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Soil Properties and Fertility Potentials for Arable Crop Production in the Drylands of Northern Nigeria

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ABSTRACT

This study examined soil fertility potentials for arable crop production in parts of Northern Guinea and Sudan savanna agroecological zones of Nigeria for optimal land use. Five physiographic units were identified in four (4) local government areas each of Kano and Kaduna states and named based on the landforms characteristics as low land plains (LLP), undulating plains with group hills (UPH), gently undulating sandy plains (GUSP), extensive sandy plains (ESP) and upland plains (UP). In each of the physiographic units, fifteen surface (0 – 15cm) and subsurface (15 - 30cm) soil samples were systematically collected and analyzed for soil physical and chemical parameters essential for arable crop production. Also, a representative soil profile was opened in each unit. The results showed that the soil pH values were within the optimal ranges required for arable crop production (5.5 – 7.0). Soil fertility parameters such as organic carbon, total nitrogen, electrical conductivity, ECEC and exchangeable bases were low in the soils except available P. The results also revealed that the values of exchangeable sodium percentage (ESP) in all the five soil units were below the critical limit for sodicity. However, better ways of fertility management such as addition of organic matter and post-harvest incorporation of plant residues into the soil is highly recommended.

Key Words: Soil Properties; Fertility Potentials; Arable Crops; Dryland; Ecological Zones

INTRODUCTION

The soil resource of any country is its most valuable natural resource that requires careful management for sustainable development. Soil information is required for soil-related agro-technology transfer, the basis for the planning and execution of sustainable agricultural land use and development and other non-agricultural projects (Braimoh, 2002; Raji *et al.*, 2013). Soil is a finite resource such that its loss and degradation is not recoverable within a human lifespan. As a core component of land resources, agricultural development and ecological sustainability, it is the basis for food, feed, fuel and fiber production and for many critical ecosystem services. It is therefore a highly valuable natural resource, yet it is often overlooked. Soils need to be recognized and valued for their productive capacities as well as their contribution to food security and the maintenance of key ecosystem services (FAO, 2015).

The need for a good knowledge of soil and land resources is as old as agriculture itself. Soil is a vital natural resource on whose proper use determines efficiency of the life supporting systems and socio-economic development (Dhar *et al.*, 1988 and Jha *et al.*, 2002). Therefore, sustainable crop production and the issue of the protection of soil resources require proper understanding of soil resources and their limitations, as well as allocation of land units to uses that are not adversely affected by the limitations posed by the land area (Orimoloye, 2016).

The nature and properties of soils can vary widely from one location to the next, even within distances of a few meters. These same soil properties can also be found to exhibit similar characteristics over broad regional areas of like climate and vegetation (Holden, 2011). Therefore, analysis and forecast of the spatial distribution and dynamics of soil properties is an important element of sustainable land management (Adhikari and Hartemink, 2016).

In Nigeria agriculture is the predominant economic activity and because of the need to increase food production to feed the ever-increasing human population and to diversify the export base of the country, agricultural production is more recognized now than ever before (Adamu, 2014). This perhaps turned the attention of both farmers and government to more exploitation of soil resources.

Crop production remain the major economic activities in the dryland of northern Nigeria. The economy of the area is based on arable cropping of both irrigation and rain-fed, and livestock rearing. The rain-fed cultivation occupies nearly 90% of the area under agriculture and is based on the production of crops which are susceptible to draught (Mortimore and Adams, 1998). There, the staples are millet, cowpea, and guinea corn. Corn is also cultivated, as well as rice in suitable lowland areas (National Programme for Agriculture and Food Security, 2010; Adamu, 2014). However, most Nigerians eat grains, but the production and consumption of sorghum (guinea corn) and millet are heavily concentrated in the savanna north. In 1980, the two grains accounted for 80 percent of Nigeria's total grain production (NSPFS, 2010).

To achieve sustainable crop production and protection of soil resources in the study area and the entire country at large, requires a proper understanding of the soil resources and limitations as well as allocation of land units to uses that are not adversely affected by the limitations posed by the land area.

MATERIALS AND METHODS

Study Area

The study area covered an area of about 4,205.57 square kilometers, between latitudes $11^0 2'23''$N and $11^0 32'47''$N and longitudes $7^0 54'21''$E and $8^0 35'45''$E, in the dryland of northern Nigeria (figure 1). It constituted a soil block that cuts across two agro-ecological zones (i.e sub-humid and semi-arid ecological zones) of northern Nigeria, comprising some parts or whole of four local government areas from Kano state (Bebeji, Kiru, Rano and Tudun Wada) and four local government areas from Kaduna state (Ikara, Makarfi, Kubau and Soba local governments). The area is selected because it is zone of high production of different arable crops, especially cereal crops such as millet, rice, maize, guinea corn, and legumes such as groundnut, beans, peanut, and soya beans. Also, important tubers such as sweet potato and cocoa yam are grown in these areas. In the dryland of northern Nigeria, dry season lasts for five to seven months, during which less than twenty-five millimeters of rainfall is received, and it lies mostly in the Sudan savanna and the arid Sahel zone.

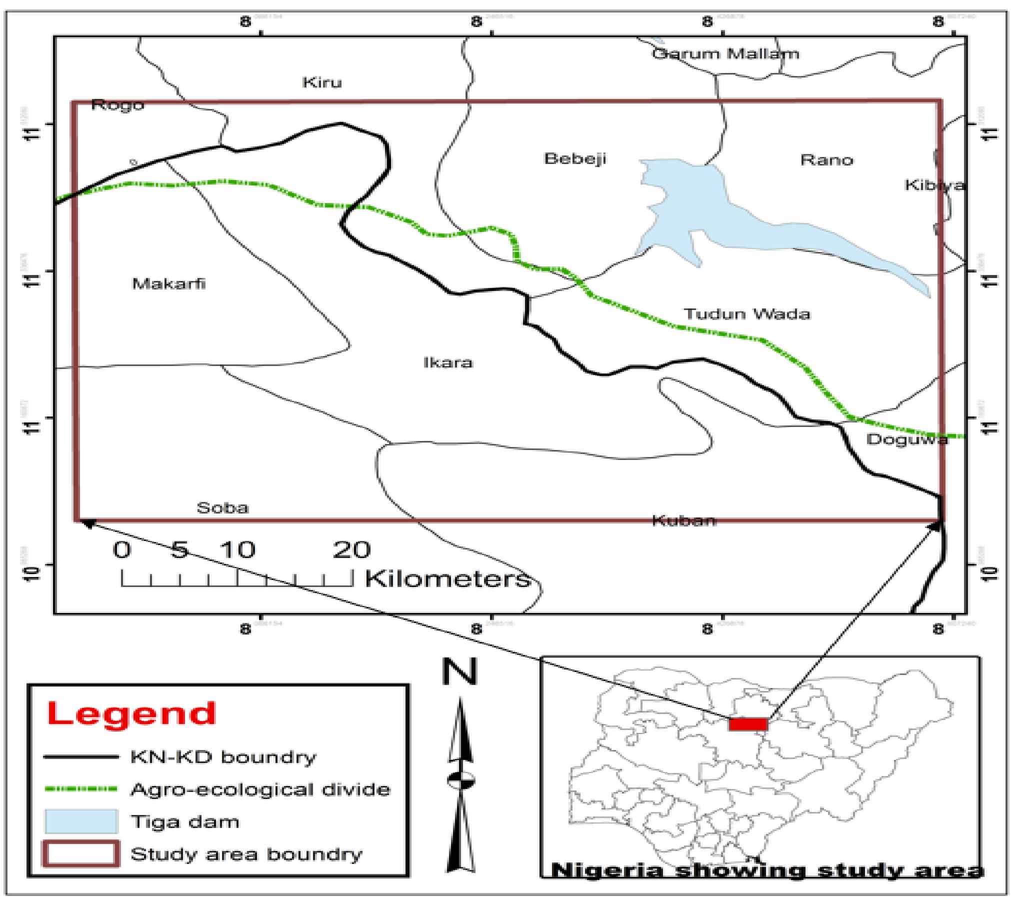

Figure 1: Study area, covering parts of northern Guinea and Sudan Savanna

Physiographic Sub-division of the Area

The physiography of the studied area was identified based on the Landsat L8 OLI/TIRS images, the Digital Elevation Model (DEM), slope map (figure 2) and extensive field work. Based on these and the analytical data (Table 1), five physiographic units were identified and mapped. The five physiographic units were named; Low land plains (LLP), Undulating plains with group hills (UPH), gently undulating sandy plains (GUSP), Extensive sandy plains (ESP) and Upland plains (UP) (Figure 3). These were further classified according to USDA soil taxonomy classes (2010) as *Typic Endoaqualfs, Typic Hapludalfs, Vertic Epiaqualfs, Typic Endoaquerts and Entic Endoaquerts* respectively (Table 1).

