PAT December, 2021; 17(2): 69-84 ISSN: 0794-5213

***Online copy available at** www.patnsukjournal.net/currentissue*

Publication of Nasarawa State University, Keffi

SALINITY ASSESSMENT OF SOILS UNDER THREE DIFFERENT LAND USE IN KARGO VILLAGE, DUTSE LOCAL GOVERNMENT OF JIGAWA STATE, NIGERIA

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Abstract

Variability in soil properties at three sites of Kargo village Dutse local government Jigawa state, Nigeria was assessed. The three different sites were: Uncultivated lower area (UnLA), Lower cultivated area (LwCU), and Upper cultivated area (UpCU). Auger samples were collected at the depth of 0-15 and 15-30 cm and subsequently mixed to obtain the composite samples for routine chemical and physical properties analyses. Undisturbed soil samples were collected for bulk density and saturated hydraulic conductivity (Ksat) determination. All data collected were analysed using Minitab 19. Results showed that loamy texture was dominant in the study area. UnLA had higher bulk density and moisture content of 1.45 Mg m^{-3} and 23.7gg^{-1}.Significant higher porosity of 45.6 % was obtained in the cultivated soils (LwCU and UpCU). Uncultivated (UnLA), LwCU and UpCU had a constant infiltration rate of 3, 3.8 and 7.4 cm min^{-1}, respectively. After 150 minutes, UpCU had higher cumulative infiltration of 879.9 cm. In terms of Ksat, UpCU was the highest with 1.8 cmhr^{-1}. Higher pH, OC, K, Na, CEC, ESP and SAR of 9.0, 1.3% 0.4, 0.9, 9.4 cmol kg^{-1}, 9.9 % and 0.5 respectively, were found in UnLA. Conversely, least of the abovementioned elements were recorded in UpCU which in turn had higher Ca, Mg and H & Al with 2.8, 5.6 and 1.3 cmol kg^{-1},respectively. Based on the results obtained, the UnLA is classified as alkaline soil which confirms the farmer's suspicion. With good management practices such as leaching using a good water, organic fertiliser, 2 to 3 harrowing before planting would help remove the salt accumulation and the soil could still be productive rather than being abandoned.

***Keywords**: Alkalinity, bulk density, infiltration, lowlands, saturated hydraulic conductivity, uplands*

Introduction

Soil salinity increase is a major concern in the world's land degradation, and it is certain to get worse in the future (Wong *et al*., 2009). Salt-affected soils are a serious concern in many arid and semiarid parts of the world, posing a growing danger to agricultural expansion and production. A saline soil is one in which the electrical conductivity (EC) of the saturation extract (SE) in the root zone exceeds 4 dS/m at 25 °C and has an exchangeable sodium percentage of 15% (Robinson *et al*., 1994), most crop plants yield decrease at this EC. Above certain threshold of the soil salinity, most crops' growth and yield are influenced in different ways. In terms of salts, however, depending on the type of soluble salts, physico-chemical features, plant response, and management strategies required for their restoration, soils are grouped into two: saline and alkaline soils (Robinson *et al*., 1994). Soils with a high pH (>8.5), weak structure, and low infiltration capacity are known as alkaline soils (Gupta and Shukla, 1991). Salt-affected soil is one of the main causes of soil degradation in most parts of the world, resulting in lower biomass output (Solanki and Chavda, 2012).

According to Gupta and Abrol (1990), alkaline soil has much higher bulk densities and smaller total porosities, indicating that a lack of disturbance causes soil compaction. Soil structure, pore size, and distribution are all altered by alkaline soil, especially in the short term (Fernández-Ugalde *et al*., 2009). High infiltration rates are critical in dryland agricultural production areas to reduce run-off and permit effective water storage when rainfall intensities are high in a short period of time (Håkansson, 1990; Nabayi *et al*., 2018; 2019). According to research conducted in Nigeria, alkaline soil has a much lower infiltration rate than non-alkaline soil (Lal, 1984). Alkaline soil in semiarid regions of Africa, according to Morin (1993), eventually leads to improved infiltration rates. Mead and Chan (1989) found that soil under cultivation had a higher Ksat than uncultivated land, however Blume (1985) reported no significant difference between cultivated and uncultivated soils. Because of the salt dominance in the area, saturated hydraulic conductivity is particularly low in saline soils due to insufficient moisture content (Moreno *et al*., 1997).Most exchangeable cations, particularly sodium and magnesium, are mobile; nevertheless, high salt levels in the soil reduce the movement of exchangeable cations within the soil (Collins *et al*., 2006). Alkaline and saline soils primarily break and destroy soil structure which prompted people to wonder whether alkaline soil should be used for agriculture (Gajri *et al*., 2002). Improved water dynamics may allow salt to be leached more effectively into deeper soil layers than farmed land (Moreno *et al*., 1997). Irrigation farming in saline soil with high CEC degraded soil structure, decreased porosity, increased infiltration rate, and increased bulk density especially in arid and semiarid soils (Diacono and Montemurro, 2015).Many agricultural activities are carried out in the Kargo area, which is part of Federal University Dutse. However, because of the expected/anticipated salinity problem based on the physical appearance of the area, the specific land in issue has been abandoned. The inhabitants of the village complain about a severe drop in production when the land is subjected to farming. Furthermore, no scientific study has been conducted to verify if the area is saline/alkaline in nature. The study area is about 11,712 m^2 (122m x 96 m). To enhance agricultural production in the area, a solution to the projected salinity/alkalinity problem is critical, which as a result will increase the farmer's income. Therefore, the objectives of the study were:(1) to determine some selected physical, hydraulic, and chemical properties of the abandoned area in Kargo village (UnLA), (2) to determine similar properties of nearby upper and lower cultivated soils (UpCU and LwCU) for comparison purposes.

