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RESEARCH ARTICLE

Characterization and classification of soils on grazing lands in Kwallatawa village, Sokoto State, Nigeria

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Abstract

Continuous extensive land use without proper land management has the potential to degrade the inherent soil fertility. Kwallatawa grazing lands are experiencing such exploitation which if not properly addressed, can dwindle their potentials. To address this, characterization and classification of the soils were carried out at reconnaissance level to assess the properties of the grazing soils. Two pedons were dug and described following FAO (2006) guidelines. The results show that pedons Gra P1 and P2 had shallow to slightly deep genetic horizons. They also show discernible colour pattern at both topsoil and subsoil layers. The pedons were sandy in texture with moderate bulk density (1.4 g Bd cm^{-3}) and low (<50%) to high (>50%) porosity at surface and subsurface horizons respectively. Similarly, the soils were moderately acidic (5.81 mean), low in organic carbon (2.3 g C/kg mean), CEC (5.37 $cmol_+$ CEC/kg mean) as well as high in total nitrogen (1.14 g N kg^{-1} mean), exchangeable sodium (>0.5 $cmol_+$ Na kg^{-1}) and percent base saturation (>80%). The Pedons Gra-P1 and P2 were respectively classified following USDA Soil Taxonomy as *Typic Ustipsamments* and *Lithic Ustipsamments*, and then subsequently correlated with WRB for Soils Classification as *Eutric Arenosols* (*Arenic*) and *Plinthic Arenosols* (*Arenic*). Our results revealed the soils to be acidic and fall within low to medium fertility class, as such liming and incorporation of organic residue were recommended to checkmate their deficiencies.

Keywords: Kwallatawa, Grazing lands, Pedons, Soil characterization, Classification

Introduction

Any direct anthropogenic activity that relates to land in terms of using its resources to derive goods and/or services or both, both within short and/or long term is referred to as land use. However, continuous extensive land use without proper land management has the potential to degrade its inherent soil fertility. Soils have been perceived and defined differently by different category of disciplines, here we perceived it, as that two- or three-dimensional natural entity possessing genetic horizons (2-dimensional body) or layers (3-dimesnional body) emanating from minerals or organic materials or both, that are of different thickness, with distinct features from their precursors biologically, chemically, mineralogically, morphologically and physically (Birkeland, 1999). The divergent behaviours exhibited by different soil types could be specifically attributed to the variability in their biological, chemical, mineralogical, morphological and physical characteristics. Broadly, the differences could be attributed to the influence of the soil forming factors and soil forming processes acting upon the soils parent material (Soil Survey Staff, 1993). Hence, the characteristics of soils on our farms, gardens, airports, recreational sites, forests, orchards, schools, septic and sewage disposal system and those around our houses, roads, shopping canters differed and exert varying influence on our pursuits. Therefore, these soils have to be treated as special and separate entities (Broderson, 2000).

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Nigeria has an estimated land area of 92, 377, 000 hectares (or 923, 770 km^2) with an estimated population of around 206.14 million inhabitants (Statista, 2020). According to Asadu *et al.* (2004), land use differs from one locality to another owing to differences in norms and values of the localities. Majorly, these revolved around agricultural (such as irrigation, orchard, forests, aquaculture etc), industrial (such as oil mining, coal and gold mining etc) and infrastructural (such as roads, schools, hospitals etc) land uses. Asadu et al. (2004) reported that of the total land mass of Nigeria, ~65% was devoted to food and forest sectors distributed into 42% (crop production), 21% (open grazing and livestock projects), <2% (plantation) and <1% (cultivation of denuded areas). However, FAOSTAT (2014) reported that Nigeria's total land mass (FAO, 2014) includes 33% (permanent meadows and pasture), 37% (arable land), 7% (permanent crops) and 7% (forests). According to Asadu et al. (2004), available data between 1976-1995 revealed drastic shrinkage in land mass by 16, 13, >400% and >150% under crop, grazing and livestock, plantation and denuded areas respectively leading to increase by >500% and >1,000% areas under sand dunes, and under gullies and salty marsh respectively. That is why Olagunju (2015) opined that about 64 percent of Nigerian total land mass is prone to desertification, which could be ascribed to consequential effects of overgrazing (FAO, 2018).