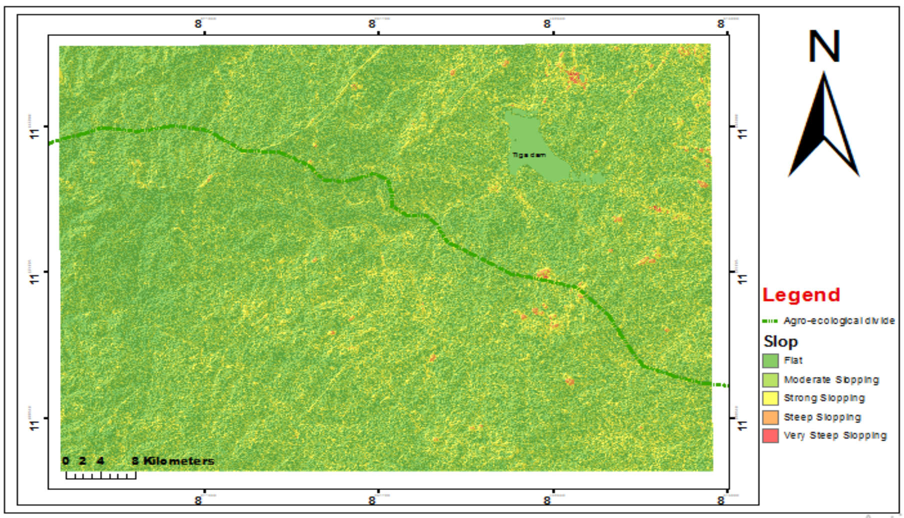

Figure 2: Slope map of the study area

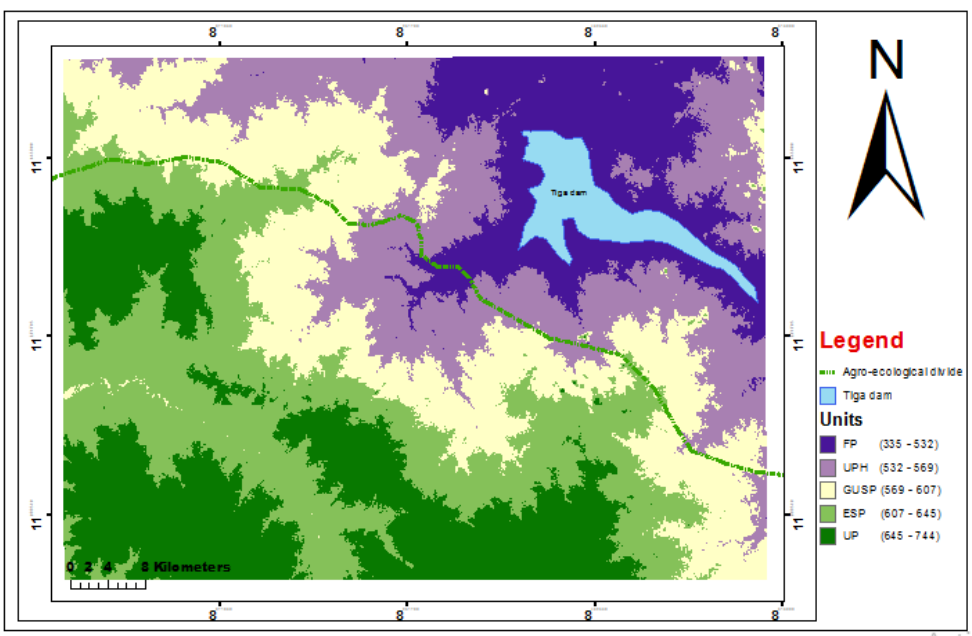

Figure 3: Physiographic units map of the study area

Soil Sampling Technique

Systematic sampling technique was employed in the collection of soil samples for this study. In each of the physiographic unit, 15 sampling points were identified making a total of 75 sampling points. In each sampling point, 2 soil samples were collected; surface soil samples (0 – 15 cm) and subsurface (15 – 30 cm) as demonstrated by Akpovwovwo (2014). Therefore, 150 samples were collected into a well labelled cotton bag container using soil auger.Also, in each of the physiographic units identified a representative soil profile of 1m^2 1m deep was opened. Based on the number of horizons identified in each of the profiles, a total of 19 soil samples were collected. This was done to enable comparison with soil taxonomy (USDA) and World Reference Base (WRB) soil classification systems. To this end, a total number of 167 soil samples were collected in the study area for laboratory analysis.

Laboratory Analysis of Soil Samples

The pH was measured in a 1:2.5 soil/water suspension (Thomas, 1996) using pH meter (Model 300408.1) which was calibrated using two buffer solutions, pH 4 and 7. Electrical Conductivity was measured using conductivity meter and texture was analyzed by the hydrometer method as described by Gee and Bauder, (1986) and Eno *et al.* (2009). Soil color was determined using Muncell color chart. Organic carbon content of the soils was determined by the modified Walkley-Black method as described by Nelson (1982). Total nitrogen, sulphur, and carbon were determined using CHNS analyzer.

Mehlich 3 extraction method (2016) was used in the digestion and extraction of soils. The filtrates were used to analyzed the following parameters; Phosphorus (P), Aluminum (Al), Iron (Fe), Zinc (Zn), Cupper (Cu), Manganese (Mn), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) using **Microwave Plasma Atomic Emission Spectrophotometer (4210 MP – AES)**.

Data Analysis

The analytical results obtained on each soil sample from the laboratory and the field measurement of morphometric land characteristics were subjected to basic descriptive statistics such as mean, range, standard deviation and the graphical presentations of the results using spread sheet (MS Excel 2013) and JMP statistical software version 14.0. Coefficient of variation and analysis of variation (ANOVA) was used to determine the variation among soil sampling points and units in the study area respectively.

RESULTS AND DISCUSSION

Morphological Characteristics of Soils in the Mapping Units

Summary of the morphological description of the soils is presented in Table 1. Generally, the soils occupied low topographic position comprises extensive tracts of almost level to gently undulating lightly dissected land and were developed on deeply weathered pre-Cambrian basement complex rocks (Shehu *et al.*, 2015). The soil morphological properties considered include soil depth, structure, consistency, horizons, concretion, pores and roots.

Table 1: Morphological Characteristics of the Mapping Units

Horizon	Depth (cm)	Colour	Textural Class	Structure	Consistency	Boundary	Other features
Low Land Plains LLP1 (*Typic Endoaqualfs*)							
Ap	0 -22	5YR5/6	SL	2mcr	vfr	cs	2frco
AB	22 - 43	5YR6/8	SL	2sbk	fr	gs	1frmp
Bt1	43 - 82	5YR6/6	SCL	2sbk	mfr	ds	nrfp
Bt2	82 - 100	5YR5/8	SCL	2fsbk	mst	ds	nrfp
Undulating Plains with group Hills UPH2 (*Typic Hapludalfs*)							
Ap	0 -23	10YR5/3	SL	2fsbk	fr	cs	3frmrmp
AB	23 - 48	10YR5/8	SCL	3abk	mfr	gs	1mrfp
Bt1	48 - 89	10YR6/4	CL	2abk	mst	cs	1mrfp
Bt2	89 - 96	10YR6/8	SCL	1abk	mst	ds	nrfp
Gently undulating sandy plains GUSP3 (*Vertic Epiaqualfs*)							
Ap	0 -23	10YR5/2	SL	2sbk	st	ds	2frfp
AB	23 -53	10YR7/2	CL	3sbk	mwstpl	dw	2mrfp
Bg1	53 - 84	10YR6/2	SCL	3sbk	mwstpl	dw	mrfp
Bg2	84 - 100	2.5Y6/4	SCL	3sbk	mwstpl	dw	mrfp
Extensive Sandy Plains ESP4 (*Typic Endoaquerts*)							
Ap	0 - 21	10YR4/2	SL	2fsbk	fr	cs	3frmrmp
AB	21 - 45	7.5YR5/4	SL	2fabk	mfr	gs	1frmrfp
Bt1	45 -52	7.5YR4/4	SL	2fabk	mst	cs	1mrfp
Bt2	52 - 59	10YR4/4	SCL	2sbk	mst	gs	nrfp
Upland Plains UP5 (*Entic Endoaquerts*)							
Ap	0 - 24	10YR5/4	L	2fsbk	fr	cs	2frmrfp
AB	24 - 51	7.5YR4/4	L	2abk	mfr	gs	1mrfp
B	51 - 58	2.5YR4/3	L	2sbk	mst	cs	1mrfp

