinder method as described by International Center for Agricultural Research in the Dry Areas [11], soil sample clods were collected in the field and water retention was determined as described by the Soil Survey Laboratory Information Manual [12]. The result of particle size distribution was used to determine soil textural

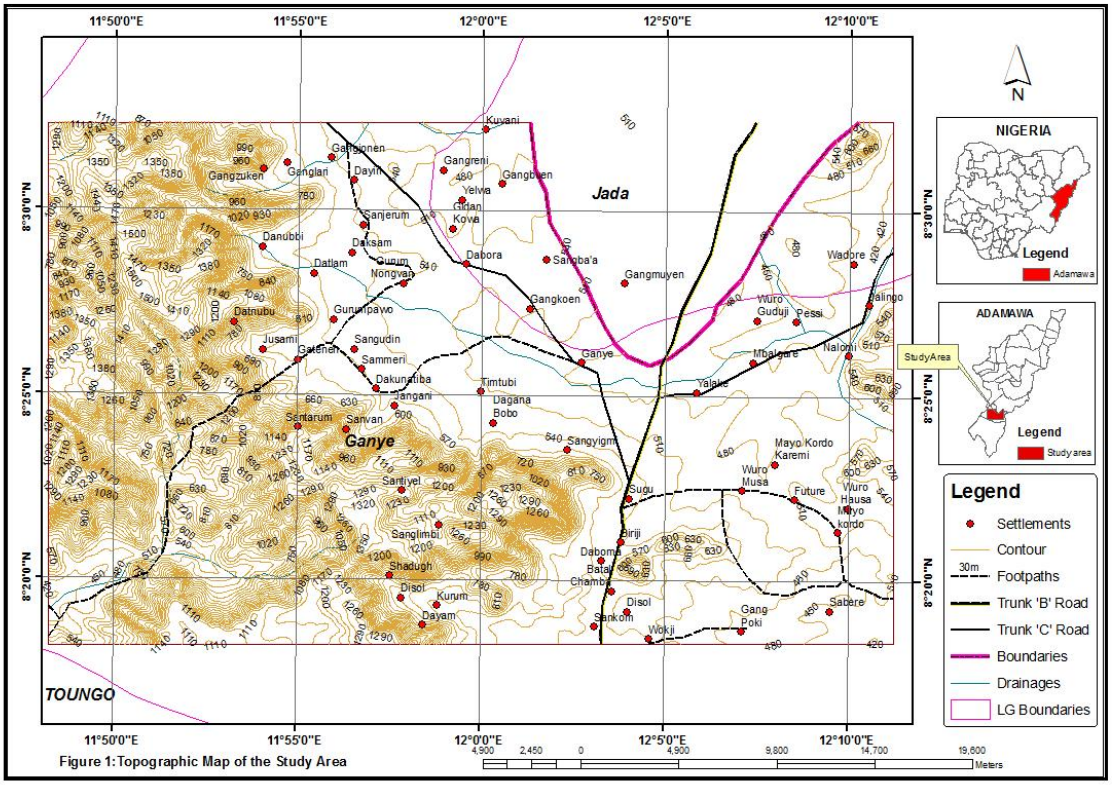

Fig. 1. Map of the study area

class by subjecting the results of the particle size distribution to Marshall's Textural Triangle as described by the Soil Survey Laboratory Information Manual [12] and Soil moisture content was determined by the gravimetric method as described by the Laboratory Testing Procedure for Soil and Water Sample Analysis [13].

Soil pH was determined by the use of Electrode method. Electrical conductivity (EC) was determined as described by the Soil Survey Field and Laboratory Methods Manual [7], Titration method was used to determine Extractable acidity, Total Nitrogen was determined using Sulphuric Acid (H_2SO_4), concentrated (98%, sp. gr. 1.84) and Potassium Permanganate Solution ($KMnO_4$) as described by International Centre for Agricultural Research in the Dry Areas [11]. Available Phosphorus was determined by extraction method using Spectrophotometer, Base saturation was determined by Sum of NH_4OAc Extractable Bases + 1N KCl Extractable method as described by the Soil Survey Laboratory Information Manual [12].

2.1.4 Data analysis

Result from the laboratory analysis of some soil physical and chemical test were subjected to descriptive statistical analyses and One-way analysis of variance (ANOVA) was carried out using [14] software, version 5.0 at $p<0.05$ to test for difference between the slope positions. Means were separated using Bonferroni's Multiple Comparison Test.

