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Evaluation of Selected Physical and Chemical Soil Properties and their Management for Arable Crop Production in Southern Adamawa State

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ABSTRACT

Soil is essential for food production, and there is needed practice for sustainable soil management. This study was aimed to evaluate physical and chemical properties of soils and their management in three farming communities: Sangasumi (SGS), Gangkoen (GGK), and Gangbuen (GGB) of Southern Adamawa State, Nigeria. The intent is to encourage optimum land use planning and increase the efficiency in the use of soil resources. In this work, a digital Terrain Model (DTM) was generated from the map of the study area, and three elevation ranges were identified: 660-780 m – representing the upper-slope in SGS, 540-660 m – representing the middle-slope in GGK, and 420-540 m – representing the lower-slope in GGB, respectively. Three slope positions were delineated using the Geographic Information System (GIS) and their coordinates were obtained by means of a handheld Geographic Positioning System (GPS). Three profile pits were dug in each of the locations and soil samples were collected in each of the identified horizons of the pits. Standard laboratory procedures were then used to determine the soil physical and chemical properties. Herein, results for particle size analysis indicated that the soils were predominantly sand, ranging between 51% to 91% across the pedons and %sand was positively correlated with bulk density. Moreover, soil pH in each sample was found to be slightly acidic to neutral (6.1-6.5 to 6.6-7.3), while organic carbon and total nitrogen levels were low (<1%, <0.15%), and available phosphorus levels were medium (10-20 ppm). In contrast, magnesium content was high (>1), sodium recorded up to 0.60 cmol/kg, potassium was also high (>0.3) and %base saturations were generally medium to high (50-80 to >80). Results suggest the soils have potentials for arable farming. However, soil erosion hazards had affected parts of the fields; this leads to reduction in soil fertility and

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crop yields. Addition of organic and inorganic fertilizers and control of soil erosion will greatly improve the soil fertility losses and increase crop yields.

Keywords**:** Pedon, Soil Fertility, Leaching, Soil Management, Continuous cultivation

1. INTRODUCTION

Man has a very close relationship with the soil, owing to the important role soil plays in the process of crop cultivation and supply, as well as purification of underground water. The soil houses and provides essential nutrients for flora and fauna which provides food and livelihood for human life. Over the years, man has attempted to conserve the soil and use it in a sustainable manner for optimum agricultural output. This is because continuous use of the soil without replenishing soil nutrients, depletes essential physical and chemical properties of soils and further degrades land resources. Anthropogenic disturbances have caused soil degradation through continuous cultural practices or over-exploitation without any soil management activities [1-5].

Therefore, management practices should be considered, planned and executed where soil and water is used for agricultural cultivation, for sustainability and increase yields. Hence, the approach adopted and used by farmers in managing their farm units greatly influences the chemical and physical properties of soils and improves or reduces yields of crops, especially on marginal lands. Agricultural planning has many benefits in terms of the environment. Agricultural landscape planning means making decisions about the future situation of agriculture land. In this case, it is necessary to predict how the land has changed over time and the effects of natural factors and human activities on the land. In this way, successful and sustainable landscape planning studies can be achieved.

The soil structure should be suitable for the germination of the seeds and the growth of the roots, and must have characteristics that enhance the storage and supply of water, nutrients, gases and heat to the crops. Soil characteristics may change due to the land use patterns, topography, vegetation and altitude within a short distance [6, 7]. For a given soil, its properties depend on the history of the soil formation and can be substantially modified by human intervention (e.g. through agricultural practices). A proper understanding of soil characteristics and adequate interpretation of the magnitudes of its properties, both combined under the broader term of soil quality is required for proper management of agricultural soils.

The twin problems of population explosion and arable land scarcity in Nigeria are driving more people to intensify farming on the highlands. The soils of the farming communities in the study area of Adamawa State are characterized by these problems. Furthermore, there is a decline in soil fertility due to continuous cultivation, which leads to leaching of exchangeable bases and land degradation. This further compounds the problems and therefore, low crop yields were observed by farmers. Some farmers use inorganic fertilizers, like the N, P, K (15:15:15) and Urea (46%), where available and affordable, usually in very small quantities on their farms. This was done in an attempt to improve suspected low soil fertility as a result of nutrient uptake by plants and leaching during the cropping season. Most times, this action was done without soil fertility test and proper guide on fertilizer recommendation and application.

The major cause of land degradation is cultivation on steep and fragile soils, with inadequate investment on soil conservation, erratic and erosive rainfall patterns, declining use of fallow, limited recycling of dung and crop residues to the soil, rapid population increment, deforestation, low vegetative cover and unbalanced crop and livestock production [8]. Changes in land use and soil management practice can have a marked effect on soil organic matter. Several studies in the past have shown a poor soil management, deforestation, topography and continuous cultivation of virgin tropical soils often leading to depletion of nutrients and high soil erosion rate [9-11].