Note: Symbols and codes were according to **FAO, 2006**.
Structure: 1 = weak, 2 = moderate, 3 = strong, m = medium, cr = crumb, abk = angular blocky, sbk = sub-angular blocky. **Consistency**: m = moist, w = wet, fr = friable, st = sticky, pl = platy. **Boundary:** c = clear, d = diffuse, g = gradual, s = smooth, w = wavy. **Roots:** 1 = few, 2 = moderate, 3 = many, fr = fine root, mr = medium root, co = coarse, mp = many pores, fp = few pores.

Soil Properties and Fertility Status of the Five Physiographic Units

Soil reaction (pH)

The pH values of the surface soils in the study sites ranged from 5.2 – 6.8 (mean, 5.5), 4.8 – 8.1 (mean, 5.4), 5.2 – 7.1 (mean, 6.2), 5.6 – 7.3 (mean, 6.1) and 5.7 – 7.2 (mean, 6.2) for physiographic unit LLP1, UPH2, GUSP3, ESP4 and UP5 respectively. The pH values for soil mapping unit UPH2 (*Typic Hapludalfs*) were moderately acidic while the other soil mapping units GUSP3 (*Vertic Epiaqualfs*), ESP4 (*Typic Endoaquerts*) and UP5 (*Entic Endoaquerts*) were slightly acidic. According to Landon (1991), a pH range of 5.5 to 7.0 is the preferred range for most arable crops. This shows that generally, the pH level of the soils across all the mapping units of the study area is the normal range for arable cropping.

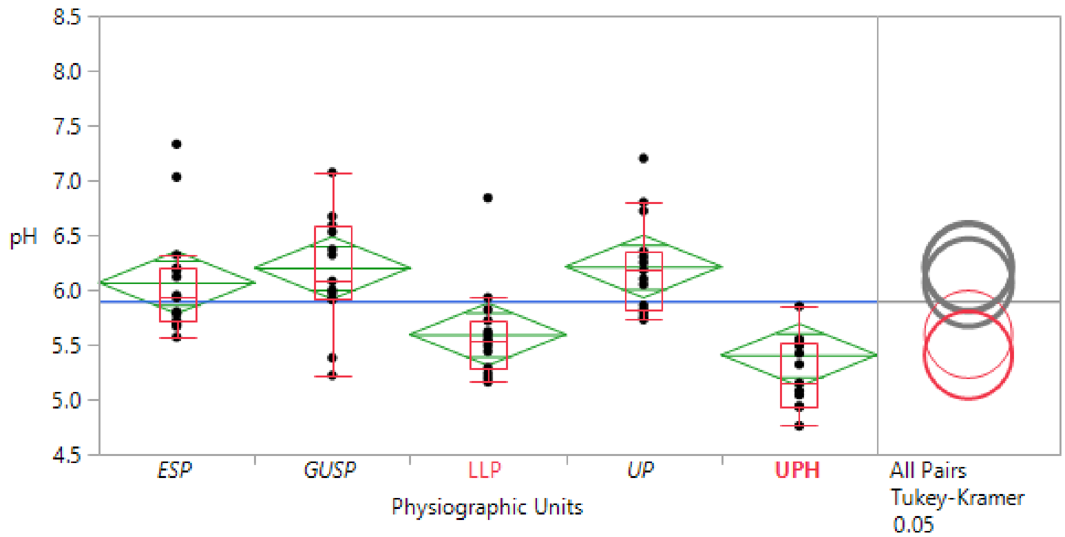

Figure 4: Means Diamond, Box Plot and Comparison Circles for pH in five physiographic units

The results of analysis of variance revealed that there is significant difference (P < 0.05) in pH between and within the physiographic units. The grand mean of pH was 5.8 (Figure 4). This indicates that the soils across all the study area were moderately acidic. The horizontal separation between the overlap marks of diamonds indicated the significant difference between the means of physiographic units. The box plots showed that the distributions of pH in all the locations were clustered around the means. This also indicate that the soils across the study area were moderately acidic. However, physiographic unit LLP and UPH were more acidic than other units (Figure 4). The comparison circle shows that unit ESP, GUSP and UP have same color which differ with that of unit LLP and UPH. This suggested that unit ESP, GUSP and UP were statistically the same and differed with unit LLP and UPH which were also statistically same.

Electrical Conductivity (EC)

Electrical Conductivity of the soils ranged from 0.01 – 0.09 (0.03), 0.01 – 0.15 (0.03), 0.01 – 0.08 (0.03), 0.01 – 0.08 (0.04) and 0.02 – 0.06 (0.04) dS/m for mapping units LLP1, UPH2, GUSP3, ESP4 and UP5 respectively. Similar trend was observed for the subsoils across the study area. The values were generally low indicating the non-saline status of the soils according to the limits set by Schoeneberger *et al.* (2002).

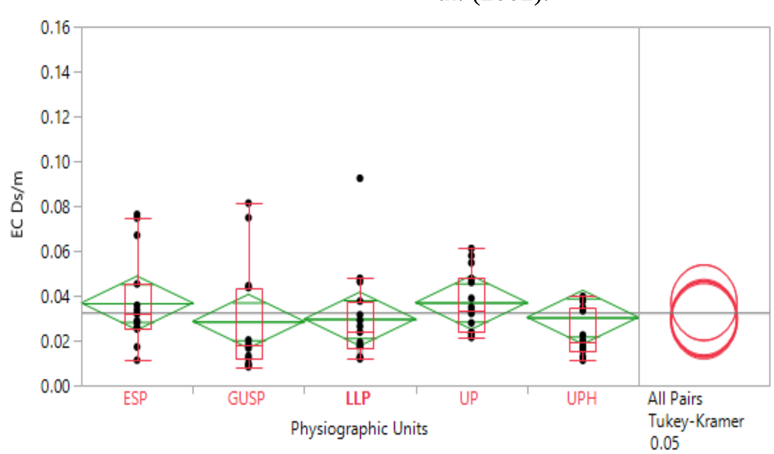

Figure 5: Means Diamond, Box Plot and Comparison Circles for EC in five physiographic units

The results of analysis of variance revealed that there is no significance difference (P > 0.05) in EC between and within the physiographic units. Figure 5 shows that there was no horizontal separation between the overlaps of the diamonds for different locations. This is indicating that no significant difference between the means of the different physiographic units. The box plots shows that the values of EC in physiographic unit LLP, UPH and UP clustered around the mean while in unit GUSP and ESP there was slight variations. The means circles shows that all the locations shared same colour (figure 5). This confirmed that the locations were statistically the same.

Cation Exchange Capacity (CEC)

The values of cation exchange capacity of the soils ranged between 2.36 – 4.69 (3.24), 1.56 – 4.76 (2.78), 1.84 – 3.85 (3.15), 2.46 – 4.07 (3.37) and 1.80 – 4.65 (3.17) Cmol (+) kg^{-1} in the respective surface soils of LLP1, UPH2, GUSP3, ESP4 and UP5 mapping units. The corresponding subsurface horizon values ranged between 2.35 – 4.37 (3.59), 1.71 – 4.16 (2.48), 1.88 – 4.03 (3.12), 2.65 – 5.24 (3.52) and 2.17 – 4.93 (3.22) Cmol (+) kg^{-1}. The soils were rated low in both surface and subsurface (Esu, 1991; Landon, 1991). This implies that nutrient retention will be low in soils and would require split dose of fertilizer in judicious quantity for crop growth. This corroborate with the findings of Maniyunda (2012) on the soils of northern guinea savanna of Kaduna state which also revealed low cation exchange capacity in the soils.

