GEOMORPHIC CHARACTERIZATION OF SOILS OF LIDO IN PINDIGA, AKKO LOCAL GOVERNMENT AREAOF GOMBE STATE, NIGERIA

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ABSTRACT

A geomorphic characterization of soils of Lido in Pindiga Akko Local Government Area of Gombe state, was conducted inorder to ascertain the variability in soil properties as influenced by different landforms. One profile pit each was dug at the upper, middle and lower slope positions and soil samples were then collected from identified generic horizons. The soil samples were then processed and analyzed in the laboratory following standard procedure. The results revealed that the studied soils were predominantly clay, sandy clay loam to silty loam in texture. The mean bulk density values ranged from 1.40 to 1.58 g/cm. The soil pH was found to be moderately to slightly acidic, while the mean values of organic carbon, total nitrogen and available phosphorus ranged from 0.32 to 0.80 g/kg, 0.05 to 0.09 g/kg, and 6.99 to 14.58 mg/kg, respectively. The mean value of Ca, Mg, K and Na contents ranged from 4.92 to 21.02, 0.79 to 1.22, 0.3 to 0.23, and 0.06 to 0.12 cmol (+) kg soil respectively, while the micronutrients disposition of the studied soils wasgenerally found to be medium to high in soil content. Owing to the low fertility status of the study area, application of organic fertilizer and chemical fertilizer containing N, P, and K is hereby recommended, while areas with evidence of slope, should adopt agronomic practices, such as, strip cropping or mulching, inorder to protect the land from the effect of soil erosion.

Key words: Characterization, Geomorphic,Mulching, Strip cropping, Topography.

INTRODUCTION

Conceptually, geomorphic/topographic surfaces are land portions defined by geographic boundaries and located within time and space (Daniels *et al*., 1971; Ruhe, 1956). The knowledge and practice of these soil study concepts enable the performance of spatial variability studies and pedological assessments. In addition, it consists of an instrument to predict pedological features from still unknown areas (Marcus *et al*., 2009). According to Esu (2008), soil's topography plays a major role as one of the factors that influences pedogenesis and in the process dictates the distribution and use of soils on the landscape.

Soil properties vary in vertical and lateral directions as a function of the geomorphic surfaces, and the soil forming factors and processes. A soil, therefore, forms an integral part of the land surface and any variations in the geomorphic and hydrologic processes influence the pedogenic processes through the effect on differential distribution of water, sediments and dissolve materials (Ovales and Collins, 1986; Young and Hammer, 2000; Brunner *et al.*, 2004). Soil properties on a geomorphic surface differ due to degree of erosion and deposition of both sediment and chemical constituents of the soil and their development (Krasilnikov*et al.*, 2005).

The effect of topography is more pronounced on young soils developed on hills because the rate of soil development equals the rate of soil removal than on old and level soils (Birkeland, 1999; Fisher and Binkley, 2000). The direction of the slope (i.e., the aspect) influences the amount and intensity of solar radiation to which a location is exposed and subsequently the temperature regime, which affects soil biological and chemical processes as well as evaporation. This can influence the degree of soil development. The slope determines not only the intensity of such processes as erosion and sediment redistribution, but also local drainage capacity. Topographical features such as curvature, slope class, slope length, and upslope area influence the hydrological conditions of a location and the soil properties (Fisher and Binkley, 2000).

The above processes cause a series of changes in soil properties such as horizon differentiation, soil texture, soil depth and chemical properties (Hall and Olson, 1991).Sibert *et al.*, (2007) reported significant correlation between topographic indices and soil properties, while Tengoun*et al*., (2005) concluded that topography is both an internal and external factor in pedogenesis and accounted for about 60% variation in soil properties (Cox *et al*., 2002). Ogban*et al*., (1999) reported that nutrient status and soil properties are related to topography.