Soil inherent products (e.g., parental material, climate, topography) and anthropogenic (e.g., tillage and cropping systems, land uses) interactions [12] are important and should be considered in improving soil physical and chemical properties and their management. Soil inherent attributes are governed by soil-forming processes and are often relatively unresponsive to soil and crop management practices. On the other hand, dynamic soil properties (e.g., soil organic carbon, pH, soil aggregation, microbial biomass activity) are responsive to management practices and/or land use, but their change rates are dependent on the inherent soil attributes [13].

The above attributes indicate that soil management can improve the physical and chemical properties of soils in Sangasumi, Gangkoen and Gangbuen farming communities in the study area, especially on sloppy areas. Soil fertility loses and land degradation is particularly increasing in these lands, as a result of population increase and more demand for food and food items in the study area. Hence, more people are involved in farming, putting more pressure on the soil and making it more vulnerable to fertility loses and land degradation. Land used for cultivation by family units, also fragment land into smaller units which encourages continuous cultivation without allowance for fallow period, could improve the soil fertility. Therefore, it is very important for farmers in these communities to have a critical information on the soil physical and chemical properties and have more knowledge on management practices that influence soil improvement or that degrade the land. The objective of this study was to evaluate some physical and chemical properties of the soils and their management with the view on improving cultural or management practices by farmers in the study area. This study also serves as a guide to farmers on the fertility of the soils for optimum land use planning, increase crop yields and sustainable land use.

2. MATERIALS AND METHODS

2. 1. Location and extent

This study was carried out in three farming communities located in Sangasumi, Gangkoen and Gangbuen in Ganye, Southern Adamawa State, Northeast Nigeria. The study area lies between Longitude 11º50’0” E and Latitude 8º20’ 0” N to Longitude 12º10’0” E and Latitude 8º30’0” N, covering a total area of about 12,525.58 ha (**Figure 1**). The study area is within the Northern Guinea Savannah Zone of Nigeria 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 occurs in April/May and drops at onset of rains due to cloudiness. Maximum temperature in the state can reach 40 ºC, with the mean monthly range of 26.70 ºC in the north eastern part.