The fringes of Kware town is blessed with vast potentially cultivable land under different land utilization types such as rainfed arable farming, irrigated arable cultivation, open grazing lands, orchard plantation among others. The soils being closer to the town are exposed to extensive use, which if not properly controlled, has a potential of degrading the fertility of the soils. Soil and land use and management studies will help in averting these situations. Evaluation of land performance for a given purpose such grazing is however, the answer. This is because evaluation provides information necessary for the understanding of soil properties and their response to a given use which is essential in addressing the issue relating to the transformation and sustainability of agro-ecosystem (Yao *et al.,* 2010). Although, some studies relating to the soils of Sokoto state have been conducted (Noma and Gabasawa, 2005; Noma et al. 2005; Yakubu, 2006; Sharu et al. 2013; Lukman et al. 2014), none of such studies focused on the potential of grazing soils of Kware Local Government. Therefore, the objective of this study was to characterize, classify the soils of the area in addition to highlighting some of the effects of grazing on the soil characteristics.

Materials and Methods

1- Study Site

This study was carried out at Kwallatatawa village, Kware Local Government area, Sokoto, Nigeria. Kware is located between latitude 13^0 0` 0`` to $13^0$ 20` 0`` N and longitude 5^0 10` 0`` to $5^0$ 30` 0`` E with an area of 554 km^2 (Latitude, 2016). Kwallatawa is located between latitude 13^0 12` 22.87`` to $13^0$ 12` 36.06`` N and longitude 5^0 12` 49.49`` to $5^0$ 12` 0.00`` E (Figure 1). The area has tropical climate characterized by an average rainfall of 565 mm/year (NMA, 2011). The minimum temperature is 27 ^{0}C while the maximum temperature is 40 ^{0}C (NMA, 2011). It has relative humidity of about 15-20% during dry season and reaches up to 70-75% during the rainy season. Agriculture especially crop and livestock production are the dominant activities engaged by the people of Kwallatawa villages. Other land uses include residential, quarry, mining and roads construction etc. The dominant underlying geology of the study area is Cretaceous and Tertiary sediments (Sombroek and Zonneveld, 1971). The vegetation is typical of Sudan zone, characterized by savannah woodland and shrub savannah.

2- Field Work

Two (2) farmers plots located at Kwallatawa village were purposely selected for the study. The farms were reserved for over 20 years for grazing. The general site description such as climate, vegetation, land use, slope gradient, drainage type and condition, type and degree of erosion and depth to ground water table were recorded. Two profile pits (2 x 1.5 x 2 m) were dug and described morphologically following FAO (2006) guidelines. For each profile, depth, colour, texture, structure, consistence, roots, pores, inclusions, as well as boundary characteristics were recorded. The coordinates of the study area pedons were recorded using global positioning system (GPS) device.

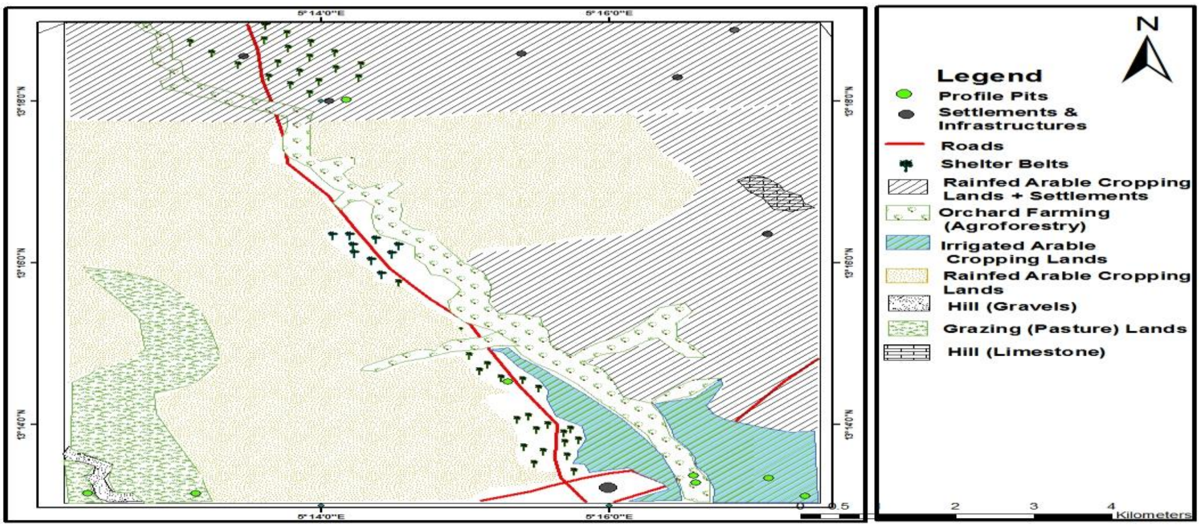

Figure 1: A map showing different land use types and location of grazing lands

3- Samples Collection and Preparation:

