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Assessment of Fertility Status of Soils under Different Cropping Patterns and Implications for Sustainable Agricultural Land Management

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Abstract
Soil fertility assessment is essential for effective land management practices. Therefore, this study was conducted to assess the physico - chemical characteristics of soil under different (Ginger, Maize, Mango and Oil palm) cropping systems and to test for significant differences in the nutrient in order to provide basis for recommending site/crop specific land management practices in the study area. Soil samples under the aforementioned cropping systems were collected from three sites (Ungwan Rana, Kurmin Kwara and Kyari) in Daddu of Jaba Local Government Areas of Kaduna State at two (surface and subsurface) levels using soil auger. The samples collected were subjected to physico - chemical analyses at the Institute for Agricultural Research (IAR) Ahmadu Bello University Zaria. The results of the analyses showed that the pH of all the soils ranged between slightly acidic to slightly alkaline. Whereas the bulk densities, organic carbon, Nitrogen, Phosphorus and Potassium contents were between moderate to high range at the surface and subsurface levels. The soil porosity, moisture content and Cation Exchangeable Capacity were mostly high for soil under all the crops investigated at the surface and sub surface levels. Results of inferential statistics revealed that there are significant differences in the soil bulk density, moisture content, pH and Phosphorus amongst the croplands and between the depths indicating the impact of agricultural practices on soil of the study area. This study therefore recommended the use of organic matter to remediate impending soil acidity under ginger and oil palm cultivation in the study area.

Keywords: Cropping systems; land management; soil fertility; statistical analyses; Sustainable productivity

INTRODUCTION
Soil is a weathered mantle of unconsolidated material covering the land surface, comprising of a mixture of mineral elements and organic matter providing anchorage (Khan, 2013), warmth and protection to plants (Doran & Parkin, 1994); purification of water, detoxification of pollutants and cycling of Carbon, Boron, Phosphorus, Sulphur and water (Lal, 2001; Beverick and Arnold, 2012). Soil is a dynamic system within where series of changes occur (Songu *et al.*, 2021). These changes directly affect the composition, properties

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and productivities of the soil (Oriola and Hammed, 2012). In some cases, spatio temporal variations in soil properties depict changes in geology (Burke, 2002; Koojman et al., 2005; Umeri *et al.,* 2017); climatic change (Dexter & Richard, 2009) and soil management practices (Amusan et al., 2006; Basaran *et al.,* 2006; Gupta et al., 2009; Yakub, 2012; Ogunkunle, 2013; Loria *et al.,* 2016). The physico - chemical properties (pH, soil texture, moisture, porosity, bulk density, soil organic carbon, organic matter, cation exchange capacity, total nitrogen, phosphorus and potassium) of soil affect nutrients' availability, biota growing conditions, and soil physico - chemical and biological properties (Yakub, 2012).

Previous studies on the influence of cropping systems on soil physico – chemical properties have indicated varied and conflicting results (Oladoye, 2015; Hacimuftuoglu and Oztaz, 2017; Oriola and Atiyong, 2020). For instance, study of Oladoye, 2015 on the physico - chemical properties of soil of tropical secondary forest indicated significant variations in Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, CEC, OM and OC but insignifcant variation in sand, clay and silt content. Whereas the studies of Ogunkunle 2013; Yahaya et al., 2014; Hacimuftuoglu & Oztaz, 2017; Suleiman, et al., 2017; Rajesh *et al.,* 2017; Oriola & Atiyong, 2020 found differences in the properties of soils under different cropping systems. Whereas, Loria *et al., 2016* found that the traditional cropping systems had no influence on the soil properties.
Given that soil fertility management is fundamentally important to achieving sustainable agricultural production (Abdulwahab *et al.,* 2019). Increasing agricultural productivities become necessary given that global hunger affecting 815 million people had been predicted to have greatest impacts in Africa than in any other parts of the World (FAO, 2017); there is therefore a need for conservation of the natural resource base for increased agricultural productivities (FAO, 2017). This research is therefore conducted to assess whether there are significant differences in the nutrient status of soil under different cropping patterns with the aim of suggesting appropriate site specific and sustainable soil management practices.

MATERIALS AND METHODS

Study Area: The study area (Daddu) is located between latitude 9^0 18′ 50′′N to 9^0 36′ 46′′N and longitude 8^0 50′ 0′′E to 9^0 10′ 12′′E. It is one of the districts in Jaba Local Government Area. Jaba Local Government Areas share boundaries with Zango Kataf in the North, Jema'a in the East, Kachia by the West, Kagarko Local Government area and Nassarawa state by the South.