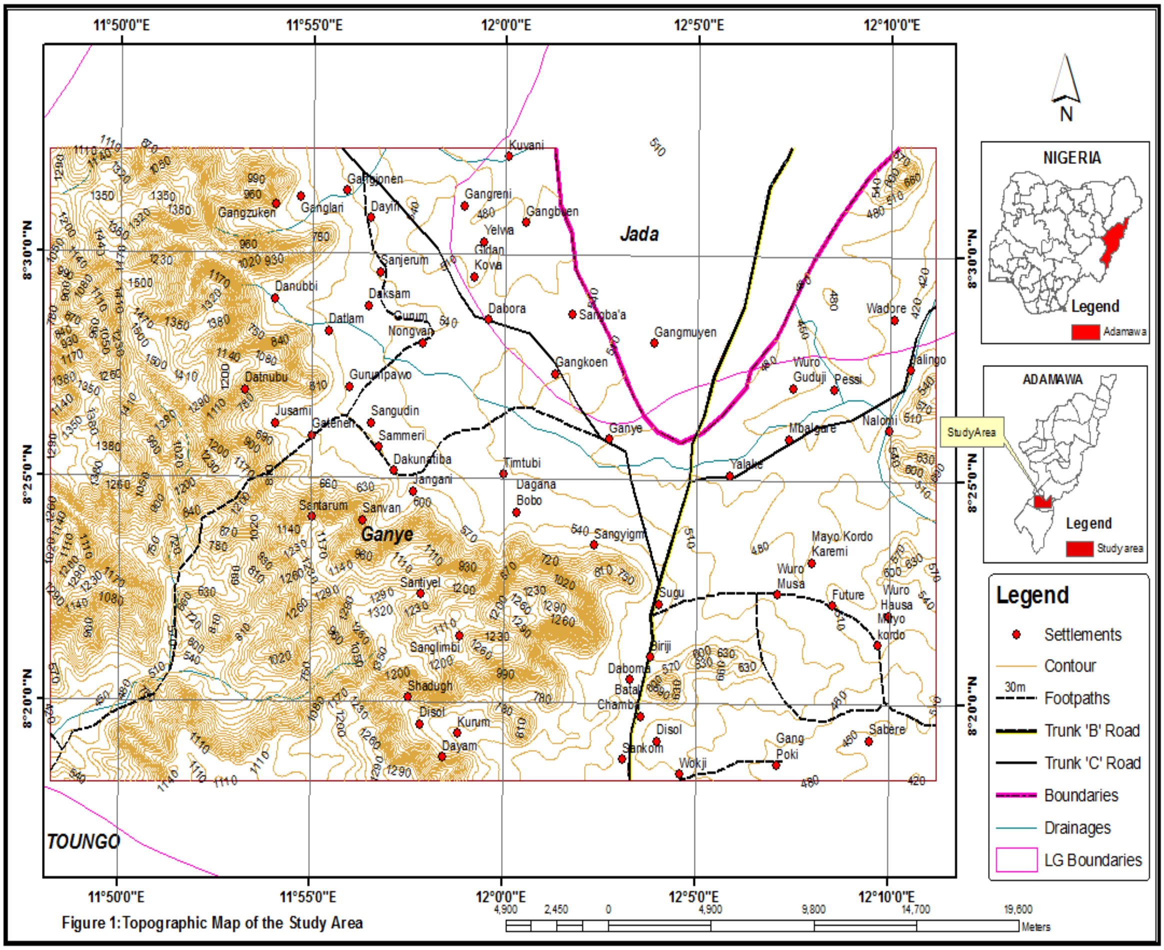

Figure 1. Topographic Map of the Study Area

2. 2. Field work and sample collection

Digital Terrain Model (**Figure 2**) was generated from the map of the study area, indicating elevations in meters. Three elevations were identified: 660-780 m, representing the upperslope in Sangasumi, 540-660 m, representing the middleslope in Gangkoen, and 420-540 m, representing the lowerslope in Gangbuen, respectively.

The slope positions were delineated using the Geographic Information System (GIS) and their coordinates were obtained (934898 N, 174135 E; 936781 N, 169991 E and 941528 N, 170657 E, respectively) at each location randomly selected and each slope position was recognized as a unit.

Three (3) profile pits were dug in each unit; located at Sangasumi (SGS), Gangkoen (GGK) and Gangbuen (GGB), respectively. Soil samples were collected in each of the identified soil horizons of the pits dug, as described by Verla *et al.* [14], placed in well labeled polythene bags [15].

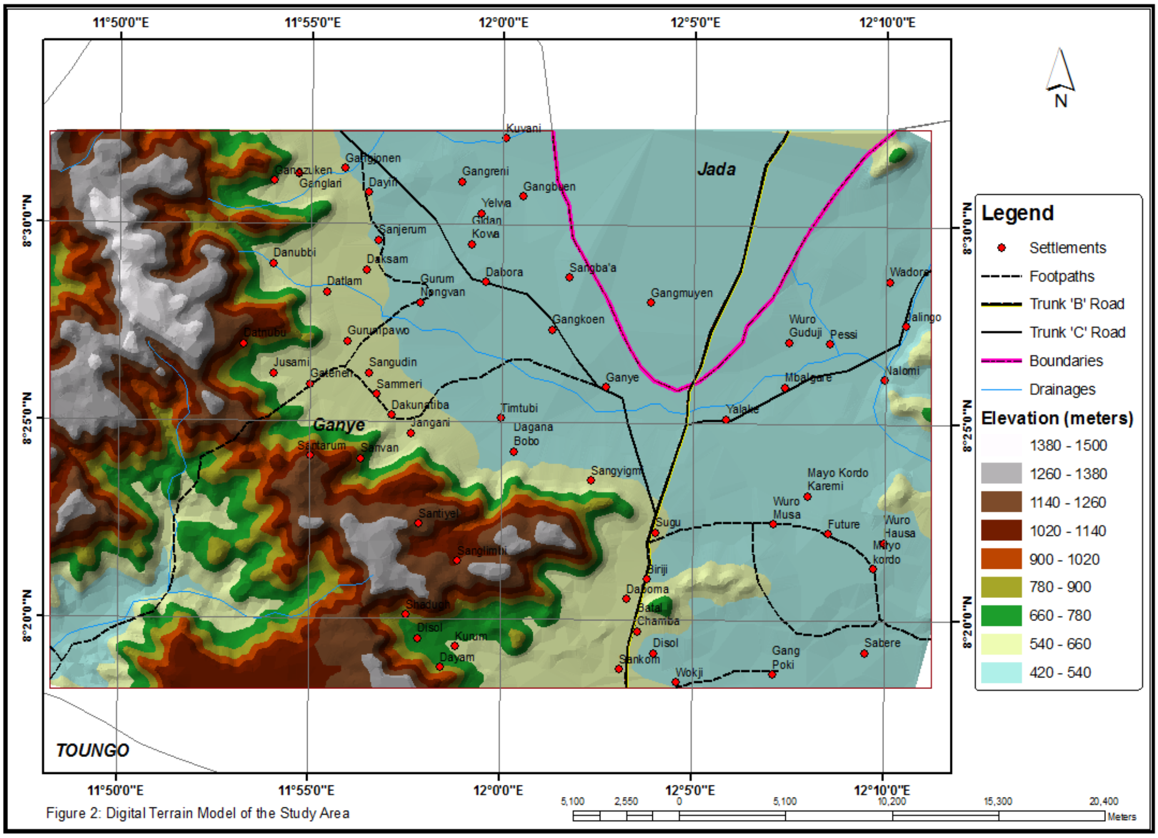

Figure 2. Digital Terrain Model of the Study Area

2. 3. Preparation of soil samples

Soil samples collected from the field were air-dried at room temperature, crushed and passed through a 2 mm sieve after a careful removal (hand-picked) of plant parts and other unwanted materials for some soil physical and chemical analysis in the laboratory, as described by Udo and Fagbami [15].