The increasing human and animal population in Nigeria in general and Gombe state, and the country's current policy and drive to attain food security, has necessitated the abandonment of the traditional extensive agricultural system, to a more scientific intensive one. These, coupled with the current governments derive todiversify the economy towards agriculture and the adoption of more scientific intensive agricultural systems has necessitated the evaluations of nutrient status of soils.

Therefore, this study was conducted with the aim of evaluating the status and distribution of physical and chemical properties across a geomorphic surface for optimum and sustainable crop productionin the study area.

MATERIALS AND METHODS

The study area

The field study was conducted at Lido in Pindiga, Akko Local Government Area of Gombe State. It lies between longitude 9° 98'20" N and latitude 10° 96'00" E and longitude 9° 98'20" N and latitude 10° 95'20" E, on the Northern fringe of the Sudan Savanna belt of Nigeria. It is located at an elevation of 523m above the sea level.The geology of the study area developed on basement complex rocks with adjoining sedimentary rocks formation (Ikusemoran*et al.,* 2018).The area has a tropical climate, with distinct wet and dry season (Abubakar, 2013). The area records about three to four months of rainfall concentrated in the months of July, August and September with the average annual rainfall of 951mm per annum (UBRBDA, 2018). The mean annual temperature ranged from 30 - 37°C, while March April and May were observed to be the dry hot months of the year. During the rainy season, the temperature drops considerably due to the cloud cover between July and August as well as during the Harmattan periods of November to February (UBRBDA, 2018).

Soil sampling and handling

A profile pit, with dimensions 2 m long, 1 m wide, and 2 m deep, was dug on each identified geomorphic surface, viz: upper, middle and lowerslopeat the study site. Soil samples and soil clods were collected from each identified genetic horizon of the three profile pits, using hand trowel.The collected soil samples were then properly labelled in polythene bags and taken to the laboratory for analysis.

Laboratory analysis

In the laboratory, the samples wereair-dried, gently crushed, and passed through a 2mm sieve for laboratory analysis as described by Agbenin (1995). Particle size distribution analysis was determined using the Bouyoucos hydrometer method (Gee and Or, 2002). The bulk density was determined by the clod method (Blakeand Hartage, 1986) while total porosity was calculated mathematically from bulk density (Db) and standard particle density (Dp) data as described by Anderson and Ingram (1993). Soil pH was determined in 1:1 water ratio using a glass electrode pH metre(Page *et al.*, 1982). Determination of organic carbon (OC), and total nitrogen (TN) were done by the wet oxidation method and regular micro-kjeldahl method respectively (IITA, 1979). Available phosphorus (AP) was determined using the Bray 1 method (Bray and Kurtz, 1945).The extractable micronutrients: Zn, Cu, Fe and Mnwere extracted with 0.1M HCl solution (IITA, 1979) and determined on anAtomic Absorption Spectrophotometer (AAS) at appropriate wave lengths.

DATA ANALYSIS

The data generated from laboratory analysis were subjected to simple descriptive statistics which include range and mean as described by Harry and Steven, (1995). The standard deviation (SD) and Grand mean of the raw values across the topography was obtained using Microsoft Excel, while the coefficient of variation(CV) was calculated using the formulaCV= $\frac{SD}{Grand\ Mean} x100$ The CV was then used to compare the means across the topography as described by Wilding (1985).

RESULTS AND DISCUSSION

Physical properties of soils of the study area

Sand fractions dominated the particle size distributions with values ranging from 13.52% to 65.52% (Table 1). The observation of sand fraction predominance in this study is consistent with the findings of Salem, *et al.* (2017).