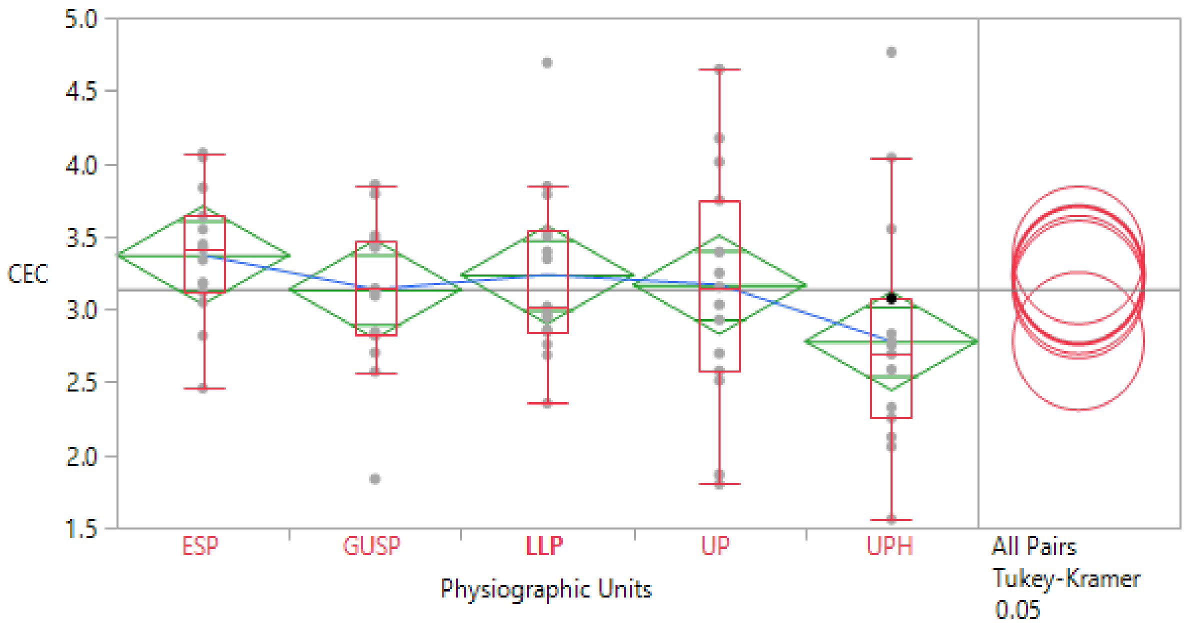

Figure **6**: Means Diamond, Box Plot and Comparison Circles for CEC in five physiographic units

The results also show there was no significant (P > 0.05) difference in CEC across the study area. There was no horizontal separation between the overlaps of the diamonds for different physiographic units (Figure 6). This shows there is no significant difference between their means. The box plots show that the distributions of CEC in the physiographic units were all clustered around the means except upland plains with group hills that varied. The means circles showed that all the soil mapping units shared same colour (figure 6). This indicates that the locations were statistically the same in CEC values.

Organic Matter/Organic Carbon

Organic matter is generally very low in the soils of the study area. According to Landon (1991) ratings (>20 % very high, 10-20 % high, 4-10 % medium, 2-4 % low and < 2 % very low). Organic matter content in the surface soils varied from 0.19 – 1.71 (mean, 0.88), 0.11 – 1.63 (mean, 1.11), 0.25 – 2.73 (mean, 1.21), 0.38 – 2.50 (mean, 1.44) and 0.41 – 3.24 (mean, 1.97) % in LLP1, UPH2, GUSP3, ESP4 and UP5 mapping units respectively. The corresponding subsurface values of organic matter varied between 0.14 – 2.04

(mean, 0.90), 0.11 – 1.75 (mean, 1.12), 0.25 – 2.72 (mean, 0.92), 0.44 – 3.20 (mean, 1.43) and 0.19 – 2.68 (mean, 1.77). Similarly, organic carbon was also low in the soils across all the mapping units with mean values of ≤ 0.78 at surface soils and ≤ 0.77 in the subsurface soils. The low organic matter and organic carbon contents of the soils in this area may be attributed to factors such as continuous cultivation, frequent burning of farm residues which tends to destroy much of the organic materials that could have been added to the soils (Raji *et al.*, 1996; Yusuf, 1997; Maniyunda, 201 2).

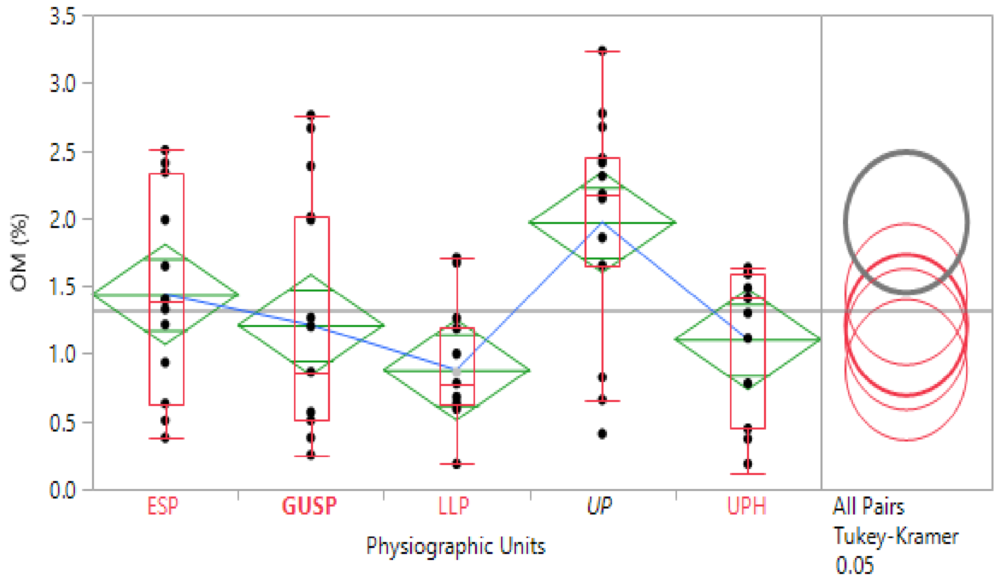

Figure **7**: Means Diamond, Box Plot and Comparison Circles for Organic Matter in the five Units

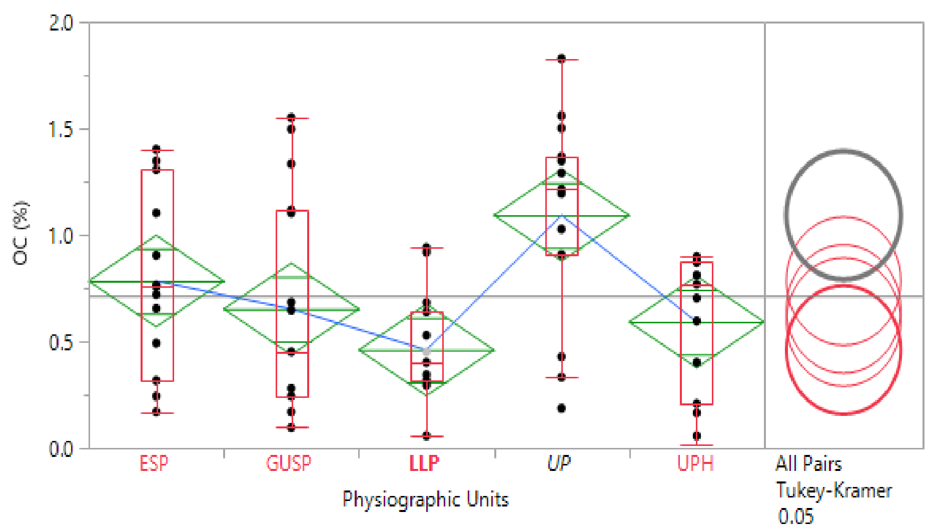

Figure 8: Means Diamond, Box Plot and Comparison Circles for Organic Carbon in the five Units

Figure 7 and 8 showed similar pattern in the distribution of organic matter and organic carbon in the study area. The results of analysis of variance revealed that there is significant ($P < 0.05$) difference in organic matter, organic carbon between and within the physiographic units. The amount of organic matter significantly differed between the different units with higher variation between low land and upland plains and this might be due to difference in physiographic position. There is little variation between gently undulating sandy plains and extensive sandy plains. The box plots show that the distribution of organic matter varied as the values were not clustered around the mean however, the low land plains and undulating plains with group hills had some little variations. The comparison circles show that only upland plains have different colours (Figure 7 and 8). This indicates that upland plains statistically differed from other physiographic units may be due to the topographic positions and density of vegetation covered.