3. RESULTS AND DISCUSSION

3.1 Particle Size Analysis

The result showed %sand, %slit and %clay did not vary significantly at $p<0.05$ (Figs. 2 3 and 4). Pedon SP1 showed %sand decrease with depth ranging between 81% to 69%, %Silt varied with increase in depth within the profile however and %clay increased with increase in depth. The textural class of pedon SP2 showed 0-14 cm depth were loamysand while, sandyloam dominated the lower horizons. Pedon SP3 indicated %sand at the surface were 71% (0-13 cm) while %silt and %clay recorded 24% and 5% (Table 1) respectively.

Table 1. Some physical properties of soils of the study area

Pedon	HD	Depth (cm)	%Sand	%Silt	%Clay	Txs classes	B.D (g/cm^3)	P.D (g/cm^3)	Porosity (%)	WHC (%)	WR (%)
SP1	Ap	0-10	81	16	3	LS	1.51	2.63	42.59	0.27	7.91
SP1	E	10-18	77	20	3	LS	1.71	2.52	32.14	0.24	8.18
SP1	Eg	18-29	77	18	5	LS	1.68	2.39	29.71	0.24	8.14
SP1	Bt	29-51	71	14	15	SL	1.51	2.62	42.37	0.27	8.17
SP1	C	51-110	69	10	21	SCL	1.46	2.51	41.83	0.26	8.15
		Mean	**75**	**15.6**	**9.4**		**1.57**	**2.53**	**37.73**	**0.26**	**8.11**
SP2	Ap	0-14	77	20	3	LS	1.66	2.53	34.39	0.21	14.25
SP2	E	14-26	75	18	7	SL	1.63	2.6	37.31	0.2	13.34
SP2	Bt	26-40	73	16	11	SL	1.56	2.61	40.23	0.19	13.33
SP2	C	40-100	71	18	11	SL	1.55	2.61	40.61	0.19	13.11
		Mean	**74**	**18**	**8**		**1.6**	**2.59**	**38.14**	**0.2**	**13.51**
SP3	Ap	0-13	71	24	5	SL	1.68	2.48	32.26	0.18	11.57
SP3	E	13-25	79	16	5	LS	1.69	2.39	29.29	0.15	13.16
SP3	Bs	25-49	61	20	19	SL	1.46	2.59	43.63	0.24	13.12
SP3	Bt	49-63	59	22	19	SL	1.45	2.61	44.44	0.22	13.14
	C	63-105	77	2	21	SCL	1.45	2.63	44.11	0.23	13.21
		Mean	**69.4**	**16.8**	**13.8**		**1.55**	**2.54**	**38.75**	**0.2**	**12.84**

Source: Field Survey, 2015

Key: HD = Horizon Designation, Txs Cls = Textural Class, BD = Bulk Density, PD = Particle Density, WHC = Water Holding Capacity, WR = Water Retention