TABLE 1: PHYSICAL PROPERTIES OF SOILS OF THE STUDY AREA

Horizon Designation	Horizon Depth (cm)	Sand	Silt	Clay	Textural Class	BD
		(%) →		←		(g/cm^3)
Upper Slope						
Ap	0-29	59.52	24.56	19.92	Sandy loam	1.60
Bw1	29-67	45.52	32.56	21.92	Loam	1.59
Bw2	67-119	23.52	56.56	19.92	Silty loam	1.56
C	119-150	23.52	52.56	23.92	Silty loam	1.54
	Mean	**38.02**	**41.56**	**21.42**		**1.57**
Middle slope						
Ap	0-17	32.52	22.56	43.92	Clay	1.42
Bt1	17-40	31.52	26.56	41.92	Clay	1.44
Bt2	40-110	25.52	42.56	31.92	Clay loam	1.49
C	110-135	13.52	28.56	57.92	Clay	1.24
	Mean	**26.52**	**29.06**	**43.92**		**1.40**
Lower slope						
Ap	0-15	65.52	12.56	21.92	Sandy clay loam	1.58
C	15-159	53.52	18.56	27.92	Sandy clay loam	1.57
	Mean	**59.52**	**15.56**	**24.92**		**1.58**
	SD	17.52	14.46	12.83		0.11
	CV(%)	47	46	41		7

BD=Bulk density

Onweremaduet *al.* (2011) earlier reported that high sand content in soils could be attributed to the nature of parent material. The sand content in all profiles also showed a decrease with depth. The decrease in sand content with depth might be attributed to pedogenic processes such as lessivage, eluviations and illuviation (Ojetadeet *al.*, 2014). There was also an observed apparent increase in mean sand content along the toposequence with the upper, middle and lower slope positions recording mean values of 38.02, 26.52,and 59.52%, respectively. The higher mean value of sand content observed at the lower slope could be attributed to the process of erosion and deposition. The percentage of silt content (Table 1) ranged from 12.56% to 56.56% across the profiles. The highest silt mean value of 41.56% was recorded at the upper slope. A notable feature in all the soils studied is their high silt content (Tables 1). Nsor and Uhie (2016) and Askiraet *al.* (2019), all reported higher silt content in their various studies. The high silt content obtained in this study could be attributed to the nature of parent material and stage of soil development (Maniyunda, 1999). The mean clay content ranged from 21.42% to 43.92% along the studied pedons, with the middle slope recording the highest mean value of 43.92% (Table 1).

But generally, thepercentage clay content obtained in most of the studied profiles was observed to be low.The low clay content obtained in most of the profiles in this study could be attributed to the fact that the parent material of the study area is rich in sand. This study also affirms the finding of Akamigbo and Asadu (1986), who worked on similar type of soils. The soil texture in the various profiles studied was dominantly silty loam, sandy clay loam, and clay.

The mean bulk density values of the soils studied ranged from 1.40 to 1.58 g/cm^3(Table 1). Agriculturally, the bulk density values obtained in all the profiles studied is considered favorable. Soil with bulk density values of 1.8g/cm^3 and above impedes root penetration, aeration and water movement thereby affecting optimum root and plant growth (Brady and Weil, 2014). The relatively higher mean values of bulk density on the surface horizon at the upper and lower slope position (Table 1) could be attributed to compaction by mechanical or animal traction (Raji *et al.,* 1996). The coefficient of variation of sand, silt and clayalong the toposequence recorded a high variability >35%, while BD recorded low variability (7%) (Table 1).

Chemical properties of soils of the study area

The data for soil chemical properties for the studied area are presented in Table 2.The mean pH values ranged from 5.84 to 6.57along the profiles indicating that the soils were moderately to slightly acidic in reaction (Esu, 1991). The lower slope recorded the lowest pH value (mean= 5.84). The low pH values recorded in this study are similar to those earlier reported byOkoli *et al.*(2017). The acidic condition of the soils under study could be attributable to greater oxidation of anions like sulphides and nitrites leading to soil acidification (Ahukaemere*et al.,* 2014).

The mean values of organic carbon (OC) content range from 0.32 to 0.80 g/kg (Table 2) across the profiles. The organic content of the studied soil was rated low (Esu, 1991). The low-level OC content recorded in this study is in line with earlier findings by Salem *et al.* (2018) and Askira*et al.* (2019) who obtained low OC content for soils in the Savanna zones of Nigeria. The mean values of OC also showed an increase down the slope (Table 2). The higher mean content of OC recorded at the lower slope could be attributed to the process of erosion and deposition.