2. 4. Laboratory analysis

Bouyoucos hydrometer method was used to determine particle size distribution in the laboratory, and the soil textural classes were determined by using USDA textural triangle. Bulk density was determined using the cylindrical metal core sampler method. The weight of empty core samples were taken, cylinder volume was also recorded and the wet core samples were oven dried at 105 ºC and dry core sampler weights were determined. Bulk density was calculated using the formula:

$$Db = (ODW - RF - CW) / [CV - (RF / PD)]$$

where:

Db = Bulk density of <2-mm fabric at sampled, field water state ($g \cdot cm^{-3}$)

ODW = Oven-dry weight
RF = Weight of rock fragments
CW = Empty core weight
CV = Core volume
PD = Density of rock fragments.

The result of particle size distribution was used to determine soil textural class by subjecting the results of the particle size distribution to Marshall's Textural Triangle. Soil moisture content was determined by the gravimetric method. Particle density was determined by the use of graduated cylinder method. Soil sample clods were collected in the field and water retention was determined by oven drying the samples at 110 ºC overnight, and the oven dry weights were obtained and water retention was calculated using the formula:

$$H_2O\% = 100 \times [(Ms + w - Ms) / (Ms - Mc)]$$

where:
$H_2O\%$ = Percent gravimetric water content
Ms+w = Weight of solids + H_2O + container
Ms = Weight of solids + container
Mc = Weight of container.

Soil pH was determined by the use of electrode method ,as described by Bamgbose *et al.* [16]. Titration method was used to determine extractable acidity, total nitrogen was determined using concentrated sulfuric acid (H_2SO_4) and potassium permanganate solution ($KMnO_4$), as described by Srikanth *et al.* [17]. Available phosphorus was determined by extraction method using a spectrophotometer, and exchangeable calcium, magnesium, potassium and sodium were determined by the use of ammonium acetate (NH_4OAC) buffer, 1 N, pH 7. The Na^+ and K^+ were measured by the use of flame photometer, while EDTA titration method was used to determine Ca^{2+} and Mg^{2+} in the laboratory. Titration method was used to determine exchangeable acidity and effective cation exchange capacity (ECEC) was obtained by summation of the exchangeable cation, while percentage base saturation was determined by dividing Ca^+ Mg with ECEC and multiplying it by 100 [17].

$$\text{Base saturation} = (A/B) \times 100\%$$

where:
A = Extractible bases (Ca + Mg) + K cmol/kg (A/B)
B = ECEC (cmol/kg).

2. 5. Data analysis

Results 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 the Fisher's Least Significance Difference (LSD), and the means were separated by using the pairwise comparison technique (comparison of two means) to test for difference between the sampling positions. Pearson's correlation analysis was carried out to determine key physical and chemical soil properties' relationships between the soil elements and their roles with the view of evaluating the soils.

3. RESULT AND DISCUSSION

3. 1. Physical Properties

3. 1. 1. Particle size distribution

The results for particle size analysis indicated that the soils were predominantly sand, ranging between 51% to 91% across the pedons (**Table 1**). All the pedons for %sand were not significantly different, while all pedons were significantly different for %silt (**Table 2**). The high %sand of 91% at the surface layer in SGS could be as a result of surface deposition by the action of rain water during the rainy season with time. The soils were coarse and might not adequately support nutrient for crop growth. The pedon revealed shallow depth due to rock impediment (<27 cm) but with well-defined horizons; close to a river there were the community cultivates groundnuts. Pedon SGS and GGK showed an increase in clay content; values ranging from 5% to 37% and pedon SGS varied statistically with all the pedons, while pedon GGK and GGB were statistically similar. These results might be due to the sandy clay loam nature of soils at SGS and erosion activities which eroded the soils and increased leaching of clay down the profile [18]. There is shown the sand predominated the soils in their study of slope land. The result of Pearson's correlation matrix showed that sand particles and bulk density were positively correlated with the correlation coefficient of 0.786 (**Table 3**).

3. 1. 2. Bulk density, particle density and porosity

The study indicated that the bulk density decreases with the increase in depth in the farming communities except for pedon GGB, where the bulk density increased from 1.66 g/cm^3 to 1.77 g/cm^3. The result showed the bulk density of the study area was statistically similar. This result could be linked to cultivation activities in the area which disturbed the bulk density. Particle density and soil porosity were not significantly different; however, the soils were porous with the highest value of 48.66% at the depth of 33-116 cm (Pedon SGS). This result is an indication of the sandy, coarse nature of the soils and hence the high values recorded for soil porosity. Result of Pearson's correlation matrix showed that the porosity and clay fraction were positive correlated with the correlation coefficient of 0.910, while the bulk density and clay indicated a negative (–0.926) correlation.