Materials and methods

Experimental Site

The study was carried out in Dutse, Jigawa state, Nigeria. It has a Sudan savannah vegetation, located along latitude 11^0 45', 22.25''N and longitude 9^0 20, 20.26''E. The area is characterized by undulating topography and hilly walls. Peculiar to the North-Western states, with the availability of agrarian land, the inhabitants of Dutse are predominantly farmers, and other occupations typical to the rural area are also available among the populace (Usman *et al*., 2013). Dutse has a Bsh climate (steppe/semiarid climate) according to the Koppen Gieger climate classification, with average temperature of 26.5^{O}C. About 743mm of precipitation falls annually with the highest in the month of August (average 262 mm).

Sample Collection

The samples were collected using random sampling for the physical and hydraulic properties of the study locations. To characterize the soils, samples were collected from three (3) different farms as follows: upper cultivated soil (UpCU), lower cultivated soil (LwCU), and uncultivated lower area soil (UnLA) (Figure 1). In each farm, four (4) soil samples were collected at 0-15 and 15-30, making 24 samples for the research. The surface and sub-surface samples of the same farm were mixed to obtain a composite sample for some physical and chemical analyses, which gave 12 samples (3 farms x 4 replications). Additionally, undisturbed samples were taken using core samplers for bulk density and saturated hydraulic conductivity determination.

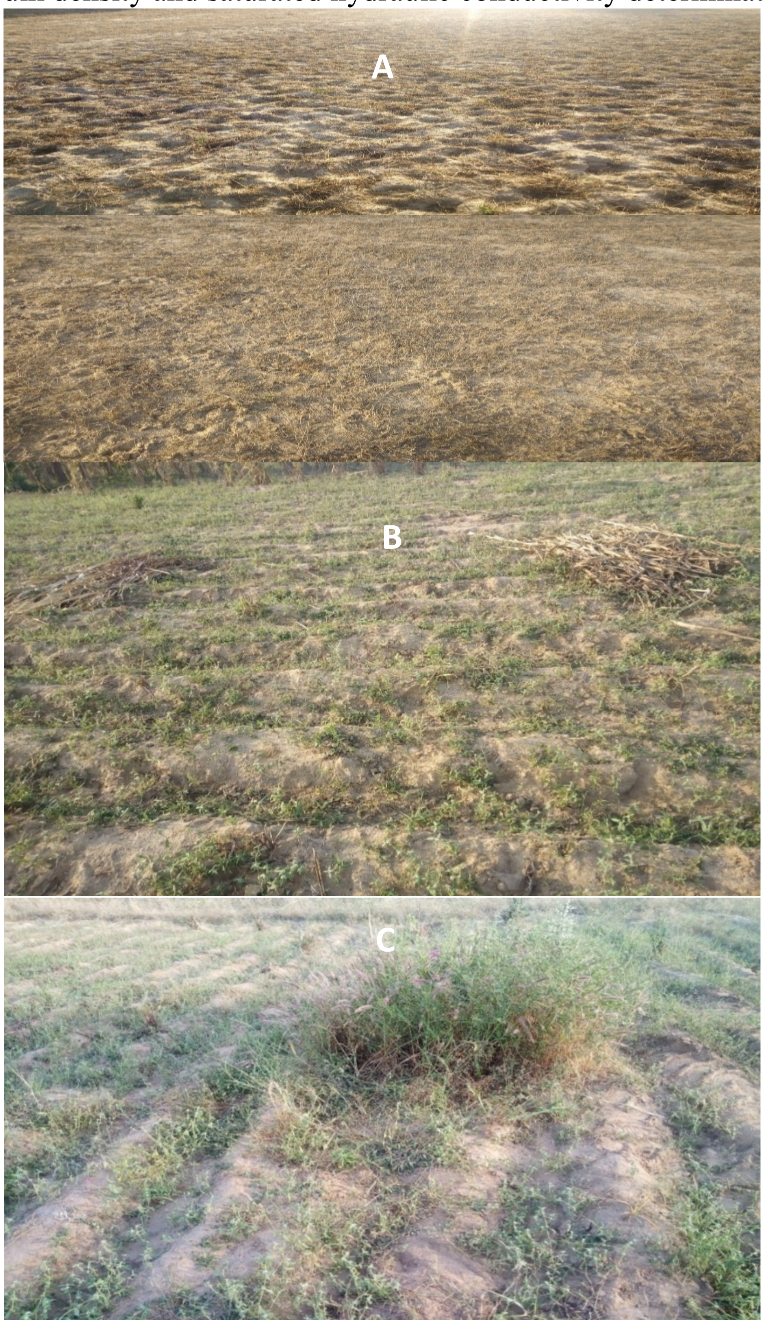


Figure 1: Experimental sites (A) uncultivated lower land (alkaline soil), (B) cultivated lower land, and (C) cultivated upper land

Treatments and Experimental Design

The different farms were considered as the treatments: upper cultivated soil (UpCU), lower cultivated soil (LwCU), and uncultivated lower area soil (UnLA) with four (4) replications each which were laid in a randomized complete block (RCB) design.