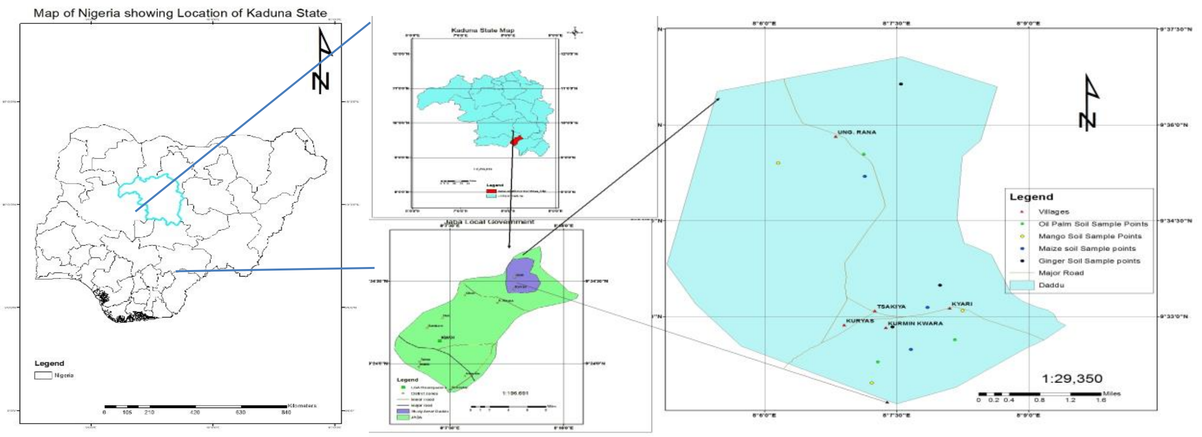

Fig. 1. Location of the Study Area with Sampling Points
Source: Author, 2021

The climate of the study area is characterized by two distinct seasons with annual average annual rainfall ranging between 1000m and 1500m (Abaje *et al.,* 2015) and temperature ranges between 27^{o}C and 30^{o}C (Danladi *et al.* 2017) and mean relative humidity 63% (Abaje *et al.* 2015). Soil of study area is predominantly sandy loam of tropical ferruginous soils (Abaje *et al.* 2010) suitable for cultivation of sorghum, millet, maize, yam, rice, cocoyam, groundnut, acha, beans, ginger, cassava, soya bean, sweet potatoes, benniseed and sugar cane, vegetables such as cabbage, spinach, tomatoes and pepper (Eroarome, 2009). Jaba local government is made up of thirteen districts (Anamayi and Anamayi, 2018) with population of 61,000 (Danladi *et. al.,* 2017) with residents mostly engaged in farming and other non – farm to secure households financial needs (Danladi *et al.,* 2017).

Sample Collection

Reconnaissance survey was conducted between 8th - 10th October, 2020. Core samples were collected using soil auger at three different sampling points within a square quadrat of 20m by 20m with two composite samples from surface and subsurface having the depths of 0 - 30cm and 30 - 60cm respectively for permanent (Oil palm and Mango) crops and depths of 0 - 15cm and 15 - 30cm for surface and subsurface respectively for annual (Ginger and Maize) crops from three (Ungwan Rana; Kurmin Kwara and Kyari) communities (Table 1).

Table 1: Sampling Locations

Ungwan Rana			
Crops	Latitude	Longitude	Height
Mango	$9^{0}35^{1}21.07^{11}$N	$8^{0}6^{1}09.68^{11}$E	746.20m
Oil Palm	$9^{0}35^{1}36.10^{11}$N	$8^{0}07^{1}08.66^{11}$E	759.56m
Ginger	$9^{0}36^{1}28.73^{11}$N	$8^{0}7^{1}33.33^{11}$E	759.50m
Maize	$9^{0}35^{1}33.78^{11}$N	$8^{0}07^{1}08.94^{11}$E	758.34m

Kurmin Kwara			
Crops	Latitude	Longitude	Height
Mango	$9^{0}32^{1}47.95^{11}$N	$8^{0}07^{1}34.60^{11}$E	759.87m
Oil Palm	$9^{0}32^{1}10.48^{11}$N	$8^{0}7^{1}12.87^{11}$E	752.50m
Ginger	$9^{0}32^{1}35.01^{11}$N	$8^{0}7^{1}19.67^{11}$E	755.29m
Maize	$9^{0}32^{1}47.78^{11}$N	$8^{0}07^{1}26.72^{11}$E	762m

Kyari			
Crops	Latitude	Long.	Height
Mango	$9^{0}33^{1}4.41^{11}$N	$8^{0}08^{1}15.27^{11}$E	752m
Oil Palm	$9^{0}33^{1}01.15^{11}$N	$8^{0}08^{1}15.59^{11}$E	758.95m
Ginger	$9^{0}33^{1}0.99^{11}$N	$8^{0}08^{1}7.01^{11}$E	758.65m
Maize	$9^{0}33^{1}10.41^{11}$N	$8^{0}08^{1}9.17^{11}$E	764.44