Both disturbed and undisturbed soil samples were taken from each genetic horizon of the two pedons. Undisturbed soil samples for bulk density determination were taken with core samplers of known volume, whereas disturbed samples for physical and chemical parameters determination were taken in nylons, labelled accordingly and transported to the laboratory. The undisturbed soil samples were oven dried for 48 hours at 105 ^oC. Disturbed soil samples on the other hand, were air-dried for 48 hours and ground to pass through 2 mm sieve.

4- Laboratory Analyses

The prepared soil samples were analyzed for particle size distribution following Bouyoucos Hydrometer (ISRIC/FAO, 2002) method. Bulk density was determined as described by Blake and Hartge (1986). Particle density was determined following Black (1965) Pycnometer bottle method. Total porosity was extrapolated using the particle and bulk density values as shown in the equation below:

$$P = 1 - [\frac{Bd}{Pd}] \times 100 \quad (1)$$

$$Bd = \frac{Weight\ of\ ovendried\ soil\ sample\ at\ 105^oC}{Total\ Volume\ of\ fresh\ soil\ sample} \quad (2)$$

where, P is porosity, Bd is bulk density (g cm^{-3}), Pd is particle density (%) of the soil

A glass electrode pH meter was used to determine soil pH both in water and 0.01 M $CaCl_2$ with 1:2.5 soil to liquid ratio (Thomas, 1996). Nelson and Sommers (1996) wet oxidation method was followed to determined organic carbon. Total nitrogen, available phosphorus and CEC were respectively determined using the Micro-Kjeldahl digestion and distillation method (Bremner, 1996), Bray No. 1 method and determined using molybdenum blue method (Kuo, 1996) and the neutral ammonium acetate saturation method buffered at pH 7 (ISRIC/FAO, 2002). Neutral 1 N NH_4OAC saturation method was used to determine exchangeable bases (ISRIC/FAO, 2002). After the extraction, atomic absorption spectrophotometer (AAS) was used to read Ca and Mg, and Flame Photometer was used to read K and Na. Percentage base saturation of the soils was extrapolated using the following equation:

$$PBS = \frac{\sum(Ca,\ Mg,\ K,\ Na)}{CEC} \times 100 \quad (3)$$

where; PBS is percent base saturation (%), CEC is cation exchange capacity ($cmol_+\ kg^{-1}$)

5- Data Analysis

The data obtained were subjected to descriptive statistics such as mean, range and percentage using Excel (2016).

Results and Discussions

1- Morphological properties

The morphological characteristics of Pedons Gra P1 and P2 under grazing lands are presented in Table 1. Both pedons of the grazing land had shallow to slightly deep (Gra-P2; 76 cm and Gra-P1; 120 cm) profiles. Pedon Gra-P1 had four genetic soil horizons (A-BA-BC1-BC2), Pedon Gra-P2 consisted of two horizons (A-BC-2C). The surface layers were formed from deposition and accumulation of humified organic materials from grasses as observed by Dessalegn et al. (2014) and gravels from weathered rock residua, which contributed immensely to the surface roughness of the land (Plate 1). The study is not at far with Dessalegn et al. (2014) in that subsurface layers were formed due to wet-dry cycles that aggregated clay-textured soil particles into blocky peds, since it is crystal clear that there was no evidence of structural formation (Plate 1 and 2).

The pedons had shown discernible variations in the colour patterns at both surface and subsoil. The colours differed from strong brown (7.5YR4/6) to yellow red (5YR5/8) dry in Pedons Gra P1 and P2 surface layers respectively (Table 1) depicting the influence of topography, location, weathering and parent material. The colour of the subsurface horizons ranged from yellowish red (BA and BC1) and pinkish white (BC2) to red (BC) in Pedon Gra P1 and P2 subsurface layers respectively. From this result, it can be deduced that the soils had low organic matter content contradicting Chimdi et al. (2012) findings that, grazing land were high organic matter content when compared with cultivated lands, which they attributed to lower surface area and presence of higher Fe and Al oxides contents due to highly weathered nature of cultivated soils.