Soil Analysis

The Bouyoucos hydrometer method was used in determining the particle size distribution of the 2mm sieved soil (Gee and Bauder, 1986). The moisture content (MC) of the soil was determined gravimetrically by subtracting the oven-dry weight from the fresh weight of the soil and divided by the oven-dry weight to get the moisture content in g $g^{-1.}$ Soil bulk density (Bd) was determined by the core method as described by Blake and Hartge, (1986). The MC, Bd and porosity were calculated by the formula below:

$$\text{Soil moisture } (g\ g^{-1}) = \frac{weight\ of\ wet\ soil - weigh\ \ of\ oven\ dry\ soil}{weight\ of\ oven\ dry\ soil} \quad (1)$$

$$\mathrm{Bd}(\mathrm{Mg\ m^{-3}}) = \frac{mass\ of\ oven\ dry\ soil(Mg)}{\text{Bulk volume of soil}(m^3)} \quad (2)$$

Porosity was determined indirectly from the calculated Bd and a constant Pd (2.65 Mg m^{-3}) of the mineral soils, using the formula below:

$$\text{Total Porosity } (\%) = (1 - \frac{Bd}{Pd}) \times\ 100 \quad (3)$$

Saturated hydraulic conductivity (Ksat) was determined by the constant head permeameter as described by Klute and Dirksen (1986), while the infiltration was determined as described by the field method procedure (Thomas, 1996) using a double ring infiltrometer. Soil pH and EC by glass electrode pH meter (Meter-Toledo Delta 320 pH meter) and EC in a water to soil ratio of 1:2.5 (McLean, 1982), organic C by Walkley-Black (Nelson and Sommers 1982), ammonium acetate extraction methods (Chapman, 1965) was used for exchangeable bases and cation exchange capacity determination, while P was extracted using bray and kurt-2 and CEC and P were determined using Auto Analyser, while Ca, Mg, K, and Na were determined by AAS. Exchangeable acidity was determined according to McLean (1965) who defined it as the amount of Al and H ions in the soil samples. The soil sample was extracted with unbuffered 1.0 M KCl, and the sum of Al and H were determined by titration. 50g of soil sample was put in a 200 ml plastic bottle, and 100 ml of 1.0 M KCl solution added. The bottle was capped and shaken for 2hrs and then filtered. 50 ml portion of the filtrate was taken with a pipette into a 250 ml Erlenmeyer flask and two drops of phenolphthalein indicator solution were added. The solution was titrated with 0.1 ml NaOH until the colour turned to pink. Sodium Absorption Ratio (SAR) and exchangeable sodium percentage (ESP) were determined using the formula below:

$$\mathrm{SAR} = \frac{Na^+}{\sqrt{Ca + Mg}} \quad (4)$$

$$\mathrm{ESP}\ (\%) = \frac{Na}{Exchangeable\ bases}\ X\ 100 \quad (5)$$

Statistical Analysis

All data collected were analysed using Minitab software (Version 19, Pennsylvania, USA). Analysis of variance (ANOVA) was used to determine the significant treatment effect on the measured parameters at a 5% significance level, and means were separated using the Tukey test.

Results and discussion

Table1 shows the textural classes of the soil of the study area. The soil texture was found to be loamy across the sampling locations. The difference in the nature of the soils due to the alkalinity of the lower uncultivated area has no impact on the texture of the soils. The textural class consistently remained loamy; sand and silt occupy the greater proportions of the soils in all the areas studied, which conforms to soils of the semiarid and arid region (Rousseve *et al.,* 2002). The lower cultivated area shows a high percentage of sand, which could result from no application of organic manure in the soil. Loamy soils are light soils with low nutrient concentration, low ability to retain moisture, low cation exchange capacity and buffer capacity, and rapidly permeable (Gupta and Shukla, 1991).

Table 1: Average particle size distribution of the study area

	Particle sizes distribution result			
Treatments	Sand (%)	Silt (%)	Clay (%)	Textural class
UnLA	38	36	26	Loam
LwCU	40	35	25	Loam
UpCU	41	34	25	Loam

UnLA- Uncultivated lower Area, LwCU- Lower cultivated, UpCU- Upper cultivated.

Figure2 shows the mean of (a) bulk density, (b) moisture content, (c) porosity, (d) pH, (e), EC, and (d) organic carbon as influenced by experimental site. The uncultivated lower area (UnLA) had a significantly higher bulk density of 1.45Mgm^{-3}which differed from the lower (LwCU) and upper cultivated (UpCU) area each with 1.44 Mgm^{-3}. The bulk density is in order of UnLA>LwCU>UpCU, while the porosity is in order of LwCU>UpCU>UnLA. Higher Bulk density in UnLA could result from non-activities (farming) in the area and sealing effect that could happen due to organic residue incorporation and decomposition (Rousseve *et al.,* 2002). Conversely, the uncultivated lower area UnLA) had a significantly lower porosity with 45.2%, which differed significantly ($p<0.05$) from the (LwCU) lower cultivated soil and UpCU that had 45.6 and 45.5 %, respectively. The porosity result agrees with Sasal *et al.* (2006), who found that no activities in the area have a greater porosity directly after farming operation compared to uncultivated surface layer is disturbed minimally. Uncultivated lower a thus are alters the pore size and distribution of the soil, especially in the short term (Fernández-Ugalde *et al*., 2009). An area with high bulk densities and lower total porosities, which indicated that a lack of disturbance produces an increase in soil compaction. Lower bulk densities are preferred in agriculture because it promotes root growth, increases water infiltration, improves soil aeration air exchange, and increases the ease of farming operations (Rousseva *et al*., 1988). Lower bulk density found under LwCU and UpCU was due to the constant tilling of the soil (Horne, 1992).