3. 1. 3. Water holding capacity and water retention

The result revealed water holding capacity showed a significant difference between the farming communities, with mean values of 0.25, 0.20, and 0.23, respectively. This result could be due to the difference in silt and clay fraction which support water holding capacity of soils. Water retention increased from 8.17% at the surface layer of pedon SGS to 11.59% at the sub-surface layer. This result might be attributed to the increase in clay content of the pedon and hence, ability to hold more water due to addition and leaching activity. Results for pedon GGB indicated the water holding capacity decreased with the increase in soil depth; from 0.19% (0-7 cm) at the surface horizon to 0.22% (16-26 cm) at the Bw horizon. This result might be due to plants and plant roots at the top layer of the pedon. The water retention varied from the top horizon down the profile, ranging between 13.10% and 13.56%.

Table 1. Some Soil Physical Properties of the Study Area (Sangasumi-SGS, Gangkoen-GGK, Gangbuen- GGB)

Pedon	HD	Depth (cm)	%Sand	% Silt	% Clay	Txs Classes	B.D (g/cm^3)	P.D (g/cm^3)	Porosity (%)	WHC (%)	WR (%)
SGS	Ap	0-10	77	18	5	LS	1.68	2.46	31.71	0.16	8.17
	E	10-23	59	20	21	SCL	1.44	2.48	41.94	0.23	11.59
	Bt	23-33	51	20	29	SCL	1.37	2.53	45.85	0.29	11.45
	C	33-116	53	10	37	SC	1.34	2.61	48.66	0.30	11.42
		Mean	**60**	**17**	**23**		**1.46**	**2.52**	**42.04**	**0.25**	**10.66**
GGK	Ap	0-13	67	28	5	SL	1.66	2.61	36.40	0.25	12.92
	E	13-25	75	18	7	SL	1.63	2.59	37.07	0.19	8.43
	Eg	25-44	75	16	9	SL	1.59	2.50	36.40	0.18	8.41
	Bt	44-61	75	14	11	SL	1.56	2.50	37.60	0.18	8.40
	C	61-115	75	14	11	SL	1.47	2.48	40.73	0.21	8.36
		Mean	**73.40**	**18.00**	**8.60**		**1.58**	**2.54**	**37.64**	**0.20**	**9.30**
GGB	Ap	0-7	91	2	7	S	1.66	2.40	30.83	0.19	13.14
	E	7-11	89	8	3	S	1.70	2.61	34.87	0.19	13.56
	Bt	11-16	55	36	9	SL	1.55	2.52	38.49	0.33	13.25
	Bw	16-26	73	24	3	LS	1.61	2.48	35.08	0.22	13.10
		Mean	**77.00**	**17.50**	**5.50**		**1.63**	**2.50**	**34.82**	**0.23**	**13.26**

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

Table 2. Results of ANOVA for Soil Physical Analysis using LSD

Pedon	% Sand	% Silt	% Clay	B.D (g/cm^3)	P.D (g/cm^3)	Porosity (%)	WHC (%)	WR (%)
SGS	60.00^a	17.00^a	23.00^a	1.46^a	2.52^a	42.04^a	0.25^a	10.66^a
GGK	73.40^a	18.00^b	8.60^b	1.58^a	2.54^a	37.64^a	0.20^b	9.30^a
GGB	77.00^a	17.50^c	5.50^b	1.63^a	2.50^a	34.82^a	0.23^c	13.26^a
LSD 5%	**25.03**	**0.00**	**12.47**	**0.54**	**0.84**	**15.28**	**0.00**	**10.64**

Means with different letters are significantly different at 5% confidence level, same letters are similar.

Table 3. Pearson's Correlation Matrix for some Soil Physical Properties

Soil Properties	Sand	Silt	Clay	B.D (g/cm^3)	P.D (g/cm^3)	Porosity (%)	WHC (%)	WR (%)
Sand	1							
Silt	–0.580	1						
Clay	–0.734	–0.128	1					
B.D (g/cm^3)	0.786	–0.036	–0.926	1				
P.D (g/cm^3)	–0.290	0.170	0.211	–0.091	1			
Porosity (%)	–0.816	0.101	0.910	–0.945	0.411	1		
WHC (%)	–0.834	0.518	0.583	–0.621	0.345	0.679	1	
WR (%)	–0.097	0.157	–0.013	0.074	0.158	–0.021	0.506	1