Table 2. Some chemical properties of soils of the study area

Pedon	HD	Depth (cm)	pH H_2O	EC (dS/m)	O.C (%)	TN (%)	AV-P (ppm)	Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}	TEB	TEA	ECEC	BS (%)
								←			cmol/kg			→	
1B	Ap	0-10	6.42	0.16	0.74	0.07	10.89	2.40	3.20	0.20	0.50	6.40	1.60	8.00	79.89
1B	E	10-18	6.31	0.15	0.49	0.05	12.33	2.80	1.84	0.30	0.50	5.50	2.00	7.50	73.24
1B	Eg	18-29	7.10	0.07	0.68	0.07	11.13	1.60	3.20	0.20	0.80	5.80	0.80	6.60	87.85
1B	Bt	29-51	6.88	0.06	0.63	0.06	11.13	3.20	1.04	0.10	0.30	4.70	1.20	5.90	79.59
1B	C	51-110	6.38	0.08	0.58	0.06	12.80	2.48	1.60	0.30	0.40	4.80	2.40	7.20	66.44
		Mean	**6.62**	**0.10**	**0.62**	**0.06**	**11.65**	**2.49**	**2.18**	**0.22**	**0.50**	**5.44**	**1.60**	**7.04**	**77.40**
2B	Ap	0-14	6.58	0.10	0.59	0.06	12.80	1.60	4.00	0.30	0.40	6.20	2.40	8.60	72.16
2B	E	14-26	6.21	0.09	0.52	0.05	11.37	1.28	4.00	0.30	0.60	6.10	3.20	9.30	65.61
2B	Bt	26-40	6.10	0.09	0.32	0.03	11.13	4.80	2.40	0.40	0.30	8.00	1.60	9.60	83.28
2B	C	40-100	6.58	0.10	0.60	0.06	13.28	2.40	2.80	0.20	0.30	5.80	2.40	8.20	70.55
		Mean	**6.36**	**0.095**	**0.51**	**0.05**	**12.15**	**2.52**	**3.30**	**0.30**	**0.40**	**6.53**	**2.40**	**8.93**	**72.90**
3B	Ap	0-13	6.65	0.10	0.50	0.05	14.24	2.40	1.60	0.20	0.80	5.00	2.80	7.80	63.96
3B	E	13-25	6.32	0.10	0.66	0.07	12.09	2.40	5.60	0.30	0.30	8.60	2.00	10.60	81.08
3B	Bs	25–49	6.12	0.12	0.57	0.06	10.65	1.52	3.20	0.20	0.60	5.50	0.80	6.30	87.27
3B	Bt	49-63	6.20	0.09	0.46	0.05	14.00	5.60	2.40	0.50	0.50	9.00	1.20	10.20	88.28
	C	63-105	6.34	0.08	0.67	0.07	13.28	0.80	4.00	0.30	1.10	6.30	1.20	7.50	83.95
		Mean	**6.33**	**0.10**	**0.57**	**0.06**	**12.85**	**2.54**	**3.36**	**0.30**	**0.66**	**6.88**	**1.60**	**8.48**	**80.91**

Source: Field Survey, 2015

Key: HD= Horizon Designation, EC= Electrical Conductivity, O.C= Organic Carbon, TN= Total Nitrogen, AV-P= Available Phosphorus, Ca= Calcium, Mg= Magnesium, Na= Sodium, K= Potassium, TEB= Total Exchangeable Bases, TEA= Total Exchangeable Acidity, ECEC= Effective Cation Exchange Capacity, BS= Base Saturation

The soils of Sammeri (SP1) were observed with trend of increasing %sand at the upperslope to the lowerslope positions as confirmed by [15]. The %silt was not significantly different as reported by [16]. The %sand at Kugon recorded a mean value of 69.40 lower than Sammeri with mean value of 75.00 which indicates increase in %sand down the slope position. This is contrary to the reported by [17] where upperslope position had the highest sand content followed by the midslope while the lowerslope position had the lowest sand content. This trend might be due to the activities of farmers and tillage practices which exposed the soils to heavy erosion leaving coarse sand in the slope positions.

3.2 Bulk Density, Particle Density and Porosity

The analysis indicated BD, PD and porosity were not significantly different (Figs. 5, 6 and 7). Pedon SP1 showed BD varied with increase in depth, ranging between 1.71 g/cm^3 to 1.46 g/cm^3, PD showed mean value of 2.53 and ranged between 2.63 g/cm^3 to 2.39 g/cm^3 and %porosity showed mean value of 37.73 respectively. Pedon SP2 showed mean values of 1.60, 2.59 and 38.14 for BD, PD and %Porosity respectively. The %porosity increased with increase in soil depth, with the highest at 37-54 cm (40.61%) depth. Pedon SP3 was characterized by varying BD values, ranging between 1.69 g/cm^3 to 1.45 g/cm^3. The %porosity of the soils were lowest (29.29%) at the depth of 13-25 cm and highest (44.44%) at 49-63 cm depth respectively. The BD showed an increase at the sub surface than the surface horizons and this might be due to cultural practices of the farmers in the study area who disturb the soil and hence increase soil porosity and reduce the soil bulk density of the area. These results are in line with the work of [18].

3.3 Water Holding Capacity and Water Retention

Pedon SP1 revealed WHC and WR did not show a particular pattern but varied with depth, ranging between 0.27% to 0.24% and 8.18% to 7.91% respectively. Pedon SP2 recorded the lowest WHC of 0.19% at the depth of 26-37 cm and 37-54 cm depth, while the WR varied between 14.25% to 13.11%. Pedon SP3 showed WHC ranging between 0.15% to 0.24% and the WR recorded the highest of 13.21% at the depth of 63-105 cm. These results might be due to more grasses at Kugon (SP3) which reduces water loss through evapotranspiration than in the soils of Sammeri (SP1). [19] observed similar trend of grass cover, less evaporation and higher moisture at higher slopes. The analysis showed SP1 (Sammeri) varied significantly with SP2 (Timdore) and SP3 (Kugon) for WHC and WR (Figs. 8 and 9) respectively. This result might be due to evapotranspiration and sandy or kaolinatic fractions responsible for water loses and promoted by cultural practices of the farmers, reducing soil texture and structure which affects the soil water holding capacity and moisture content in the study area.