Total Nitrogen

The total nitrogen content of the surface soils ranged from 0.02 – 0.48 (mean, 0.08) %, 0.01 – 0.11 (mean, 0.07) %, 0.01 – 0.30 (mean, 0.08) %, 0.03 – 0.19 (mean, 0.07) % and 0.04 – 0.21 (mean, 0.08) % in the mapping units LLP1, UPH2, GUSP3, ESP4 and UP5 respectively. The values of the total nitrogen in the soils of the area changed irregularly with depth which could be attributed to the influence of continuous cultivation, a common practice in the area that is accompanied by nearly crop residue removal (Noma *et al.*, 2011).

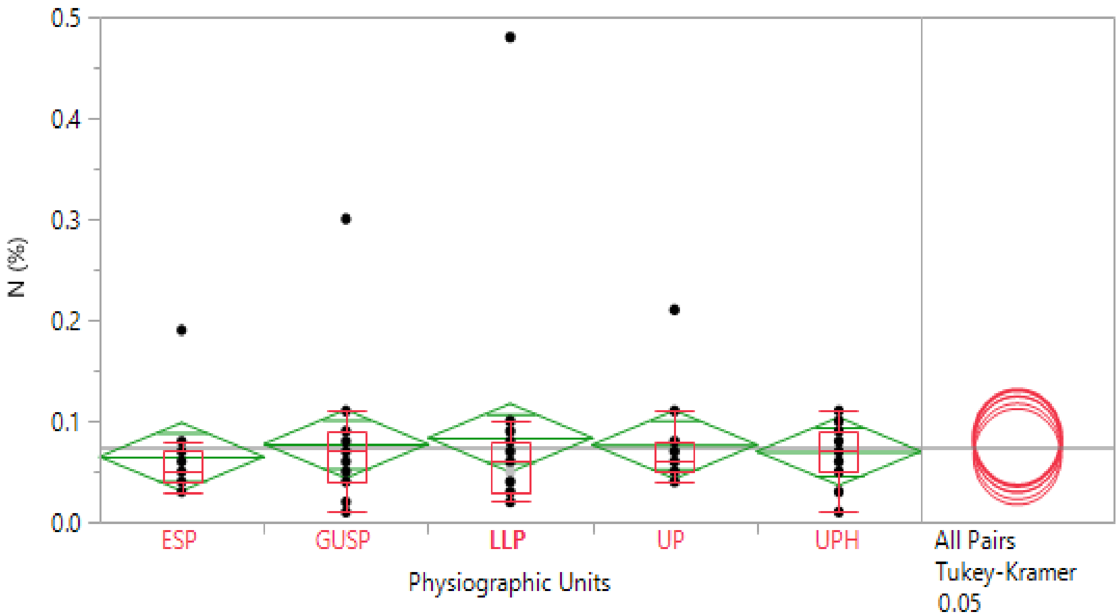

Figure 9: Means Diamond, Box Plot and Comparison Circles for Nitrogen among the five Units

Figure 9, presents the results of analysis of variance of total nitrogen for the five physiographic units, which indicates that there is no significant (P > 0.05) difference in nitrogen contents of the soils among the physiographic units of the area. There was no horizontal separation between the overlaps of the diamonds for different physiographic units, meaning that there is no significance difference between their means. The box plots show that the distributions of total N in the physiographic units were all clustered around the means. The means circles also show that all the soil mapping units shared same colour (figure 9). This indicates that the locations were statistically the same in total N content.

Available Phosphorus

The content of available P in the soils studied ranged from 5.94 – 15.96 (mean, 13.21), 14.05 – 17.12 (mean, 15.65), 16.28 – 17.30 (mean, 16.79), 16.12 – 17.68 (mean, 17.23) and 17.43 – 18.52 (mean, 17.98) at the surface and from 7.55 – 16.11 (mean, 13.57), 14.56 – 16.92 (mean, 15.71), 15.63 – 17.13 (mean, 16.50), 17.06 – 17.90 (mean, 17.44) and 17.34 – 18.33 (mean, 17.88) in the subsurface soils for mapping units LLP1, UPH2, GUSP3, ESP4 and UP5 respectively. According to rating by Esu (1991) and Landon (1991), the soils are rated moderate in available P. The result also showed that available P in the soil was not significantly affected by either depth or location, it varied within narrow limit in the soils studied.

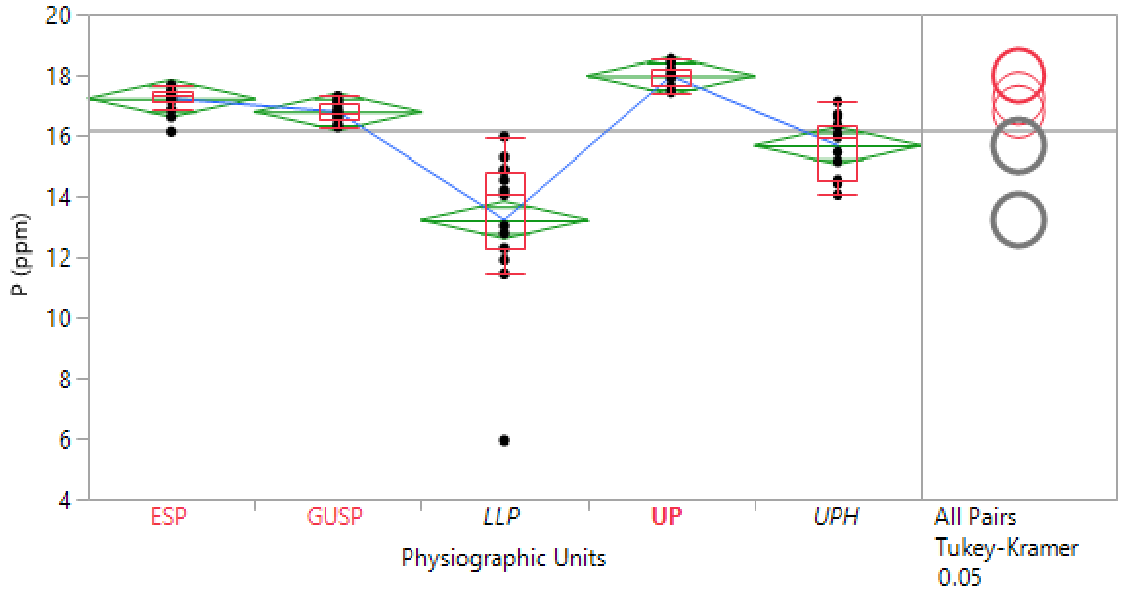

Figure 10: Means Diamond, Box Plot and Comparison Circles for Available Phosphorus

The results of the analysis of variance show that there was significant ($P < 0.05$) difference in available phosphorus between the physiographic units. The horizontal separation between the overlap marks of diamonds (Figure 10) indicate the significant difference between the means of physiographic units. The box plots shows that the distributions of P in the physiographic units were all clustered around the means. This indicates that there is no much variation within the units. The comparison circles show that low land and undulating plains with group hills have similar colors which differed from that of ESP, GUSP and UP (Figure 10). This indicates that low land and undulating plains with group hills statistically differed from other physiographic units. This may be due to the topographic positions and density of vegetation cover.

Exchangeable potassium (K^+)

Exchangeable potassium (K) varied between 0.21 and 0.1.25 (mean, 0.54), 0.14 and 0.55 (0.28), 0.05 and 0.59 (0.16), 0.03 and 0.26 (mean, 0.12) and 0.01 and 0.19 (0.07) Cmol (+) kg^{-1} in the surface horizons of FP1, UPH2, GUSP3, ESP4 and UP5 respectively. In the corresponding subsoil horizons, the values varied between 0.17 – 1.65 (0.46), 0.11 – 0.55 (0.26), 0.06 – 0.36 (0.16), 0.03 – 0.26 (0.12) and 0.02 – 0.20 (0.09) respectively. Mapping unit FP1 was rated high, UPH2 moderate while GUSP3, ESP4 and UP5 were low.