The results (Table 1) revealed that both Pedons had similar horizon thickness, horizon boundary and soft soil structure ranging from weak medium crumb in the surface layers to structureless at the subsurface layers. The result also did not show great variability in relation to soil texture, indicating the similarity in parent material.

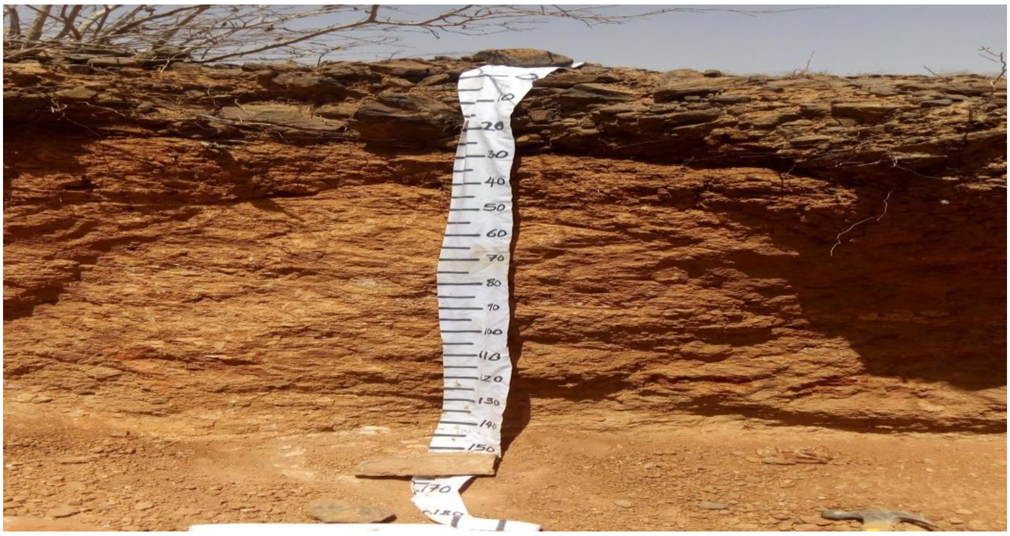

Plate 1: Pedon Gra-P1 showing horizons and gravelly surface horizon

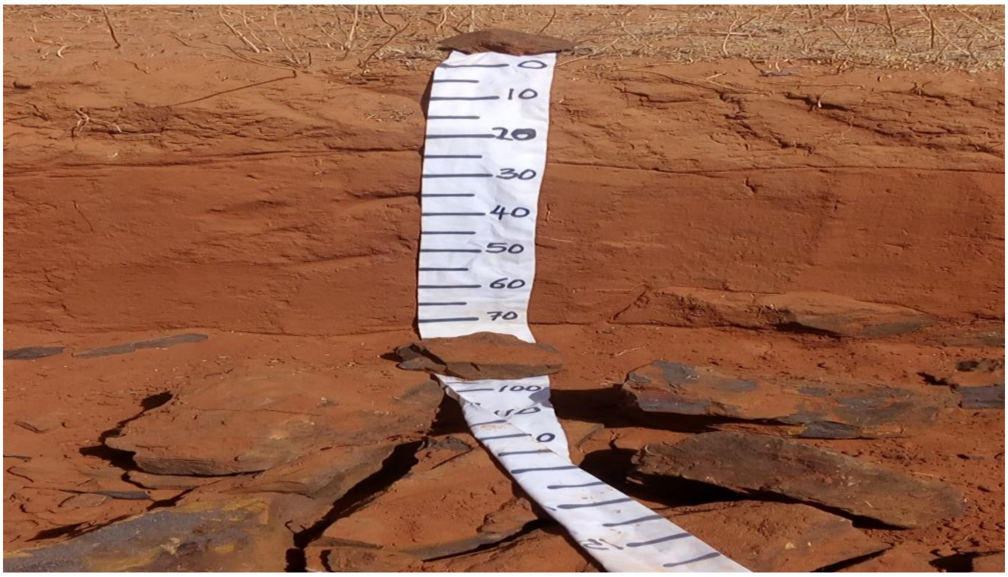

Plate 2: Pedon Gra-P2 showing impermeable layer with plinthic materials

Table 1: Morphological Properties of Pedons Gra P1 and P2

Horizon	Depth (cm)	Colour	Texture[1]	Structure[2]	Consistence[3]	Boundary[4]	Other Features[5]
Kwallatawa Series- Pedon Gra P1 (Typic Ustipsamments/Eutric Aresonols (Arenic)							
A	0-29	7.5YR4/6	S	wmc	s	ds	mfmr, mfp, mmcf
BA	29-54	5YR5/6	S	wmc	s	ds	mfmr, mmp, ffcf
BC1	54-83	5YR4/6	S	Structureless	s	ds	fmr, mmp, ffcf
BC2	83-120+	5YR8/2	S	Structureless	s	ds	fmr, mmp, ffcf
Kwallatawa Series- Pedon Gra P2 (Lithic Ustipsamments/Plinthic Aresonols (Arenic)							
A	0-26	5YR5/8	S	wmc	s	ds	mmr, ffp, mmcf
BC	26-76	2.5YR4/6	S	Structureless	s	dw	fmr, ffp
2C	>76	Plinthic layer, indurated					

[1]S= sand, [2]wmc= weak medium crumb, [3]s= soft, [4]ds= diffuse soft, dw= diffuse wavy, [5]mfmr= many fine and medium roots, fmr= fine medium roots, mmr= many medium roots, mfp= medium fine pores, mmp= many medium pores, ffp= few fine pores, mmcf= many medium coarse fragments, ffcf= few fine coarse fragments

2- *Physical properties*

The soil texture was generally sandy (Table 2) both at the topsoil and subsoil layers of both pedons. The topsoil layers of Pedons Gra P1 and P2 has sand contents that ranged between 89.6 to 91.6 % (90.6% mean) and was rated high. The silt and clay values of the soils ranged from 1.4 to 5.9% (3.7%) and 2.5 to 9.0% (5.8%) respectively and were rated very low. For the underlying horizons, the sand, silt and clay contents varied from 89.6 to 91.6% (90.6%), 1.4 to 5.9% (3.7%) and 2.5 to 9.0% (5.8%) respectively. The results have agreed with the findings by DAFF (2013) and Rueda et al. (2020) who observed that the most suitable soils for pasture and grazing are sandy soils, loamy soils or clay soils. However, the sandy nature of the soils could be ascribed to the nature of the parent materials.