There was no significant ($p>0.05$) difference between the three (3) areas under study in terms of moisture content. However, uncultivated lower area (UnLA) had the higher soil moisture of 23.2%, and the least was observed under the upper cultivated area (UpCU)with 22.4%. The soil moisture is in order of UnLA>LwCU>UpCU. Higher moisture content in the uncultivated lower area could result from being in a depression point and due to the higher proportion of clay as shown in the texture, which makes it retain more water compared to its counterparts. The result agrees with the research conducted by Blevins *et al*. (1971), who reported that loamy soil had greater soil moisture content which was attributed to reduced evaporation and a greater ability to store water. Uncultivated lower area (UnLA) had a soil pH of 9.1, which differed significantly ($p<0.05$) from LwCU and UpCU that had 7.5 and 7.1, respectively. However, there was no significant difference ($p>0.05$) between UnLA and LwCU, with both having an EC of 0.9 dS $m^{-1,}$ but the two differed significantly ($p<0.05$) from UpCU that recorded an EC of 0.7 dS m^{-1}. The electrical conductivity is in order of UnLA≥LwCU>UpCU, while the soil pH is in order UnLA>LwCU>UpCU. Higher pH in the uncultivated lower area (UnLA) could result from no fertilizer and non-farming activities on the land. Cultivated soils are frequently more acidic in the surface layers (Tisdal and Oades, 1982). When comparing an EC of soils, several researchers reported that soils are frequently more acidic in the surface (Fuentes *et al*., 2009). Lower EC in UpCU could be because of high infiltration rate, which agrees with Balesdent*et al*. (2000), who reported that with more water infiltrating into the soil, salts accumulated to the surface are leached downwards into the shale parent material and reduces the salt concentration of the soil. Researchers indicated that EC is an important soil quality indicator (Fuentes *et al*., 2009). It is a measurement that correlates with soil properties that affect soil texture, cation exchange capacity, drainage condition, organic matter level, salinity, and subsoil characteristics (Heil and Schmidhalter, 2017). There was no significant difference ($p>0.05$) between the experimental sites in terms of OC. The highest was obtained under UnLA with 1.3 %, followed by LwCU and UpCU, with each having 1.2%. The organic carbon is in the order UnLA>LwCU ≥UpCU. Higher organic carbon in the uncultivated lower area could result from the lack of farming activities as well as accumulation of tree litters on the land. The result agrees with Watts *et al.* (2001), who reported that the incorporation of fresh organic materials by ploughing could also improve the abundance and strength of small aggregates. Organic matter content in soil is directly proportional to organic carbon (OC) content (Montanarella *et al*, 2015). This observation, however, appeared to be in contrast with Ball *et al.* (1997), who stated that organic matter content of soil varies drastically in response to different land uses thus, promotes surface accumulation of soil organic carbon (Hamblin, 1984; Murtaza *et al*., 2006; Agboola and Fayemi, 1972). In highly saline soil, organic matter is a major determinant of cation exchange capacity. Its reduction leads to decrease in nutrient and water retention ability which all lead to lower soil fertility (Gupta and Abrol, 1990).