3.4 Some Chemical Properties of Soils of the Study Area

3.4.1 Soil pH and electrical conductivity

Soil pH is a "master variable" and it regulates almost all biological and chemical reactions in soils [20]. Pedon SP1 showed varying soil pH ranging between 6.31 to 7.10 (10-18 cm and 18-29 cm) and recorded a mean value of 6.62. The EC showed a trend of decreasing values with soil depth, ranging between 0.16 ds/m (0-10 cm) to 0.06 ds/m (29-51 cm). However, the EC slightly increased at the last horizon (51-110 cm) of the pedon. Pedon SP2 revealed a decreasing pattern for pH values, ranging between 6.58 (0-14 cm) to 6.10 (26-37 cm). Pedon SP3 recorded mean values of 6.33 and 0.10 for pH and EC respectively. The pH and EC did not show significant difference (Figs. 10 and 11) and this might be due to similarities in the nature of soils of the study area ranging between slightly acidic to neutral (6.1-6.5 to 6.6-7.3). [21] recorded similar result with no significant difference in soil pH in Eastern Iran.

The pH slightly increased at the lowerslope position than the upperslope position. The result might be due to presence of Ca in the area which might have accounted for the trend of pH in the area. [22] also reported slightly higher pH at the lower slope positions. The increase in soil pH down the profile could be attributed to the downward movement of Ca and accumulation down the profile. [23,24] also reported increase in pH with increasing soil depth.