The Bd values of the surface horizons of Pedons Gra P1 and P2 ranged from 1.3 to 1.4 gcm^{-3} (1.4 $g\ cm^{-3}$ mean) and was rated moderate. In the subsurface horizons, bulk density values varied from 1.3 to 1.5 gcm^{-3} (1.4 $g\ cm^{-3}$ mean) and was also rated moderate (Table 2). The moderate bulk density values could be ascribed to the sandy nature of the soils and paedogenic processes taking place therein. Our results were in line with that of Sonneveld (2005), who observed that, bulk density of the soils of the Northern region of Nigeria is about 1.4 gcm^{-3}. This result has further indicated low stocking rate or generally low grazing activities taken place on the soils, as their bulk densities are still below the critical value of 1.6 gcm^{-3} that can hinder proper growth and development of grazing pasture.

Total porosity followed similar trend with bulk density (Table 2). In the surface horizons of Pedons Gra P1 and P2, the total porosity varied from 43 to 46% (45%) and was rated low. For subsurface horizons, total porosity ranged from 51 to 60% (56%) and was rated high. The eroded soil particles that filled the pore spaces could have led to the moderate bulk densities (1.4 gcm^{-3}) and lower total porosity (43 and 46%) observed in the horizons of both pedons.

Table 2: Physical Properties of Pedons Gra P1 and P2

Horizon	Depth (cm)	Particle Size Distribution (%)			Textural Class	Bd	Pd	Porosity (%)
		Sand	Silt	Clay		gcm^{-3}		
Kwallatawa Series- Pedon Gra P1 (Typic Ustipsamments/Eutric Aresonols (Arenic)								
A	0-29	89.6	1.4	9.0	S	1.3	2.6	46
BA	29-54	89.6	1.4	9.0	S	1.3	2.5	56
BC1	54-83	91.6	5.9	2.5	S	1.4	2.4	58
BC2	$83\text{-}120^{+}$	91.6	5.9	2.5	S	1.5	2.5	60
Kwallatawa Series- Pedon Gra P2 (Lithic Ustipsamments/Plinthic Aresonols (Arenic)								
A	0-26	91.6	5.9	2.5	S	1.4	2.5	43
BC	26-76	91.6	5.9	2.5	S	1.5	2.6	51
2C	>76	Plinthic layer, indurated						
Mean		90.9	4.4	4.7	S	1.4	2.5	52
SE		2.71	1.39	2.21	-	0.08	0.04	3.12