3. 2. Chemical Properties

3. 2. 1. Soil pH and electrical conductivity

Soil pH is a "master variable" and it regulates almost all biological and chemical reactions in soils. Pedon SGS recorded a pattern of varying values with soil depth. Soil pH ranged between 6.15 (33-116 cm) to 7.14 (0-12 cm) and recorded a mean value of 6.73. Electrical conductivity (EC) revealed the highest value in the pedon was 0.10 ds/m (0-12 cm) and the lowest value was 0.06 ds/m (12-23 cm), respectively (**Table 4**). The result from analysis of variance was not significantly different for soil pH and EC for all pedons (**Table 5**). This might be due to the soils ranging between slightly acidic to neutral (6.1-6.5 to 6.6-7.3), according to soil pH classes. The result also showed an increase in pH value, which could be due to accumulation of Ca^{+} at the sub-surface layer of the pedon. This agrees with the findings of [19]. The result for Pearson's correlation matrix showed that the soil pH and available phosphorus were positive correlated with the correlation coefficient of 0.355 (**Table 6**). Pedon GGK indicated varying trend for pH values, ranging between 6.06 (25-44 cm) to 6.80 (13-25cm), and the mean value of 6.36. The EC showed values between 0.08 to 0.16 (13-25 cm and 44-61 cm). These results indicated that pH affects the electrical conductivity due to the cation in the study area. As the soil pH increases, the electronic conductivity of the layer decreased, and vice versa.

3. 2. 2. Soil organic carbon, total nitrogen and available phosphorus

Pedon SGS recorded pattern of varying values for organic carbon (OC). The highest value of 0.69% was recorded at the depth of 12-23 cm. The OC of the soils were rated low (<1%) and this result could be attributed to the crop removal as a result of continuous cultivation over the years without deliberated action to replenishing lost nutrients. Poor management practices by farmers also increased organic carbon reduction as the soils were exposed, due to removal of all vegetative cover for domestic use and failure to add organic matter to augment lost nutrients. This result is supported by Khan *et al.* [20]. Additionally, heavy erosion activity at the site might have accounted for organic carbon losses, as soils were eroded down slope [21]. The result of Pearson's correlation matrix showed that soil organic carbon and soil total nitrogen were positively correlated with the correlation coefficient of 0.957. Similar results of positive correlation for organic carbon and total nitrogen were observed by [22].

The total nitrogen of the soils were generally rated low (0-0.15%). This result could be attributed to the total nitrogen distribution and management practices of farmers in the study area. Farmers add inorganic fertilizers in very small quantity and the sandy nature of the soils made the soils porous and further susceptible to leaching of minerals down the profile. Continuous cultivation, organic matter and crop removal due to year-in-year out farming activities, contributed to the low total nitrogen content in the study area. Similar reports were documented by [23]. The available phosphorus content ranged between 9.46 ppm to 14.96 ppm across the farming communities, and were generally rated medium (10-20 ppm). This result might be due to weathering of phosphorus rich parent materials that were broken down and acted upon by soil forming processes. The available phosphorus slightly increased at the sub-surface horizons. This might be as a result of leaching and slightly acidic nature of the soils which support high phosphorus content in soils.

3. 2. 3. Soil calcium, magnesium, sodium, and potassium

Pedon SGS indicated varying values for calcium. The value of 2.40 cmol/kg was recorded at the surface layer and increased to 4.00 cmol/kg (12-23 cm). These results suggested leaching of Ca^{2+} down the profile. Magnesium in all the farming communities were rated high (>1) and values recorded were between 1.60 cmol/kg to 6.40 cmol/kg. These values recorded for Mg^{2+} could be as a result of dominance of magnesium bearing minerals in the study area. Similar findings for magnesium bearing minerals were reported by Khormali *et al.* [24]. Soil sodium were rated medium (0.1-0.3) at pedon SGS, while in pedon GGK, 0.60 cmol/kg was recorded for Na^{+} (25-44 cm) and was rated high. These varying values might be attributed to predominant erosion activities at pedon SGS which wash off soil fraction along with soil minerals in the area, while pedon GGK and GGB were relatively gentle slope and level land, respectively. Values for potassium in the study area were rated high (>0.3) across the farming units. This result might be due to cultural practices carried out by farmers in burning plant residue after harvest, and sometimes due to the addition of ash which might have increased the content of potassium. Pedon GGB showed values for potassium varied with increased depth; from 0.50 cmol/kg at the surface layer to 1.10 cmol/kg at the last horizon. This result suggests an increase down the profile due to the leaching activities owing to the porous nature of the soils at the surface layer.

3. 2. 4. Soil total exchangeable bases, total exchangeable acidity, effective cation exchange capacity, and percentage base saturation

Result from analysis of variance indicated that the total exchangeable bases significantly varied with the mean values of 8.03, 6.76, and 8.53, respectively. This result might be connected with deposition of exchangeable bases at the lower slope farming community and the decomposition of organic materials applied by the farmers. These differences indicated the different cultural approaches, like addition of organic materials or erosion control adopted, or otherwise by farmers at each farming community in managing their soils. Result from Pearson's correlation matrix showed that the total exchangeable bases and effective cation exchange capacity were positively correlated with the correlation coefficient of 0.646. The total exchangeable acidity increased with increase in profile depth (Pedon SGS), that is form surface to subsurface horizon (0.80 cmol/kg to 3.20 cmol/kg). The total exchangeable acidity was rated low to medium (<2.0 to 2.0-5.0) across the farming units. The effective cation exchange capacity of the soils were rated medium to high (4.0-10.0 to >10.0). This result might be attributed to weathered materials that are rich in cation which broken-down into the soil through pedogenic processes. Percentage base saturation appeared to accumulate at the surface horizons (91.44%, 83.60%, and 91.11%, respectively) across the farming units and decreased at the subsurface horizons.