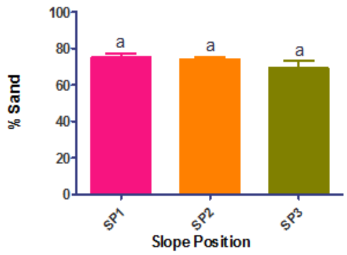

Fig. 2. % sand of the study area

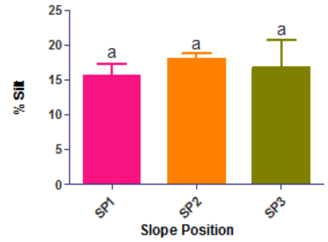

Fig. 3. % silt of the study area

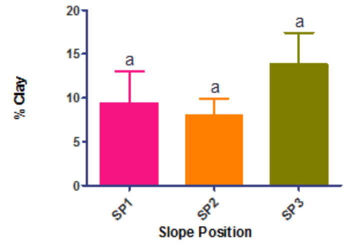

Fig. 4. % clay of the study area

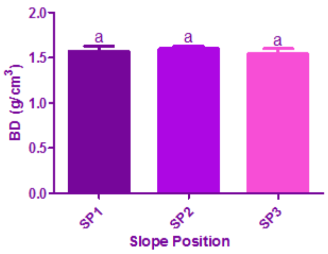

Fig. 5. BD (g/cm^3) of the study area

Fig. 6. PD (g/cm^3) of the study area

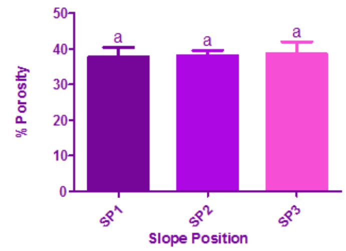

Fig. 7. Porosity (%) of the study area

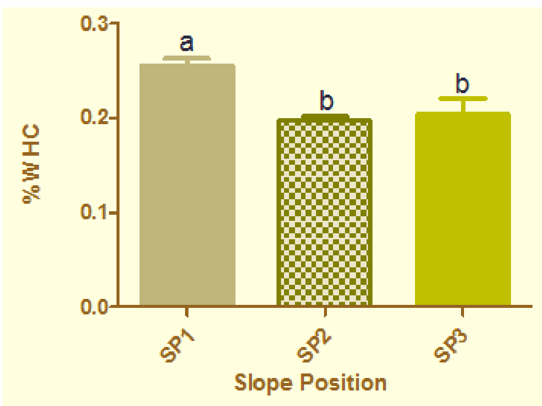

Fig. 8. % water holding capacity

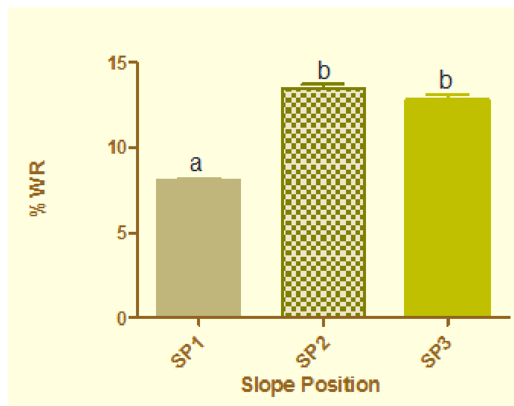

Fig. 9. % water retension

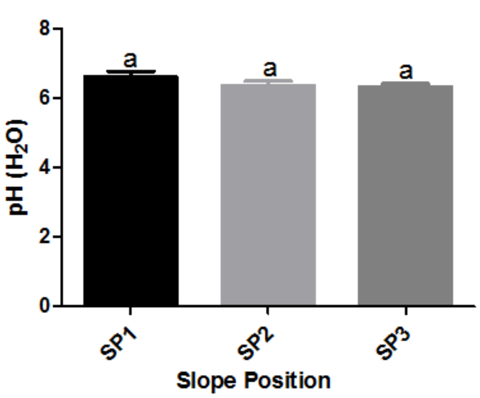

Fig. 10. pH of the study area

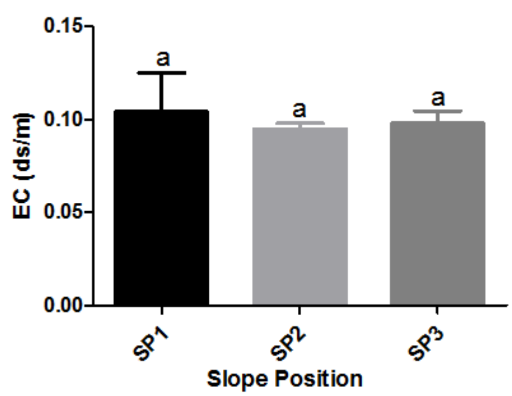

Fig. 11. EC of the study area

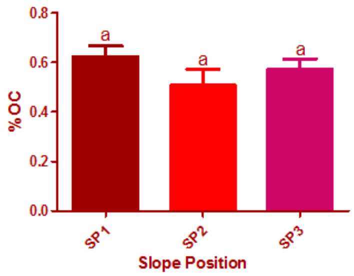

Fig. 12. OC of the study area

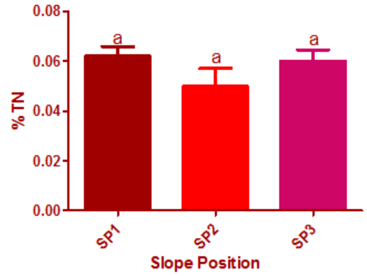

Fig. 13. % total nitrogen

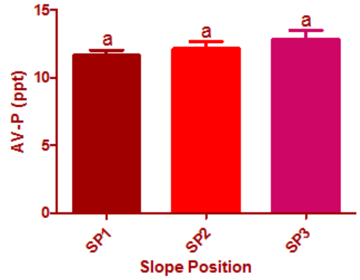

Fig. 14. AV-P (ppt)

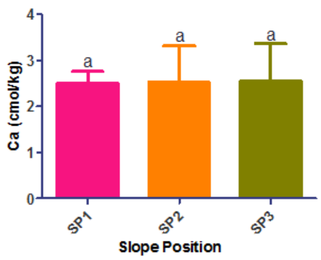

Fig. 15. Ca (cmol/kg)

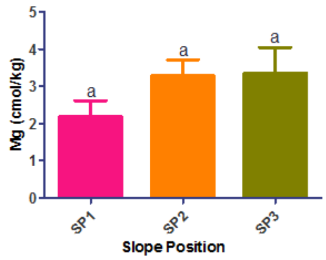

Fig. 16. Mg (cmol/kg)

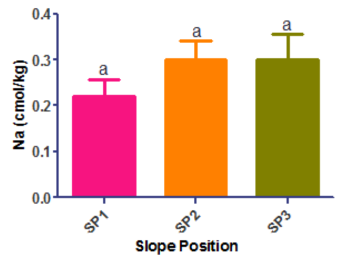

Fig. 17. Na (cmol/kg)