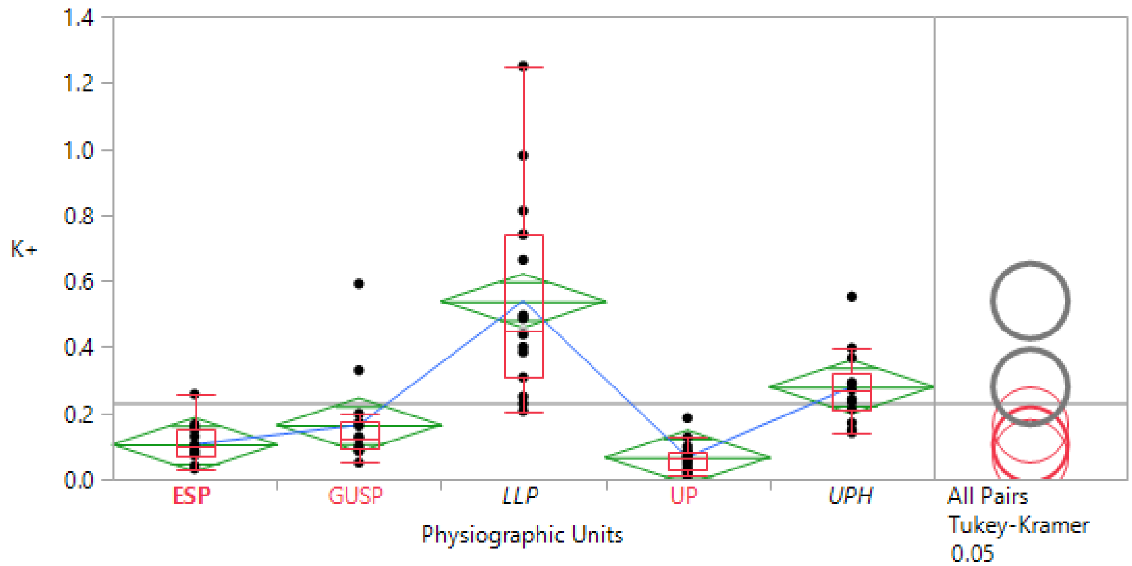

Figure 1**1**: Means Diamond, Box Plot and Comparison Circles for K^+

The results of analysis of variance revealed that there was significance ($P < 0.05$) difference in potassium between and within the physiographic units of the study area. The potassium content of the soils significantly differed between the different units with higher variation between low land and upland plains and this might be due to differences in the physiographic positions. There is little variation between gently undulating sandy plains and extensive sandy plains. The box plots show that the distributions of N in the physiographic units were all clustered around the means except LLP that varied (Figure 11). The comparison circles show that LLP statistically differed from other physiographic units. This may be due to the topographic positions of the mapping units.

Exchangeable Sodium Percentage (ESP)

The values of exchangeable sodium percentage (ESP) in all the five soil units were generally below 15%, the critical limit for sodicity (Brady and Weil, 2005). The Sodium Adsorption Ratio (SAR) values were rated low, below the threshold value of 13 for sodic soils (Sanda *et al.*, 2007). Similar results were obtained by Yakubu *et al*. (2011) and Maniyunda (2012). Consequently, at present, all the soils of the study area could be said to be free from salinity and sodicity problems as the values are less than 15% critical limit (Brady and Weil, 2005).

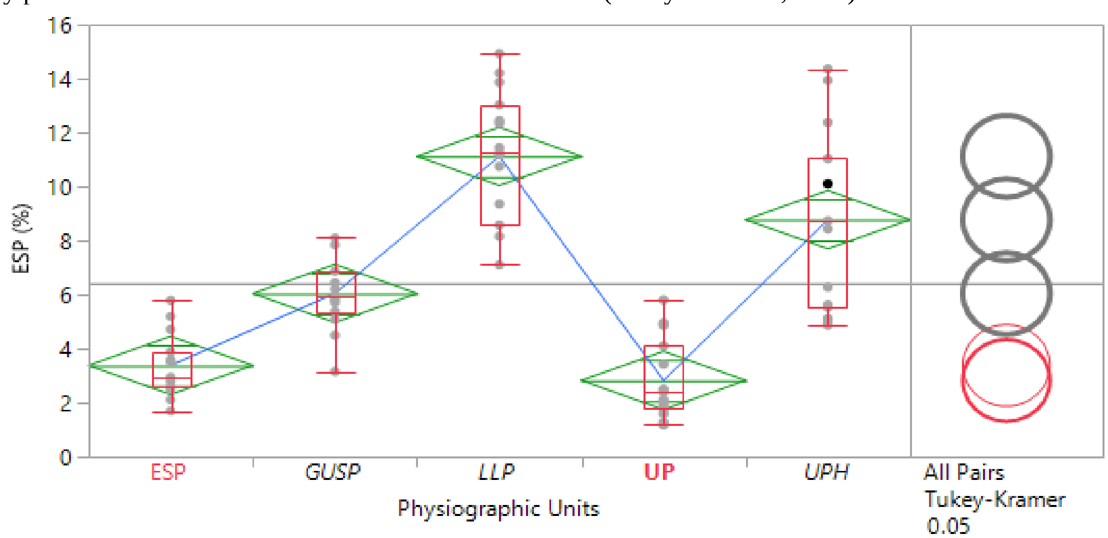

Figure 12: Means Diamond, Box Plot and Comparison Circles for ESP

The results show that there was significant (P < 0.05) difference in exchangeable sodium percentage between and within the physiographic units. The horizontal separation between the overlap marks of diamonds indicate the significant difference between the means of physiographic units. The box plots show that the distributions of ESP in all the locations were clustered around the means. The comparison circles show that physiographic units GUSP, LLP and UPH has same colour (Figure 12). This indicates that these units were statistically the same, also, the physiographic units ESP and UP were statistically the same.

Effective Cation Exchange Capacity (ECEC)

The effective cation exchange capacity (ECEC) of the soils across the five physiographic mapping units were low (<6.0 Cmol (+) kg^{-1}). The low ECEC level implies that the soils were dominated by low activity clays and sesquioxides (Tan, 2000) and low organic colloidal fractions suggesting the soils would be susceptible to leaching (Shehu *et al*., 2015). This is also an indication that the soils at their natural pH levels remain low in CEC indicating a low capacity of the soils to retain nutrients (Yakubu 2006; Sharu *et al*., 2013).

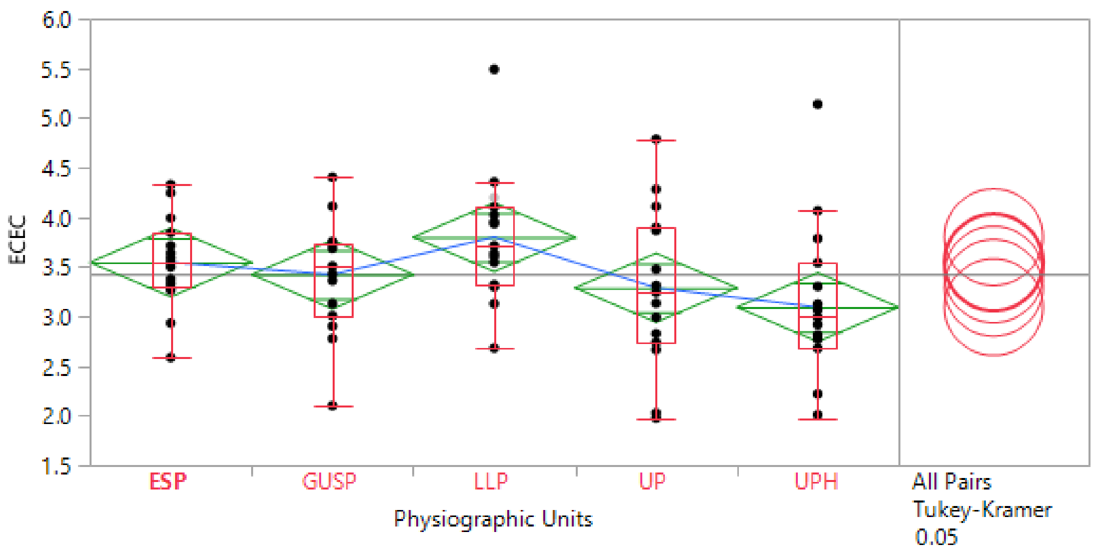

Figure 13: Means Diamond, Box Plot and Comparison Circles for ECEC

The result in figure 13 shows that there was not significant (P > 0.05) difference the values of the ECEC of the soils among the physiographic units of the area. There was no horizontal separation between the overlaps of the diamonds for different physiographic units (Figure 13), indicating that there was no significant difference between their means. The box plots showed that the distributions of ECEC in the physiographic units were all clustered around the means. The means circles also show that all the soil mapping units shared same colour, indicating that the locations were statistically the same.