The mean values of total nitrogen (TN) content obtained along the profiles ranged from 0.05 to 0.09 g/kg (Table 2). The values of TN obtained for the study were rated as low (Esu, 1991). Also, low total nitrogen in soils has been reported by Salem *et al.* (2017) and Askira*et al.* (2019). The low values of TN content obtained in the study could be attributed to the removal of nitrogen due to continuous cultivation of crops (Wakene, 2001). The result also revealed that soil TN content increased down the slope (Table 2). The relatively higher TN recorded in the lower slope of the study area may be attributed to the relatively higher organic carbon content in the lower slope of the studied soils. This is in accordance with the findings of Kelly and May (1989), who reported a high positive correlation between organic carbon and total nitrogen in soils.

TABLE 2: CHEMICAL PROPERTIES OF SOILS OF THE STUDY AREA

Horizon Designation	Horizon Depth (cm)	pH (water) (1:1)	OC	TN	AP	Ca	Mg	Na	K	TEB
			← g/kg	→	mg/kg	←		Cmol (+)/kg		→
			Upper Slope							
Ap	0-29	7.14	0.48	0.05	9.54	37.75	1.03	0.25	0.11	39.14
Bw1	29-67	6.33	0.34	0.05	7.29	39.95	0.75	0.30	0.13	41.13
Bw2	67-119	6.49	0.26	0.04	6.11	2.93	0.93	0.20	0.12	4.18
C	119-150	5.89	0.18	0.04	5.03	3.47	0.45	0.18	0.10	4.2
	Mean	**6.46**	**0.32**	**0.05**	**6.99**	**21.02**	**0.79**	**0.23**	**0.12**	**22.16**
			Middle Slope							
Ap	0-17	6.75	0.86	0.07	12.95	5.23	0.93	0.25	0.09	6.50
Bt1	17-40	6.34	0.32	0.04	15.33	5.06	1.15	0.27	0.10	6.58
Bt2	40-110	6.30	0.26	0.04	10.42	4.11	0.83	0.18	0.10	5.22
C	110-135	5.83	0.14	0.04	8.16	5.29	0.66	0.14	0.08	6.17
	Mean	**6.31**	**0.39**	**0.05**	**11.72**	**4.92**	**0.89**	**0.21**	**0.09**	**6.12**
			Lower Slope							
Ap	0-15	6.13	1.06	0.12	15.29	6.35	1.25	0.31	0.06	7.97
C	15-159	5.54	0.53	0.06	13.86	7.72	1.18	0.29	0.06	9.25
	Mean	**5.84**	**0.80**	**0.09**	**14.58**	**7.03**	**1.22**	**0.30**	**0.06**	**8.61**
	SD	0.46	0.30	0.03	3.79	14.34	0.25	0.06	0.02	14.38
	CV(%)	7	68	50	36	122	27	25	20	110

OC= organic carbon, TN= total nitrogen, AP= available phosphorus, TEB = total exchangeable bases

The mean value of available phosphorus (AP) ranged from 6.99 to14.58mg/kg(Table2). The values of AP obtained in this study were rated medium according to Esu, (1991). There was an observed increasein the soils' available phosphorus down the slope,with thelower slope recording a higher AP mean value of 14.58mg/kg (Table 2). Also, the coefficient of variation of soil chemical properties (Table 2) along the toposequence, showed that variability in soil pH was found to be low (7%). The result is in conformity with the findings of Ndukwu*et al.* (2010) that pH of most tropical soils indicates low variation due to parent material. However, soil pH is an important variable in soil; it regulates the biochemical functions in the soil (Brady and Weil, 2014). Variation in OC, TNand AP were high by recording 68, 50 and 36%, respectively. This high variation in OC could be associated with amount of organic material deposit and rate of decomposition, while highvariation in TN could be related to the rate of mineralization and volatilization due to high temperature. From the above results OC, TN and AP distribution are highly influenced by geomorphic surfaces.