The percentage base saturation were generally rated medium to high (50-80 to >80). These results could be attributed to weathering of basaltic rich parent materials which found its way to the soils. Plant cover and root uptake of the bases and cultural practices by farmers to support plant growth might have resulted in accumulation of the bases at the surface horizons. These results suggest that the soils have potentials to support arable farming, owing from the basaltic weathered materials in the soils. Furthermore, the high base saturation might be linked to the low to medium total exchangeable acidity of the soils which increased the base saturation. **Table 7** discusses the soil management practices for selected arable crops in the study area and ways to improve productivity.

Table 4. 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^+ cmol/kg	TEB	TEA	ECEC	BS (%)
SGS	Ap	0-12	7.14	0.10	0.50	0.05	13.04	2.40	5.60	0.10	0.40	8.50	0.80	9.30	91.44
	E	12-23	6.75	0.06	0.69	0.07	13.52	4.00	2.40	0.20	0.60	7.10	3.20	10.30	69.05

	Bs	23-33	6.89	0.09	0.42	0.04	11.85	1.60	5.60	0.20	0.50	7.90	2.80	10.70	73.80
	Bt	33-116	6.15	0.09	0.60	0.06	12.80	1.60	6.40	0.20	0.50	8.60	2.00	10.60	81.19
		Mean	**6.73**	**0.09**	**0.55**	**0.06**	**12.80**	**2.40**	**5.00**	**0.18**	**0.50**	**8.03**	**2.20**	**10.23**	**78.87**
GGK	Ap	0-13	6.08	0.09	0.64	0.06	12.80	3.20	2.40	0.30	0.30	6.10	1.20	7.30	83.60
	E	13-25	6.80	0.08	0.36	0.04	12.57	1.90	4.80	0.20	0.30	7.30	2.80	10.10	72.14
	Eg	25-44	6.06	0.15	0.51	0.05	13.04	2.40	4.80	0.60	0.20	8.00	2.40	10.40	77.01
	Bt	44-61	6.25	0.16	0.53	0.05	9.46	4.08	1.60	0.20	0.50	6.30	2.40	8.70	72.54
	C	61-115	6.60	0.15	0.42	0.04	12.80	3.20	2.40	0.10	0.40	6.10	3.20	9.30	65.55
		Mean	**6.36**	**0.13**	**0.49**	**0.05**	**12.13**	**2.96**	**3.20**	**0.28**	**0.34**	**6.76**	**2.40**	**9.16**	**74.17**
GGB	Ap	0-7	5.95	0.12	0.53	0.05	11.61	3.28	4.00	0.40	0.50	8.20	0.80	9.00	91.11
	Ag	7-11	6.88	0.14	0.56	0.06	14.48	5.80	2.40	0.30	0.30	8.80	2.00	10.80	81.47
	Bt	11-16	6.68	0.08	0.65	0.06	13.76	3.68	4.00	0.30	0.50	8.60	3.60	12.20	70.41
	Bw	16-26	6.57	0.14	0.65	0.06	14.96	3.20	4.00	0.20	1.10	8.50	1.20	9.70	87.63
		Mean	**6.52**	**0.12**	**0.60**	**0.06**	**13.70**	**3.99**	**3.60**	**0.30**	**0.60**	**8.53**	**1.90**	**10.43**	**82.66**

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.

Table 5. Results of ANOVA for Soil Chemical Analysis using LSD

Pedon	pH H_2O	EC (dS/m)	O.C (%)	TN (%)	AV-P (ppm)	Ca^{2+} ←	Mg^{2+}	Na^{2+}	K^+ cmol/kg	TEB	TEA	ECEC →	BS (%)
SGS	6.73^a	0.09^a	0.55^a	0.06^a	12.80^a	2.40^a	5.00^a	0.18^a	0.50^a	8.03^a	2.20^a	10.23^a	78.87^a
GGK	6.36^a	0.13^a	0.49^a	0.05^b	12.13^a	2.96^a	3.20^a	0.28^a	0.34$_b$	6.76^b	2.40^a	9.16^b	74.17^a
GGB	6.52^a	0.12^a	0.60^a	0.06^a	13.70^a	3.99^a	3.60^a	0.30^a	0.60^c	8.53^c	1.90^a	10.43^c	82.66^a
LSD 5%	**4.97**	**0.05**	**0.78**	**0.00**	**10.81**	**4.82**	**6.48**	**0.56**	**0.00**	**0.00**	**4.29**	**0.00**	**66.77**

Means with different letters are significantly different at 5% confidence level, same letters are similar.