Exchangeable Bases

The result obtained shows that the values of exchangeable bases of the soils in the study area were generally low. Similar results were reported by Noma *et al.* (2004) in the soil of Sokoto and Raji *et al.* (2011) in the soils of Kaduna state that Calcium and magnesium are the predominant basic cations in the soils. Similar observations have been made in the past for West African soils in general (Kowal and Knabe, 1972). The result is also in tune with the findings of Yakubu *et al* (2011) and Maniyunda (2012). The exchangeable calcium was generally low for both surface and subsurface soils in all the mapping units. The Mg values across the five mapping units varied from low to moderate. In mapping units LLP (*Typic Endoaqualfs*) and UPH (*Typic Hapludalfs*) Mg contents fell within moderate (0.3-1.0 Cmol (+) kg^{-1}) fertility status while in the soil mapping units GUSP (*Vertic Epiaqualfs*), ESP (*Typic Endoaquerts*) and UP (*Entic Endoaquerts*), the values fell in the low (< 0.3 Cmol (+) kg^{-1}) fertility status.

The exchangeable Na values varied between 0.27 – 0.42 (0.30) and 0.25 – 0.59 (0.36) in the surface and subsurface soils respectively for the mapping unit LLP1 (*Typic Endoaqualfs*). Thses values are rated high based on the ratings by Esu (1991) and Landon (1991). In mapping unit UPH2, exchangeable Na is rated moderate to high in both surface and subsurface soils. Mapping unit GUSP3 recorded moderate value of exchangeable Na (0.09 – 0.25 (mean 0.19) and (0.10 – 0.23 (mean 0.19) for surface and subsurface soils respectively. ESP4 unit was rated low to moderate in exchangeable Na (0.06 – 0.18 (mean 0.11) and (0.05 – 0.18 (mean 0.19)) while mapping unit UP5 (*Entic Endoaquerts*) fell within low class in the ratings. The general pattern of Na distribution across the five mapping units was in this order LLP1 > UPH2 > GUSP3 > ESP4 > UP5.

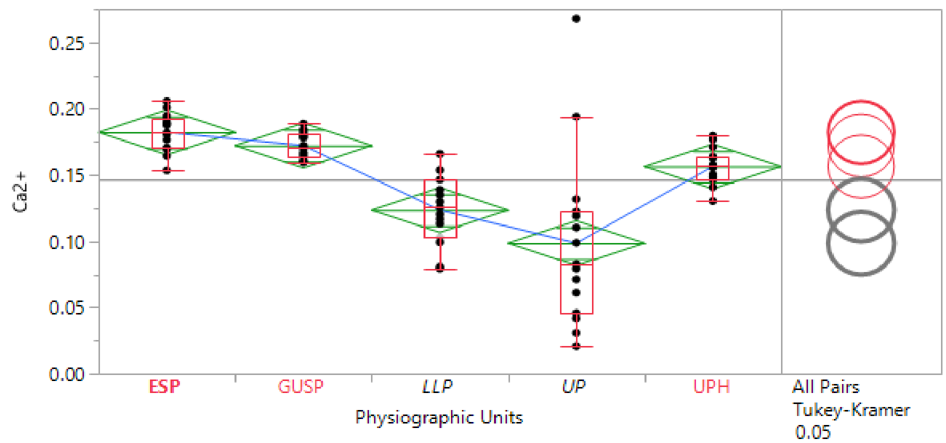

Figure 14: Means Diamond, Box Plot and Comparison Circles for Ca^{2+}

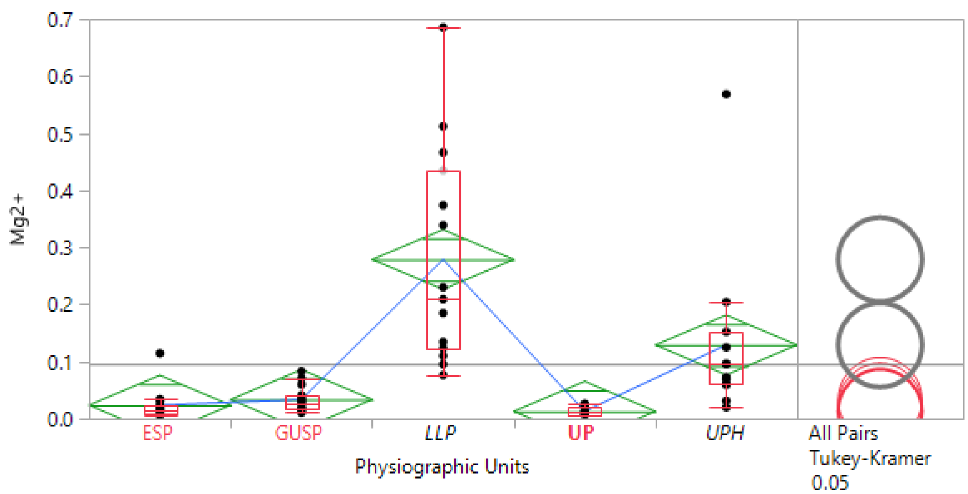

Figure 15: Means Diamond, Box Plot and Comparison Circles for Mg^{2+}

The results show that there was significant ($P < 0.05$) difference in exchangeable calcium between and within the physiographic units. The horizontal separation between the overlapped marks of diamonds indicate the significant difference between the means of physiographic units (Figure 14). The box plots show that the distributions of Ca^{2+} in all the locations were clustered around the means. The comparison circle showed that physiographic units LLP and UP had same colour. This indicates that these units were statistically the same, the figure also showed that physiographic units GSUP, ESP and UPH were statistically the same.

Figure 15 shows that there was significant ($P < 0.05$) difference in exchangeable magnesium between and within the physiographic units. The horizontal separation between the overlap marks of diamonds indicated the significant difference between the means of physiographic units. The box plots showed that the distributions of Mg^{2+} in all the physiographic units were clustered around the means only LLP varied. The comparison circle showed that physiographic units ESP, GUSP and UP had same colour indicating that they are statistically same.

CONCLUSION

The study identified five physiographic units which were named based on the landforms characteristics. The soils were generally yellowish to reddish brown, well drained, poorly structured with texture ranging from coarse particle in the northeastern part of the area to fine in the southwestern part. The fertility status of the study soils were generally low. Also, the values of exchangeable sodium percentage (ESP) in all the five soil units were below 15% critical limit for sodicity. Hence, all the soils of the study area are currently free from salinity and sodicity hazard. The study concluded that the use of quantitative method of physiographic subdivision of land for soil mapping is suitable for soil classification and mapping.

REFERENCES

Adamu, G.K, (2014). Assessment of the Surface Characteristics and Potentials of Padama Soils in the Reaches of two Major Streams in Kano State, Nigeria. Unpublished PhD. Thesis, Department of Geography, Bayero University Kano.

Adhikari, P.P., and Hartemink, A.E. (2016). Linking soils to ecosystem services-A global review. *Geoderma* 262 (2016) 101–111.

Akpovwovwo, U.E. (2014). Fertility Capability Classification and GIS mapping of soils in Agbarho town, Delta State, Nigeria. *African Journal of Agricultural Research*. 9(21): 1635-1640.

Brady, N.C. and R.R. Weil, (2002). *The Nature and Properties of Soils*. 13th Edn. Pearson Education, Singapore, ISBN-13: 9780130167637, Pages: 960.