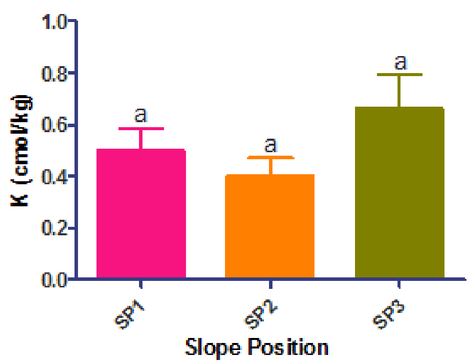

Fig. 18. K (cmol/kg)

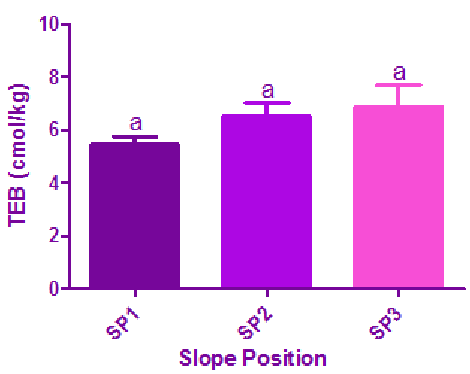

Fig. 19. TEB (cmol/kg)

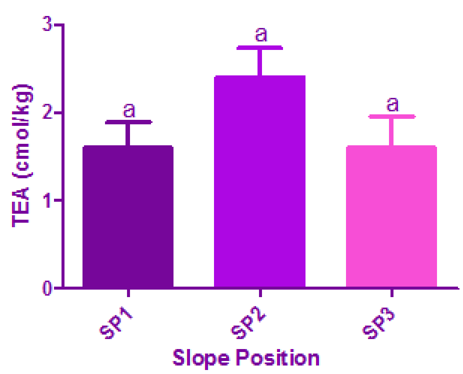

Fig. 20. TEA (cmol/kg)

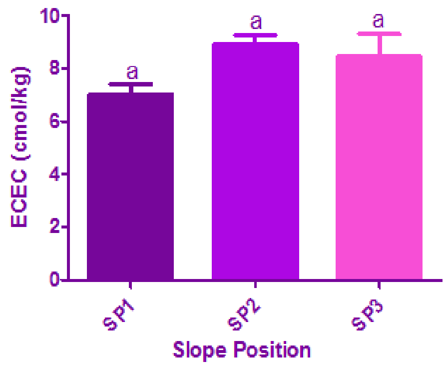

Fig. 21. ECEC (cmol/kg)

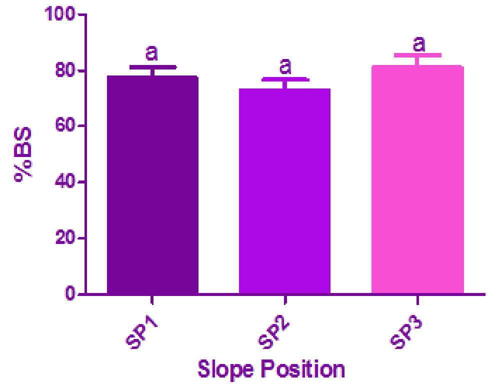

Fig. 22. % base saturation

3.4.2 Soil organic carbon, total nitrogen and available phosphorus

Analysis of the chemical properties were not significantly different at $p<0.05$ in the study area (Figs. 12-22). The OC of the study area were rated low (<1%) according to [25]. Pedon SP1 showed varying values of OC, TN and AV-P and recorded mean values of 0.62, 0.06 and 11.65 respectively. Pedon SP2 revealed a decreasing pattern of values for OC from 0.59% to 0.32% between horizon 0-14 cm, 14-26 cm and 26-37 cm depth respectively. This trend of varying values could be attributed to management practices carried out by farmers in the study area, distribution of soil OC and the effect of soil erosion and deposition on the slope positions. This result is supported by [26]. The result indicated an increasing trend of OC at the lowerslope position with mean value of 0.62 followed by the upperslope position (0.57) and the lowest recorded a mean value of 0.51 at the middleslope position. This trend was also observed by [27]. The TN of the study area were rated low (0-0.15%) according to [25].