Table 6. Pearson's Correlation Matrix for some Soil Chemical Properties

Soil Properties	pH	EC	OC	TN	AV-P	Ca	Mg	Na	K	TEB	TEA	ECEC	BS
pH	1												
EC	–0.291	1											
OC	–0.232	–0.211	1										
TN	–0.120	–0.282	0.957	1									
AV-P	0.355	–0.176	0.398	0.470	1								
Ca	0.079	0.322	0.424	0.479	0.199	1							
Mg	0.119	–0.339	–0.263	–0.248	0.123	–0.797	1						
Na	–0.593	0.225	0.141	0.122	0.038	0.081	0.035	1					
K	0.081	0.030	0.441	0.327	0.272	0.033	0.008	–0.335	1				
TEB	0.238	–0.107	0.180	0.239	0.500	–0.036	0.617	0.216	0.220	1			
TEA	0.253	–0.201	–0.138	-0.106	–0.027	0.040	–0.167	–0.086	–0.162	–0.237	1		
ECEC	0.397	–0.247	0.042	0.116	0.395	0.002	0.382	0.112	0.056	0.646	0.588	1	
BS	–0.168	0.098	0.207	0.186	0.169	-0.050	0.321	0.155	0.200	0.487	–0.960	–0.348	1

Table 7. Soil Management Practices for Arable Crops and Recommendations in the Study Area

Location	Land Use	Crop Cultivated	Soil Management Practice	Comment
SGS	Cultivation	Maize, Guinea corn, Yam	Land was cultivated year in year out with little or no use of fertilizers. Hips of soils were made to accommodate yam cultivation in some areas and inter planted with maize. Little or nothing was done to reduce rill and gully erosion in many parts	Soil erosion is a serious threat to the land and farmers should incorporate organic materials to the soils in other to improve the soil texture and structure. This will improve the soil condition and make it less prone to erosion. Economic trees should be planted at strategic positions. Farmers should form cooperatives and

			of the fields. Farmers just avoid erosion sites and cultivate where they can. Farmers remove maize and guinea corn residues (stalk) to make local fens and use them as source of fire wood for cooking.	solicit for local and state government assistance in dealing with soil erosion hazards. State and Federal government and other interest bodies should provide inorganic fertilizers to farmers. Crop rotation should be adopted to replace use of high feeder crops on the same plot at the same time.
GGB	Cultivation	Maize, Ground nut, Yam, Cassava	Continuous cultivation and land fragmentation. Burning of plant residues after harvesting. Dumping plant parts into rill erosion sites. Tillage practices and in-cooperating old plant materials into the soils in a small and uncoordinated manner.	Land is a gentle slope and rill erosion sites should be made flat. In addition, channels for free water movement should be created to avert destruction of larger poisons of the fields. Addition of organic materials to the soil should be adopted more significantly to improve soil fertility. Use of inorganic fertilizers will improve soil quality and yields.
GGK	Cultivation and Grazing	Ground nut, Cow pea, Maize	Grazing of farm animals like cattle on the field due to presence of nearby river. Cultivation of some garden crops like tomatoes and amarantus near the river in small quantities. Some farmers collect cow dung for use on their fields and most times; just throw them on the fields. This is done in small quantity and inconsistently.	After harvest, animals should graze on the cultivated fields so that their droppings will be added to the soil. The field should be ploughed using mould plough so that the animal droppings will be mixed with the soil and decomposition processes will be enhanced. Water from nearby river can be channeled to the field for dry land farming. Inorganic fertilizers should be used to improve soil fertility losses. Due to the shallow nature of the soils as a result of underlying rock, shallow rooted crops should be cultivated.

4. CONCLUSIONS

The importance of soil management had been highlighted and emphases were laid on improving soil organic carbon. The physical and chemical properties of soils can greatly improve the crop growth and yields of farmers. The soils were generally sandy in nature; porous and susceptible to leaching of soil minerals beyond the rhizosphere where plant roots cannot access essential nutrients for their normal physiological activities. Clay content for SGS significantly varied from GGk and GGB, which indicated that the soils differ in distribution. Due to the porous nature of the soils, water holding capacity and water retention were poor and led to poor performance by crops. Soil pH values were slightly acidic to neutral. Organic carbon was rated low and positively correlated with total nitrogen, available phosphorus, sodium, potassium, total exchangeable bases and base saturation, which indicated that organic carbon is partly responsible or related to the chemical behavior of other soil chemical properties. The soils were prone to erosion thereby; soil minerals were washed away by moving water. Total nitrogen, potassium total exchangeable bases and effective cation exchange capacity indicated a significant difference between the farming units which showed how the soils varied in chemical composition. Continuous cultivation and land fragmentation can be minimized by adopting crop rotation. Inorganic and organic materials should be added to the soils in order to improve the soil texture and structure. Economic trees should be planted at strategic positions. Farmers should form co-operative societies and solicit for local and state government assistance in dealing with rill and gully erosion hazards. Animal dropping in some parts of the fields should be added and incorporated to the soils for decomposition and release of soil nutrients to crops.

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