Brady, N.C. and Weil, R. C. (2005). *The Nature and Properties of Soils.* Thirteenth Edition. Pearson Printice-Hall Inc. India. 881 PP.

Braimoh, A.K (2002). Integrating indigenous knowledge and soil science to develop a national soil classification system for Nigeria. Agric. Hum. Values, 19: 75-80.

Dhar, B.L., Jha, M.N. and Kukretee, S.P. (1988). Mineralogy of soils under forests in the Lesser Himalaya. *J. Indian Soc. Soil Sci.*, 36 : 151-157.

Eno, J.U., Trenchard, O.I., Joseph, A.D., Anthony, O.A., andIvara, E.E. (2009). *Manual of Soil, Plant and Water Analysis.* Sibon Book Ltd, Lagos.

Esu, I.E. (1991). Detailed soil survey of NIHORT farm at Bunkure Kano state, Nigeria. Institute for Agricultural Research Samaru, Zaria, Nigeria.

FAO (2015). The State of Food Insecurity in the World Meeting the 2015 international hunger targets: taking stock of uneven progress. www.fao.org/publications

Gee, G. W. and Bauder, J. W. (1986). Particle soil analysis. In: A . Klute (ed), *Methods for soil analysis. Part 1: Physical and Mineralogical Methods*. Madison, Wisconsin, USA: Soil Science Society of America. American Society of Agronomy, pp. 383– 411

Holden, J. (2011). Physical geography the basics. First edition, published in the USA and Canadaby Routledge 711 Third Avenue, New York, NY 10017

Jha, M.N., Gupta, M.K. and Dimri, B.M. (2002). Impact of changing natural forest cover and site conditions on the soil resources in 53 western Himalaya. In: Ashok K.Pandit (Ed.) Natural Resourses of Western Himalaya. Srinagar Valley Books, Srinagar, 254 p.

Kowal J.M and Knabe, D.T. (1972). An Agro-climatological Atlas of The Northern State of Nigeria. ABU Press, Zaria, Nigeria. P.111

Landon, J.R., (1991). Booker Tropical Soil Manual. Longman Publishers, Harlow, UK, Pages: 134.

Maniyunda, L.M. (2012). Pedogenesis of A Lithosequence In The Northern Guinea Savanna of Kaduna State, Nigeria. Unpublished PhD. Thesis. Department of Soil Science, Ahmadu Bello University Zaria, Nigeria.

Mortimore, M.J. and Adams, W.M. (1998). 'Farming intensification and its implications for pastoralism in northern Nigeria', In: I. Hoffman, M von C. Schäfer, J. Steinbach, C. Willeke-Wetstein (Eds.) Prospects for Pastoralism in West Africa, Giessener Beiräge zur Entwicklungsforschung, Tropeninstitut Giessen. pp. 262-273.

Nelson, R.E. (1982). Carbonate and gypsum. In: Page AL, Miller RH, Keeney DR, editors. Methods of soil analysis. Part 2. Madison (WI): American Society of Agronomy. p. 181–196.

Noma, S.S., Ojanuga, A.G., Ibrahim, S.A. and Iliya, M.A. (2004). Detailed soil survey of the Sokoto-Rima floodplains at Sokoto, Nigeria. In: Salako, F.K, Adetunji, M.T, Ojanuga, A.G, Arowolo T.A. and Ojeniyi, S.O. (Eds). *Managing Soil Resources for Food Security and Sustainable Environment*. Proceedings of the 29th annual conf. of SSSN/University of Agriculture, Abeokuta, Nigeria Dec. 6-10, 2004.

Noma, S.S., Tanko, I.I, Yakubu, M. Dikko, A.U., Abdullahi A.A. and Audu, M. (2011). Variability in the physico-chemical properties of the soils of Dundaye District, Sokoto State, Nigeria. In: Hassan, W.A. Kyiogom, U.B. Tukur, Y.A. and Muhammad, N. (Eds). *Mobilizing Agricultural Research Towards Attaining Food Security and Industrial Growth in Nigeria*. Proceedings of the 45th annual conferences of the Agricultural Society of Nigeria held at the Faculty of Agriculture, Usmanu Danfodiyo University Sokoto, Nigeria, 24th to 28th Oct, 2011

NSPFS (2010). National Special Programme for Food Security (NSPFS), Abuja, Nigeria.

Orimoloye, J. R. (2016). Fertility Capability Classification of Some Floodplain Soils in Kogi State, Central Nigeria. *Life Science Journal*, 213(1s) P 48 – 55.

Raji, B. A., Malgwi, W. B., Berding, F. R. and Chude, V. O. (2011). Integrating indigenous knowledge and soil science approaches to detailed soil survey in Kaduna State, Nigeria. Journal of Soil Science and Environmental Management Vol. 2(3), pp. 66 - 73.

Raji, B. A., Malgwi, W. B., Berding, F. R. and Chude, V. O. (2013). Integrating indigenous knowledge and Soil Science approaches to detailed soil survey in Kaduna State, Nigeria. *African Journal of Soil Science*, 1 (1): 9-15,

Sanda, A.R., Ogunwale, J.O., Oluwasemire, K.O. and Raji, B.A. (2007). Effects of Drainage water recycles and irrigation scheduling on soil properties and yield of tomato under a high water table in Northern Nigeria. In: Uyovbisere, E.O., Raji, B.A., Yusuf, A.A, Ogunwale, J.O, Aliyu, L. and Ojeniyi, S.O (Eds). S*oil and Water Management for Poverty Alleviation and Sustainable Environment*. Proceeding of the 31st annual conference of SSSN/ABU, Zaria, Nigeria Nov. 11 to 17th, 2006.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C. and Broderson, W.D. (Eds). (2002). Field book for describing and sampling soils, version 2.0 Nat. Soil survey center. NRCS, USDA, Lincolns, NE.

Sharu, M.B., M. Yakubu, S.S. Noma and A.I. Tsafe (2013). Characterization and Classification of Soils on an Agricultural landscape in Dingyadi District, Sokoto State, Nigeria. *Nigerian Journal of Basic and Applied Science*s. 21(2): 137-147 DOI: http://dx.doi.org/10.4314/njbas.v21i2.9

Shehu, B.M., J.M. Jibrin and A.M. Samndi (2015). Fertility Status of Selected Soils in the Sudan Savanna Biome of Northern Nigeria. *International Journal of Soil Science*, 10 (2): 74-83, 2015 ISSN 1816-4978/ DOI: 10.3923/ijss.2015.74.83

Tan, K.H., (2000). Environmental Soil Science. 2nd Edn., CRC Press, Boca Raton, FL., Pages: 452.

Thomas, G. W. (1996). Soil pH and soil acidity. In: D. L. Sparks, *Methods for Soil Analysis. Part 3: Chemical Methods*. Madison, Wisconsin, USA: Soil Science Society of America. American Society of Agronomy, pp. 475–490

USDA (2010). Keys to Soil Taxonomy. Eleventh Edition, 2010

Yakubu, M. (2006). Genesis and classification of soils over different geological formations and surfaces in the Sokoto plains, Nigeria. PhD Thesis submitted to the Department of Soil Science and Agricultural Engineering, Usmanu Danfodiyo University Sokoto (Unpublished).

Yakubu, M., Baraya, S. and Noma, S.S. (2011). Assessment of soil and water quality along river Kadarko in Sanyinna District, Sokoto State. In: Hassan, W.A. Kyiogom, U.B. Tukur, H.M. Ipinjolu, J.K. Maigandi, S.A. Singh, A., Ibrahim, N.D., Dikko, A.U., Bashir, Y.A. and Muhammad, N. (Eds). *Mobilizing Agricultural Research Towards Attaining Food Security and Industrial Growth in Nigeria*. Proceedings of the 45th annual conferences of the ASN held at the Faculty of Agriculture, UDUS, Nigeria, 24th to 28th Oct.

Yusuf, M.A. (1997). "Soil Quality and Sustainability of Agricultural Management under Small Holder Conditions in the Kano Closed-Settled Zone, Kano State, Nigeria". *International Journal of Advanced and Innovative Research* (IJAIR). 2(7): 1-10, 1997. ISSN: 2278 – 7844.