The low TN observed in the study area might be due to continues cultivation by farmers over the years and crop removal. Also, low OC and the effect of erosion and deposition on the slopes might have contributed to the trend. Similar findings were recorded by [28,29]. The AV-P were generally rated medium (10-20) according to [25] and this might be attributed to weathering of P-rich parent rock releasing phosphorus into the soils of the slope positions. There was slight increase of AV-P with increase in soil depth and this might be due to leaching activities in the area. This is supported by [30].

3.4.3 Soil calcium, magnesium, sodium and potassium

Pedon SP1 showed varying Ca^{2+} ranging between 1.60 cmol/kg (18-29 cm) to 3.20 cmol/kg (29-51 cm), with a mean value of 2.49. The Mg^{2+} varied with depth and recorded mean value of 2.18, Na^{2+} also varied with depth and recorded the highest value of 0.30 cmol/kg at 10-18 cm and 51-110 cm depths, and the lowest value recorded was 0.10 cmol/kg at 29-51 cm depth. K^{+} indicated at 0-10 cm and 10-18 cm depths values were 0.50 cmol/kg. Pedon SP2 showed a trend of varying values for Ca^{2+}, Mg^{2+}, Na^{2+} and K^{+} with mean values of 2.52, 3.30, 0.30 and 0.40 respectively. Pedon SP3 (Kugon) recorded high Ca^{2+} (>5) at the Bt horizon (49-63 cm) according to [25], Mg^{2+} for all slope positions were rated high (>1). This might be due to the dominance of Mg bearing minerals in the area. This result is supported by the work done in Ethiopia where High Mg content was recorded [30]. The high Ca Mg trend in this study is comparable to a study report by [31]. Result indicated that Ca was the dominant cation in the exchangeable complex, followed by Mg and K, this is supported by the findings of [32]. High soil Na^{2+} (>0.3) were recorded at the Bt horizons in Kugon 0.50 cmol/kg (49-63 cm) and Sammeri 0.40 cmol/kg (26-40 cm). This decreasing trend down the profile might be due to leaching of minerals activities as a result of sandy loam nature of the soils of the study area. Similar result was reported by [33].

3.4.4 Soil TEB, TEA, ECEC and %BS

Investigation revealed Pedon SP1 recorded between 4.7 cmol/kg to 6.40 cmol/kg for TEB, TEA varied with depth ranging between 0.80 cmol/kg (18-29 cm) to 2.40 cmol/kg (51-110 cm) respectively. The ECEC decreased with increase in depth from 8.00 to 5.90 cmol/kg at 0-10 cm to 29-59 cm depths. In pedon SP1 (Sammeri), the ECEC were rated low to medium (<6, 6-12) according to [34]. This might be attributed to weathering activities and little of the weathered materials in the sand dominated soils with kaolinite fractions in the study area. This report is supported by [15]. However, the ECEC in pedon SP3 (Kugon) were rated medium to high (4-10, >10) according to [25]. Similar results were reported by [35] in Mina, Nigeria and agrees with the finding of [36].

The %BS also varied with depth ranging between 66.44% to 87.85%. The result showed %BS did not vary significantly in the study area. Similar result was reported by [28]. The %BS in all the locations in the study area regardless of slope position were rated medium to high (50-80, >80) according to [25]. Similar work was reported by [36]. These soils are considered fertile soils due to the high %BS developed from basaltic parent material in the study area and might support agricultural cultivation and productivity. This result is supported by similar findings of [37].

4. SUMMARY AND CONCLUSION

The soils were slightly acidic to neutral and predominantly sandy in nature. The study revealed that slope position influenced water holding capacity and water retention in the study area and were significantly different which might have been contributed by the management practices of the farmers and the evaportranspiration rate of the slope positions. The soils were low in nitrogen and organic carbon which could be attributed to continuous cultivation over the years and crop removal. Soil chemical properties were not significantly affected by the slope positions in the study area. The surface horizon recorded low exchangeable base and increased down the profile due to kaolinatic fraction which are easily leached. However the soils have potential to support agricultural cultivation and productivity owing to the high %base saturation and are considered fertile lands. Good and improved management practices like use of organic material and integrated nutrient management (INM) practice will improve the soil texture and structure and reduce leaching activities in the area. Soil erosion hazards can be controlled by planting of economic trees and by the use of animal dung and compost which is available in the study area. This will improve the physical condition of the soils through humification and cementation processes and reduce erosion effects.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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