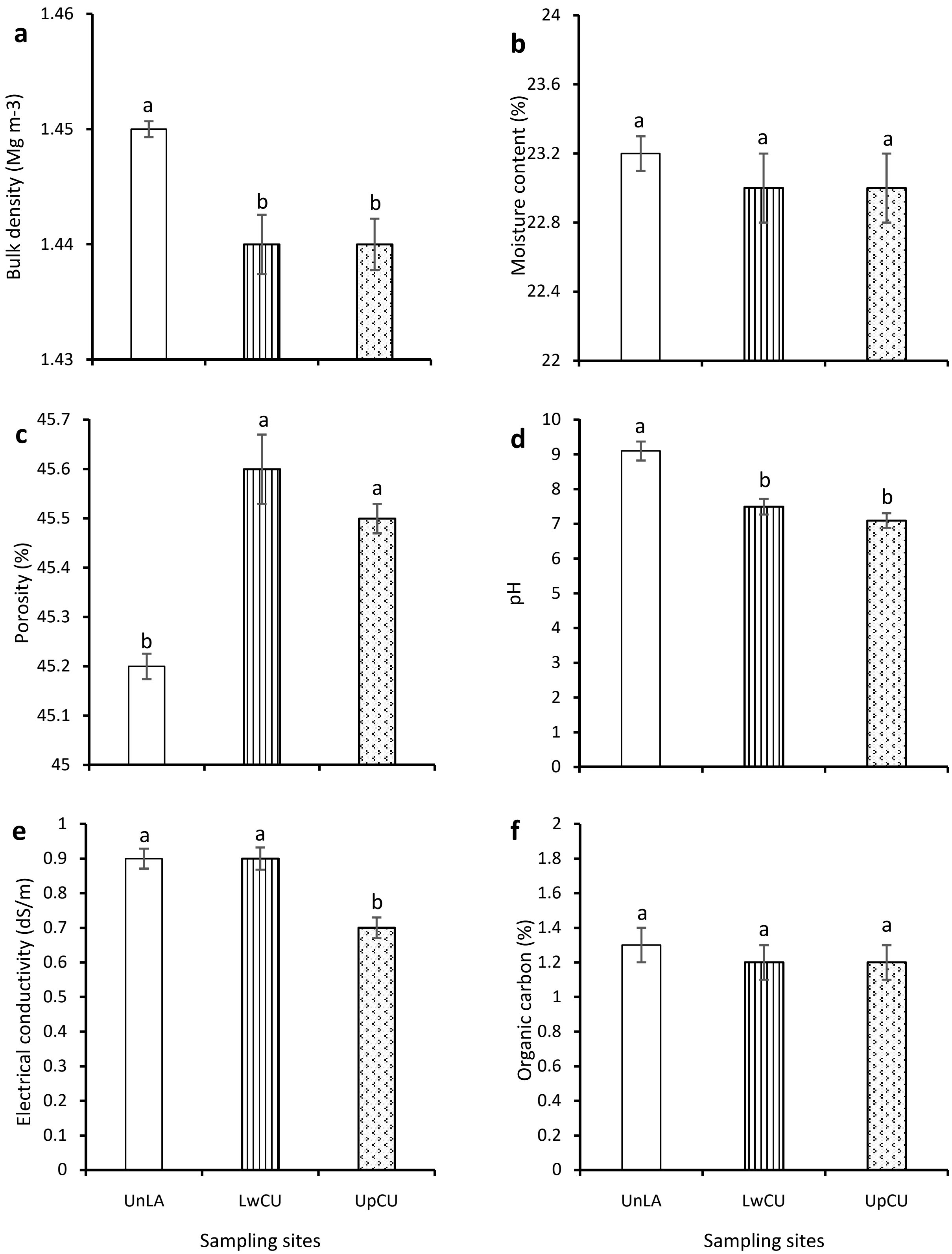


Figure 2: Means (±standard error) of (a) bulk density, (b) moisture content, (c) porosity, (d) pH, (e), EC, and (d) organic carbon as influenced by sampling site [UnLA= uncultivated lower area, LwCU= lower cultivated area, UpCU= Upper cultivated area]. Means with the same letters do not differ significantly from one another at a 5% level of significance

Hydraulic Properties

Figure 3 shows the soil infiltration rate and cumulative infiltration of the soils under study. Upper cultivated (UpCU) had a constant infiltration rate of 7.4cm min^{-1}while lower cultivated area (LwCU), and the uncultivated lower (UnLA) area had 3.8and 3.0 cm min^{-1} respectively. The (UpCU) had7.4 cm min^{-1}mainly due to the greater percentage of sand, as shown in Table 1. The higher constant infiltration rate of the soil could also be due to the lower moisture content shown in Figure 2b, which shows that soil water infiltration is directly affected by soil management. Moreno *et al.* (1997) made similar findings and concluded that the infiltration rate was only higher in places with low moisture content.After 150 minutes of infiltration study, UpCU had a cumulative infiltration rate of 879.9 cm, followed by LwCU with 516.6 cm and the least was UnLA with 286.15 cm. Higher cumulative infiltration rate in UpCU could be attributed to the nature of the soil with a greater proportion of the sand, the site's position at the crest point, and the farming activities taking place in the area (plant utilisation). The result agrees with Moreno *et al*. (1997), who reported a higher infiltration rate of loamy soil due to farming activities.

Figure 4 shows the result of the saturated hydraulic conductivity of the soils under study. The Upper cultivated area (UpCU) had a significant ($p<0.05$) higher saturated hydraulic conductivity of 1.8 cm hr$^{-1,}$ which differed significantly from other areas. Lower cultivated and UnLA had 1.6 and 1.2 cm hr^{-}1, respectively with UnLA having the least. The hydraulic conductivity is in order of UpCU>LwCU>UnLA. Higher Ksat in UpCU may be due to less soil compaction, leading to higher porosity and greater water absorption than UnLA, which was more or less a compacted soil, which in turn recorded a lower Ksat (1.2cm hr^{-1}). Hydraulic conductivity in agricultural soils is affected by the porosity and pore-size distribution, bulk density, soil compaction, and aggregation (Lipiec *et al*., 2006). Power and Peterson(1998) found improvement in soil Ksat in upper cultivated and lower cultivated lands compared to the uncultivated lower area, which they attributed to the maintenance of soil structure and the hydraulically functioning pores size under farming practices. Benjamin (1993) reports that an increase in Ksat under uncultivated lower area is mainly due to greater continuity of pores and flow of water through a few very large pores which agree with my result.