SE= standard error, S= sand, Bd= bulk density, Pd= particle density

3- *Chemical properties*

pH values of the surface horizons of Pedons Gra P1 and P2 ranged from 5.76 to 5.85 (5.81 mean) and was rated moderately acidic. For underlying horizons, pH values varied from 5.48 to 5.75 (5.62 mean) and was also rated moderately acidic (Table 3). Similar pH values were previously reported from cattle grazing system (Rueda et al. 2020). The pH values appeared similar among the Pedons Gra P1 and P2 and did not vary much with depth. The EC values in the surface horizons of Pedons Gra P1 and P2 varied between 0.01 to 0.05 (0.02 dS m^{-1} mean) and was rated low. According to Horneck *et al.* (2008), pH values between 6-7 were the ideal pH range for pasture, though pasture plants can withstand a wide range of soil pH. However, grass yields are usually reduced when soil pH drops below 5.1. This shows that the pH (water) of these soils (Table 3) are good for pasture grass as it does not fall below the critical value of 5.1 and did not exceeds 7.0.

The OC content of the topsoil soils ranged from 0.60 to 3.99 g C kg^{-1} (2.30 g C kg^{-1} mean), which is generally low. For the underlying soils, OC content varied from 0.98 to 4.40 g C kg^{-1} (2.69 g C kg^{-1}) and was also rated low (Table 3). The low OC could be attributed to the low organic matter and texture of the soils. Correlation analysis showed insignificant negative relationship between sand and silt contents with OC (r = -0.805, P>0.05) contents, and also between OC and soil pH (r = -0.299, P>0.05) (Table 4). The low OC values were not similar with that obtained by Chimdi et al. (2012) and Dessalegn et al. (2014) who observed significantly higher OC values in grazing land as compared to other land use types.

Total nitrogen content in the surface horizons of Pedons Gra P1 and P2 ranged from 0.88 to 1.39 g N kg^{-1} (1.14 g N kg^{-1} mean) which was rated high. For the subsurface horizons, TN values varied between 0.97 to 3.16 g N kg^{-1} (2.07 g N kg^{-1} mean) and were also rated high (Table 3). The total nitrogen content of the soils varied irregularly with depth. Chimdi *et al.* (2012) observed similar values under grazing land, contrary to Horneck et al. (2008)

who opined that, nitrogen is the most deficient nutrients in many grass pasture soils, since the grasses used it the most as compared to other nutrients.

The available phosphorus content in the surface horizons of Pedons Gra P1 and P2 ranged from 11.69 to 20.36 mg P kg^{-1} (16.03 P mg kg^{-1} mean) and was rated medium. For the subsurface horizons, available phosphorus content varied from 7.54 to 28.28 mg P kg^{-1} (17.91 mg P kg^{-1} mean) and was also rated medium (Table 3). The low available phosphorus values (7.54 mg P kg^{-1}) observed in Pedon Gra-P1 could be attributed to P-fixation. According to Mishra *et al.* (2004), lower available P values in grazing land may be due to lower soil organic matter status. Correlation analysis indicated negative but insignificant relationship between available phosphorus (r = -0.546, P>0.05) and organic carbon (Table 4).

The exchangeable bases contents in the topsoil horizons of Pedons Gra P1 and P2 ranged from 2.00 to 4.81 $cmol_+$ Ca kg^{-1} (3.41 $cmol_+$ Ca kg^{-1} mean), 0.68 to 0.70 $cmol_+$ Mg kg^{-1} (0.69 $cmol_+$ Mg kg^{-1} mean), 0.03 to 0.08 $cmol_+$ K kg^{-1} (0.06 $cmol_+$ K kg^{-1} mean) and 0.55 to 0.99 $cmol_+$ Na kg^{-1} (0.77 $cmol_+$ Na kg^{-1} mean) respectively. For the underlying horizons, Ca, Mg, K and Na content varied from 2.95 to 4.59 $cmol_+$ Ca kg^{-1} (3.77 $cmol_+$ Ca kg^{-1} mean), 0.38 to 0.65 $cmol_+$ Mg kg^{-1} (0.51 $cmol_+$ Mg kg^{-1} mean), 0.03 to 0.05 $cmol_+$ K kg^{-1} (0.04 $cmol_+$ K kg^{-1} mean) and 0.57 to 0.94 $cmol_+$ Na kg^{-1} (0.76 $cmol_+$ Na kg^{-1} mean) respectively. The exchangeable bases complex of the soils (Table 3) is dominated by Na in the following sequence Na>Ca>Mg>K i.e. the least in abundance is potassium. The low K could be attributed to imbalance between nutrient loss via crop removal and those applied via fertilizers.