The mean values of exchangeable calcium (Ca) content for the studied soils ranged from 4.92 to 21.02 cmol(+)/kg across the profiles (Table 2). The exchangeable calcium content in this study is the dominant cation on the exchange sites of the studied soils (Table 2). This is in line with earlier findings by Kefas *et al.*(2016) who reported the preponderance of Ca over other cations. The dominance of Ca over other cations in these soils may be due to the occurrence of exchange sites that shows specific affinity for Ca (Esu,1982).The values of exchangeable calcium obtained in this study were therefore rated medium to high (Esu, 1991). The medium to high content of calcium obtained in this study may be attributed to inherent calcium content of the soil dictated by the parent material (Nahusenay*et al*., 2014). Magnesium (Mg) is the second most dominant extractable cation in the exchange complex of the studied profiles (Table 2).The mean exchangeable magnesium content values ranged from 0.79 to 1.21cmol (+)/kg across the profiles. The soil content of exchangeable Mg within the profiles and across slope was rated as medium to high according to Esu(1991). Ogbodo, (2011), also encountered high Mg soil content in his studies. This seemingly medium to high value of Mg content obtained in this study could be related to the calcareous nature of the parent material, (Havlin *et al*., 1999). Garcia (2003) stated that high accumulation of Mg in soil may cause deterioration of soil structure, lower water intake rates and affect chemical and biological properties of the soil.

The mean potassium content of the studied soils ranged from 0.21 to 0.30cmol (+)/kg along the profiles (Table 2). The values of soils potassium content obtained in the study were therefore rated medium according to Esu(1991). The value greater than 2cmol (+)/kg of K in soil indicates a fairly good supply and the response to K fertilizer is unlikely (Fink and Venkateswarlu, 1982). These levels of exchangeable K obtained in this study are generally adequate to support the production requirements of crops such as wheat, maize, rice, sorghum, and millet. Potassium, being one of the three primary nutrients, apparently its sufficient presence and its availability is a requisite for optimum crop production.The higher mean potassium content observed in the lower slope (Table 2) may be attributed to more intense weathering, release of labile K from organic residue and by the application of chemical fertilizers containing K (Sai Kumar *et al*., 2013).The mean sodium content of the studied soils ranged from 0.06 to 0.12cmol (+)/kg across the profiles (Table 2). The values of sodium content obtained in this study were therefore found to be low to medium (Esu, 1991). The upper slope recorded the highest Na content of 0.12cmol (+)/kg. This slightly higher exchangeable Na at the upper slope may be attributed to the capillary movement of water from the water table to the surface (Malgwi, 2001), aided by the climatic condition at the upper slope due to more exposure to solar radiation.

The mean total exchangeable bases (TEB) of the studied soils ranged from 6.12 to 22.16cmol (+)/kg across the profiles (Table 2). The value of total exchangeable bases obtained in this study was rated high to medium across the slope (Esu, 1991). Salem, *et al.*, (2017), also reported a medium to high value of TEB in their studies. The high to medium rate of TEB obtained in the study area may be linked to the parent material on which the soils are formed.The coefficient of variation of soil exchangeable bases (Table 2) along the toposequence, showed thatMg, K and Na recordedmoderate variation of 27, 25 and 20% respectively, while Ca and TEB recorded high variability. This is an indication that of all the exchangeable bases only Ca and TEB are highly influenced by the geomorphic nature of the study area.

Soil micronutrients of the study area

The mean Manganese (Mg) values ranged from 2.48 to 6.13 mg/kg across the slopes (Table 3). The values of Mn obtained in this study are generally low, according to Metson (1961). One of the main factors that determine Mn availability in soil is pH (Brady and Weil, 2014). According to Harmsen and Vlek (1985), a pH value of below 6.0 favours reduction of Mn and the formation of the more available divalent form (Mn^{2+}).The distribution of extractable iron (Fe) content in the study area showed that the mean Fe values ranged from 1.79 to 6.64 mg/kg across the slope, and was rated low to medium (Esu, 1991). Lombin and Esu (1987) also reported marginal to low level of Fe in the soils of the Nigerian savannah. The higher value of Fe obtained at the upper slope could be attributed to anthropogenic factor through organic matter addition (Brady and Weil, 2014).