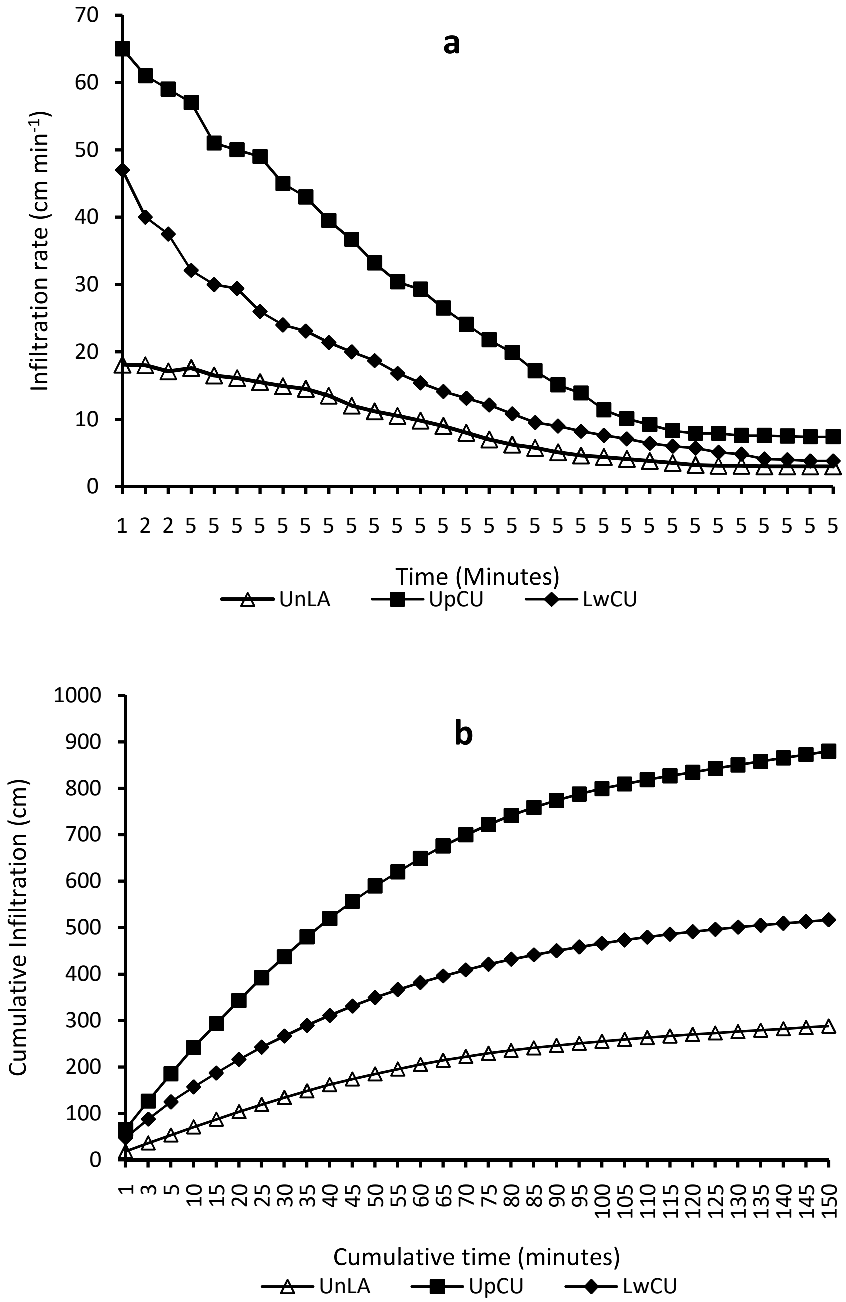


Figure 3: (a) Infiltration rate, and (b) cumulative infiltration as influenced by the sampling sites [UnLA= uncultivated lower area LwCU= lower cultivated, UpCU=upper cultivated soil].

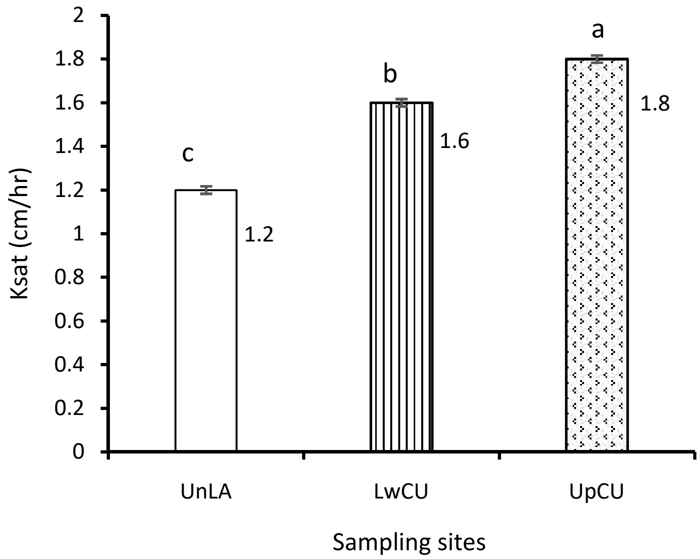
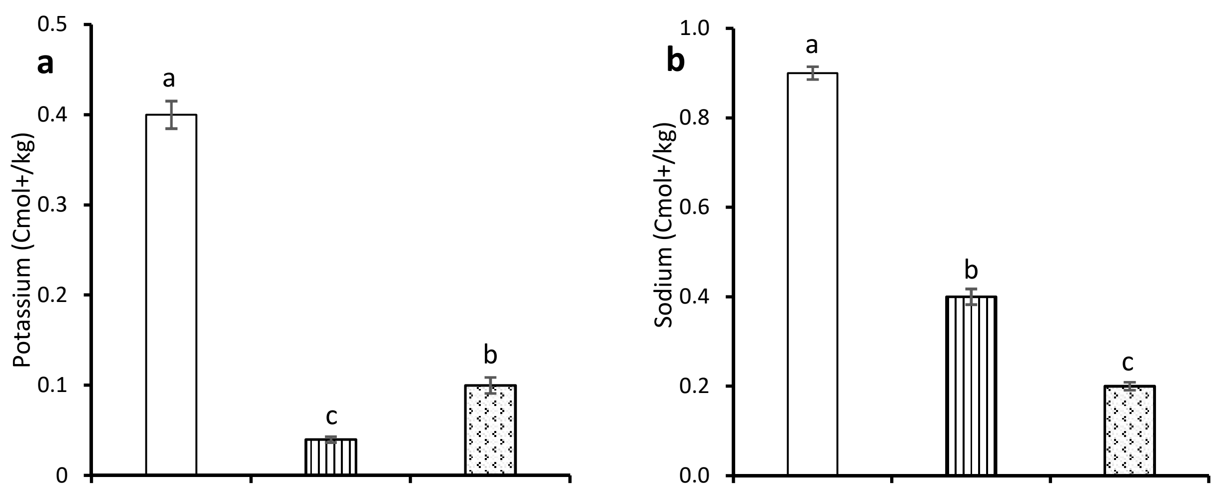


Figure 4: Means (±standard error) of saturated hydraulic conductivity as influenced by sampling site [UnLA= uncultivated lower area, LwCU= lower cultivated area, UpCU=Upper cultivated area]. Means with the same letters do not differ significantly from one another at a 5% level of significance.