The cation exchange capacity in the surface horizons of Pedons Gra P1 and P2 varied from 3.70 to 6.80 $cmol_+$ CEC kg^{-1} (5.25 $cmol_+$ CEC kg^{-1} mean) and was rated low. For the underlying horizons, CEC values ranged 4.80 to 6.20 $cmol_+$ CEC kg^{-1} (5.50 $cmol_+$ CEC kg^{-1} mean) and was also rated low (Table 3). The low CEC values could be due to texture and low OC content (Tables 2 and 3) of the soils. The result contradicts that of Mganga et al. (2011) who recorded high CEC values (up to 19.59 $cmol_+$ CEC kg^{-1}) in an open grazing land. Soils with cation exchange capacity of <16 $cmol_+$ kg^{-1} are considered not to be fertile and such soils are highly weathered while fertile soils have a cation exchange capacity of >24 $cmol_+$ kg^{-1}.The result shows that these soils are not fertile judging by their CEC values.

The base saturation of the soils was generally high (Table 3), ranging from 88.65 to 96.47% (92.56% mean) in the surface horizons of Pedons Gra P1 and P2. For the subsurface horizons, percent base saturation varied from 92.22 to 96.67% (94.45% mean). The percent base saturation was similar for both Pedons Gra P1 and P2. The high base saturation observed could be ascribed to the inherent characteristics of the parent materials. In this result, insignificant negative relationship between base saturation and soil pH (r = -0.521, P>0.05) was observed (Table 4).

4- Soil Classification

The soils were classified following the United State Department of Agriculture (USDA) Soil Taxonomy System guidelines (USDA-NRCS, 2010) which was later Correlated with World Reference Base

Table 3: Chemical Properties of Pedons Gra P1 and P2

Horizon	Depth (cm)	pH (1:2.5) Water	EC dSm^{-1}	OC (gkg^{-1})	TN (gkg^{-1})	AP $mgkg^{-1}$	Ca (cmol+ kg-1)	Mg (cmol+ kg-1)	K (cmol+ kg-1)	Na (cmol+ kg-1)	CEC (cmol+ kg-1)	BS (%)
Kwallatawa Series- Pedon Gra P1 (Typic Ustipsamments/Eutric Aresonols (Arenic)												
A	0-29	5.76	0.01	3.99	1.39	11.69	4.81	0.68	0.08	0.99	6.80	96.47
BA	29-54	5.69	0.01	4.40	3.16	13.20	4.59	0.45	0.05	0.83	6.20	95.48
BC1	54-83	5.48	0.05	3.40	1.08	13.95	4.15	0.38	0.04	0.94	5.70	96.67
BC2	83-120+	5.54	0.01	1.60	0.97	7.54	2.95	0.62	0.05	0.82	4.80	92.50
Kwallatawa Series- Pedon Gra P2 (Lithic Ustipsamments/Plinthic Aresonols (Arenic)												
A	0-26	5.85	0.01	0.60	0.88	20.36	2.00	0.70	0.03	0.55	3.70	88.65
BC	26-76	5.75	0.01	0.98	2.35	28.28	3.73	0.65	0.03	0.57	5.40	92.22
2C	>76	Plinthic layer, indurated										
Mean		5.68	0.03	2.50	1.64	15.84	3.71	0.58	0.48	0.78	5.43	93.67
SE		0.19	0.02	0.95	0.32	3.17	2.08	0.13	0.03	0.15	2.16	0.94

SE= standard error, pH= soil reaction, EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, AP= available phosphorus, $CaCl_2$= calcium chloride, Ca= calcium, Mg= magnesium, K= potassium, Na= sodium, CEC= cation exchange capacity, Mg= magnesium, BS= base saturation

Table 4: Correlation (r) Analysis of the Soils of Kwallatawa Series Pedons Gra P1 and P2