The mean copper content of the studied soils ranged from 0.31 to 0.57 mg/kg across the slope (Table 3). The values of the soils copper (Cu) content obtained in this study were found to be generally low (Esu, 1991). Harmsen and Vleg (1985) pointed out that factors affecting the soils availability to provide Cu to plants include pH, humus content, and proportion of sand to clay. Also, the higher mean Cu content (0.57mg/kg) recorded at the lower slope position could be attributed to the higher organic matter content. The value of extractable Zn content of the studied soils ranged from 0.61 to 1.02 mg/kg across the slope (Table 3), and was generally rated low to medium according to Esu(1991). The low levels of Zn obtained in this study are similar to those obtained by

Maniyunda*et al.* (2017). There was also an observed increase in mean Zn content across the slope. The higher mean content of Zn in the lower slope (1.02 mg/kg) (Table 3) might be due to the associations of zinc with soil organic carbon.

TABLE 3: DISTRIBUTION OF SOIL MICRONUTRIENTS OF THE STUDY AREA

Horizon Designation (cm)	Horizon Depth	**Mn**	**Fe**	**Cu**	**Zn**
			(mg/kg)		
Upper Slope					
Ap	0-29	6.93	5.13	0.18	0.54
Bw1	29-67	5.29	6.15	0.34	0.66
Bw2	67-119	7.33	8.95	0.48	0.79
C	119-150	4.98	6.33	0.80	0.47
	Mean	**6.13**	**6.64**	**0.45**	**0.61**
Middle Slope					
Ap	0-17	2.75	1.45	0.23	0.84
Bt1	17-40	3.18	1.95	0.45	0.95
Bt2	40-110	2.25	2.13	0.38	0.63
C	110-135	3.16	1.63	0.17	0.45
	Mean	**2.84**	**1.79**	**0.31**	**0.72**
Lower Slope					
Ap	0-15	2.33	1.75	0.48	0.75
C	15-159	2.63	3.84	0.66	1.28
	Mean	**2.48**	**2.80**	**0.57**	**1.02**
	SD	1.91	2.60	0.20	0.25
	CV(%)	47	66	48	34

Earlier findings by other researchers have indicated that soil layers rich in organic carbon such as recorded at the lower slope have higher zinc concentrations (Shittu, 2013). FAO (1998) indicated that the critical levels for plant available Zn is 1.0mg/kg. Also, the coefficient of variation of soil micronutrients (Table 3) along the toposequence, showed that variability in soil Zn (34%) was found to be moderate, while Cu (48%), Mn (53%), and Fe (68%) showed high variability. This finding confirmed the effect of toposequence on soil content and distribution of Cu, Mn and Fe.

CONCLUSION AND RECOMMENDATION

Based on the result of the study, the soils were observed to be moderately to slightly acidic, low in OC, TN, and AP, while the exchangeable bases were also found to be generally medium. The micronutrients' contents (Zn, Fe, Cu and Mg) were found to be generally low. The results further indicated thatsoil properties, such as sand, silt, clay, OC, TN, AP, Ca, TEB, Cu, Mn and Fe are found to be highly variable and could easily be influenced by differences in physiographic positions.For sustainable agricultural production, management practices such as strip cropping and mulching, will help in controlling the flow of water across the toposequence. Also,addition of organic manures and chemical fertilizers containing especially N,P, and K should be adopted.Finally, periodic monitoring of the physical and chemical properties of soils of the study area should be carried out, so that appropriate and preventive measures could be embarked upon as at when due, for optimum agricultural productivity.

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