Chemical Properties

Figure 5show the results of K, Na, Ca, Mg, H & Al, and CEC as influenced by the experimental sites. The UnLA had the highest amount of potassium and sodium content with 0.4 and 0.9 cmolkg^{-1},while LwCU and UpCU had a K and Na of 0.04and 0.4 cmolkg^{-1}, and 0.1 and 0.2cmol/kg^{-1}, respectively. Higher Ca, and Na in the UnLA could be as a result of non-farming activities in the area with uniform parent materials. Figure 5c and 5d show that UnLA had1.8 and 5.8 cmol/kg^{-1}, while UpCU had 2.1, and 3.8 cmol/kg^{-1}of Ca and Mg, respectively. The exchangeable Ca and Mg are in order of UpCU>UnLA>LwCU. The lower amount of Ca and Mg in the UnLA could result from the management practices of the soil. Thomas *et al.* (2007) found greater exchangeable Ca and Mg concentrations under the upper cultivated area compared to the lower cultivated area (Fullen and Catt, 2004).



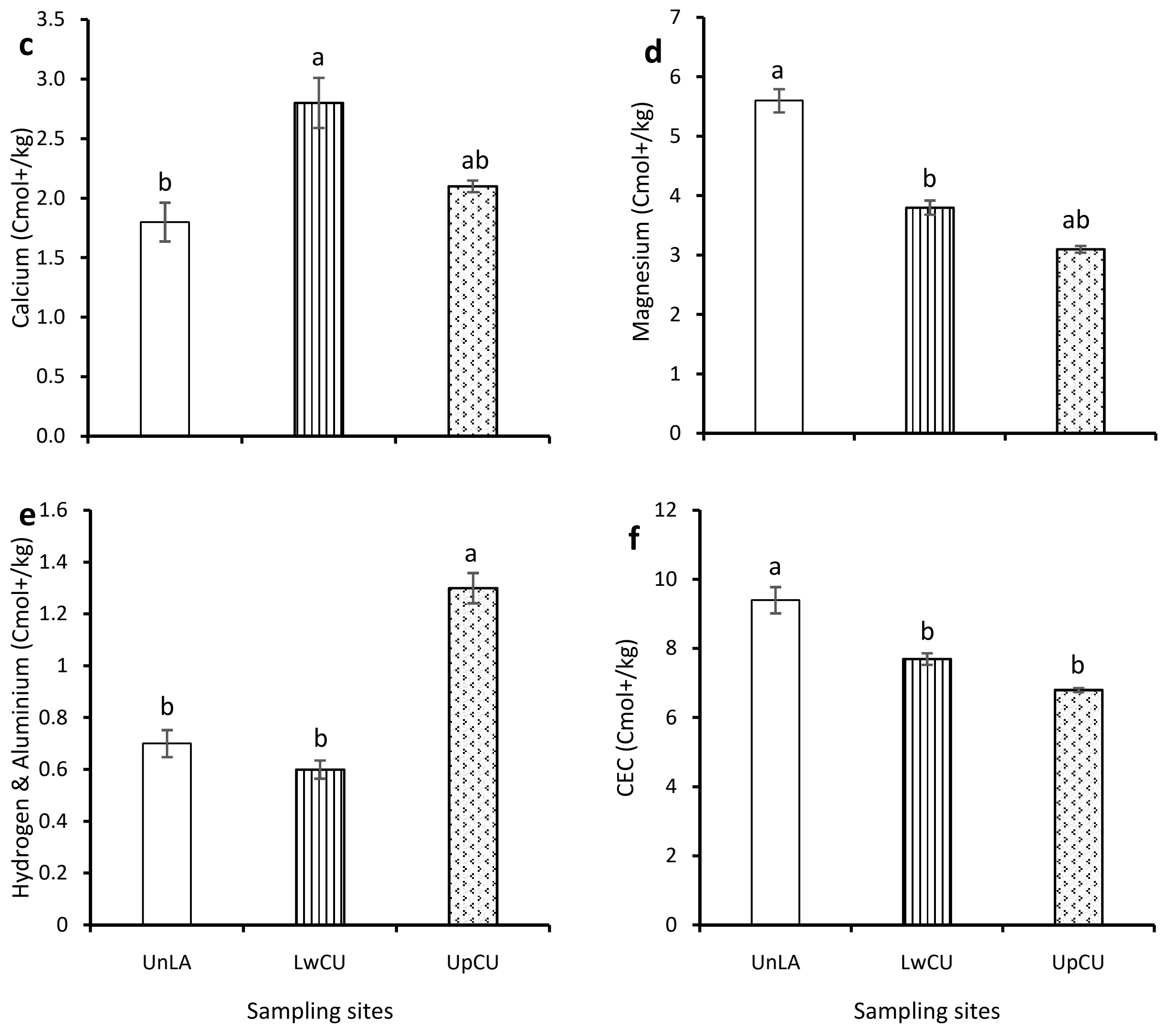


Figure 5: Means (±standard error) of (a) K, (b) Na, (c) Ca, (d) Mg, (e), H & Al, and (d) CEC as influenced by sampling site [UnLA= uncultivated lower area, LwCU= lower cultivated area, UpCU=Upper cultivated area]. Means with the same letters do not differ significantly from one another at a 5% level of significance.