	Sand	Silt	Clay	Bd	Por	pH	OC	TN	AP	Ca	Mg	K	Na	CEC	BS
Silt	1.000**														
Clay	-1.000**	-1.000**													
Bd	-0.204	-0.204	0.204												
Por	0.151	0.151	-0.151	-0.972**											
pH	-0.256	-0.256	0.256	0.925**	-0.902*										
OC	-0.805	-0.805	0.805	-0.273	0.277	-0.299									
TN	-0.537	-0.537	0.537	-0.042	0.159	0.187	0.397								
AP	0.356	0.356	-0.356	0.518	-0.463	0.541	-0.546	0.267							
Ca	-0.723	-0.723	0.723	-0.142	0.243	-0.231	0.873	0.539	-0.226						
Mg	0.088	0.088	-0.088	0.764**	-0.696	0.709*	-0.598	-0.294	0.284	-0.462					
K	-0.763	-0.763**	0.763**	0.113	-0.052	-0.033	0.683	-0.011	-0.648	0.628	0.097				
Na	-0.531**	-0.531	0.531**	-0.399	0.395	-0.567	0.842	-0.079	-0.776	0.715	-0.475**	0.789			
CEC	-0.758	-0.758	0.758	-0.077	0.189**	-0.188	0.859	0.478	-0.279	0.989	-0.349**	0.726	0.744		
BS	-0.573	-0.573	0.573	-0.383	0.429	-0.521	0.905	0.275	-0.461	0.927	-0.631	0.630	0.891	0.911	
EC	-0.632	-0.632	0.632	-0.258**	0.263	0.040	0.571	0.812	-0.175	0.407	-0.481	0.088	0.124	0.345	0.285**

Bd= bulk density, Por= porosity, OC= organic carbon, TN= total nitrogen, AP= available phosphorus, Ca= calcium, Mg= magnesium, K= potassium, Na= sodium, CEC= cation exchange capacity, BS= base saturation, EC= electrical conductivity

(WRB) for Soil Resources (WRB-IUSS, 2014).

4.1 Classification following USDA Soil Taxonomy:

Kwallatawa Series: These soil units were classified at order level as *Entisol*, because they did not fit into other soil orders of USDA system. At suborder level soils of Kwallatawa series were classified as *Psamments*, because of their sandy nature. They were further classified as *Ustipsamments* at great-group level due to Ustic moisture regime. However, at subgroup level:

- Kwallatawa Series (Gra-P1): it was categorized as *Typic Ustipsamments*, for not fitting into other subgroups of the order Entisols.
- Kwallatawa Series (Gra-P2): was classified as *Lithic Ustipsamments* due to lithic contact it posses within the 50 cm.

4.2 Correlation with WRB for Soil Classification:

- Kwallatawa Series (Gra-P1): Having a soil texture class of loamy sand, this soil unit was at RSG of WRB system classified as *Arenosols*. Having a base saturation (NH_4OAC buffered at pH 7) above 50 percent, it was ascribed to *Eutric Arenosols*. It was further classified as *Eutric Arenosols* (*Arenic*) at supplementary qualifier level, since it shows a texture class of sand in a layer >30 cm thick but within <100 cm.
- Kwallatawa Series (Gra-P2): Being predominantly sandy in nature, this soil unit was classified as *Arenosols* at RSG level of WRB system. Also, having a plinthic layer that started <100 cm from the topsoil, it was ascribed to *Plinthic* principal qualifier. Furthermore, the soils shows a textural class of sand within <100 cm of the mineral soil surface, it was further categorized as *Plinthic Arenosols* (*Arenic*) at supplementary qualifier level.

Conclusion

The result showed that the grazing lands had soils from weathered rock residua and aeolian sand and were also well-drained. The pedons of the grazing lands had shallow to slightly deep layers with different genetic horizons designations and discernible colour pattern but similar soil structure, depicting the influence of topography, location, weathering and parent material. Soils of grazing lands were sand in texture. Bulk density values of the grazing lands were below the critical value (1.6 g Bd cm-3). The soil units studied were low in organic carbon content and were moderately acidic. The available P values of the soils was rated medium across the soil profile. The soils were generally of low fertility class, except for exchangeable sodium and percent base saturation, which were observed to be high. The electrical conductivity of the soils across the grazing land were generally low. The soil was also found to be high in total N.

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