The UpCU had significantly($p<0.05$) higher Hydrogen (H) and Aluminum (Al) content of 1.3 cmol+kg^{-1}which differed significantly ($p<0.05$) from UnLA and LwCU areas each with 0.7 and 0.6 cmol+kg^{-1},respectively (Figure 5e). The H and Al is in order of UpCU >UnLA>LwCU. Higher H and Al in the UpCU may be due to the farming activities in the land. In terms of the CEC, UnLA had 9.4cmol+kg^{-1}which differed significantly ($p<0.01$) from LwCU and UpCU that recorded 7.8 and 6.4 cmol+kg^{-1}, respectively. There was no significant ($p>0.05$) difference among the lands under cultivation (LwCU and UpCU), probably due to the farming activities being carried out year in year out. The CEC is in order of UnLA>LwCU>UpCU. Higher cation exchange capacity in uncultivated lower may be as a result of non-farming activities in the land. Since SOM enhances CEC, any process that will result in the loss of organic carbon (organic matter) would also affect the soil CEC. The higher CEC of UnLA corresponds to the higher OC % (1.3%) which is higher than that of UpCU and LwCU area (Figure 2f). Ploughing exposes the soil organic carbon to volatilization and losses may also occur by soil erosion, which is increased by ploughing due to topsoil exposure (Fullen and Catt, 2004).

Figure 6 show the SAR and ESP of soils of the study area as influenced by the sampling location. The UnLA showed to have the higher amount of SARand ESP with 0.5 and 99%, followed by LwCU with 0.2 and 5.7 % and the least was UpCU with 0.1and 3.1%. the SARand ESP results are in order of UnLA>LwCU>UpCU. The highest SARand ESP found in uncultivated lower area could be due to the lack of farming activities and the presence of the greater exchangeable bases compared to the LwCU and UpCU as anthropogenic activities are taking place, which agrees with Munkholm *et al.* (2001) and Antonio *et al.* (2002). The increase of salinity is mainly due to greater continuity of pores and due to the flow of water through very few large pores. These large pores might be created by earthworms and other biological activity due to less disturbance of the soil improving sodium absorption ratio (Benjamin, 1993).

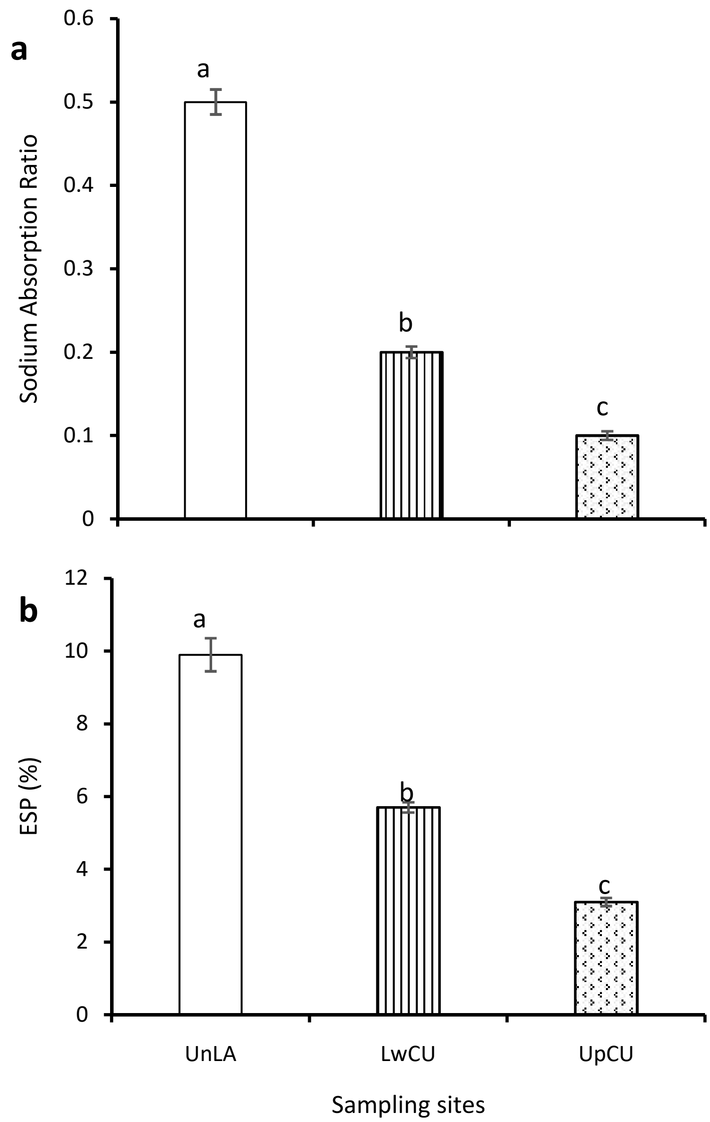


Figure 6: Means (±standard error) of (a) sodium absorption ratio, (b) Exchangeable sodium percentage as influenced by sampling site [UnLA= uncultivated lower area, LwCU= lower cultivated area, UpCU=Upper cultivated area]. Means with the same letters do not differ significantly from one another at a 5% level of significance.

Conclusion and Reccommendations

The current study showed alkaline soil has an impact on soil physical and chemical status, and farmers, unfortunately, had little knowledge about this fact. The effects of alkaline soil were more prominent in the physical properties of the soil than the chemical properties. The constant Infiltration rate and cumulative infiltration of UnLA was found to be the least, and that of the UpCU was the highest. UnLA can be categorized as alkaline soil based on its pH, EC, Na, ESP and SAR, which were well within the limit of alkaline soil. The UpCU and LwCU were found to have chemical and physical properties within the normal range, as such, they are not classified as alkaline soils. The UnLA had higher exchangeable bases as well as the CEC despite being an alkaline soil. This suggests that with good management, the soil could be cultivated and give a significant yield.

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