Source: Authors, 2021

Samples were well labeled and then transported to the Institute for Agricultural Research (IAR) Ahmadu Bello University Zaria (ABU, Zaria) for the laboratory analyses. The samples were air - dried at room temperature, crushed and passed through a 2mm sieve for the determination of physio - chemical characteristics of the soil samples. The particle size distribution was determined by Bouycouos hydrometeric method using sodium hexametaphosphate as a dispersant (Tel and Hagarthy, 1984). The textural classes were determined with the aid of USDA textural triangle. Bulk density was determined by the methodology described by Grossman and Reinsch, 2002 (Eqn. 1)

$$Bulk\ density(g/\text{cm3}) = \frac{weight\ of\ oven\ dry\ soil(g)}{Volume} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(Eqn\ 1)$$

Gravimetric moisture content was determined by comparing the weight of the field wet soil (Wt) with the oven – dried soil (Wd) for about 24 hours at 105^{0}C. The water content was calculated using Equation 2:

$$Gravimetric\ moisture\ content = \theta d = \left(\frac{Wt - Wd}{Wd}\right) x\ 100\ \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (eqn\ 2)$$

Soil porosity was computed from bulk density and particle density using a formula
Total Porosity = 1 - Bulk Density/Particle Density assuming a Particle Density of 2.65mg/m^3
Soil pH was measured in water and calcium chloride (0.01M $CaCl_2$) using a glass - calomel combined with electrode after equilibrating for 30 minutes.
Organic carbon was determined using method described by Walkey and Black (Nelson and Sommers, 1996) (Eqn. 3).

$$\%\ OC = \frac{(blank - titre)\ x\ 0.3\ x\ m\ x\ f}{weight\ of\ soil}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eqn\ 3)$$

where: f = corrected factor (1.33). m = concentration of $FeSO_4$.

Total Nitrogen was determined using Kjeldahl digestion method (Eqn. 4).
Percentage Nitrogen content in the soil was calculated thus:

$$\%\ N = \frac{(gms)\ Nitrogen}{(gms)\ Sample}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (Eqn\ 4)$$

Available Phosphorus (P) - Total available phosphorus was determined using Bray II method (Olsen and Sommers, 1982). Potassium was determined using flame photometer after the photometer had been standardized with blank solutions. Cation exchange capacities were estimated tritometrically by distillation of ammonium that was displaced by sodium from NaCl solution. Organic matter was determined using Walkey Black Wet Oxidation method. Inferential (one - way ANOVA) statistics was used to test for significance differences in the soil physico - chemical parameters under different cropping systems at 95% confident level.

RESULTS AND DISCUSSION

The tables showed the summary the results of the laboratory analyses conducted on the soil samples for the crop farms under investigation and at the surface (Table 2) and the subsurface levels (Table 3).

Table 1: Physico – Chemical Parameters of Soil under Different Cropping Systems at Surface Level

Level (Surface)	**0 - 15**		**0 - 30**	
Crops	**Ginger**	**Maize**	**Oil Palm**	**Mango**
Parameters	Mean ±Std	Mean ±Std	Mean ±Std	Mean ±Std
Bulk Density	1.52(0.17)	1.46(0.24)	1.26(0.16)	1.08(0.05)
Soil Porosity	15.31(6.33)	20.44(2.24)	13.54(4.18)	15.31(11.38)
Moisture Content	3.47(1.81)	4.13(4.25)	1.27(0.34)	2.22(0.40)
pH (H_2O)	6.40(0.92)	7.60(0.10)	6.73(1.33)	7.431(0.06)
pH ($Cacl_2$)	5.60(0.82)	6.80(0.10)	5.93(1.24)	6.70 (0.10)
Organic Carbon	1.42(0.40)	1.34(0.27)	1.24(0.30)	1.19(0.31)
Organic Matter	2.45(0.70)	2.30(0.47)	2.14(0.52)	2.06(0.53)
Nitrogen	0.31(0.09)	0.29(0.06)	0.27(0.07)	0.26(0.07)
Phosphorus	27.67(21.34)	10.58(3.64)	12.91(8.08)	4.63(0.86)
Potassium	0.35(0.14)	0.19(0.04)	1.03(1.41)	0.52(0.22)
ECEC	16.04(6.51)	14.06(3.37)	19.53(11.34)	16.07 (2.69)
Clay	4.67(1.15)	6.67(1.15)	6.67(3.06)	6.67(3.06)
Silt	11.67(3.21)	14.00(1.00)	16.00(4.36)	14.67(4.51)
Sand	83.67(3.79)	79.33(1.53)	77.33(7.23)	73.67 (7.51)

Table 2: Physico – Chemical Parameters of Soil under Different Cropping Systems at Subsurface Level

Level (Subsurface)	**16 - 30**		**31 - 60**	
Crops	**Ginger**	**Maize**	**Oil Palm**	**Mango**
Parameters	Mean ±Std	Mean ±Std	Mean ±Std	Mean ±Std
Bulk Density	1.49(0.15)	1.43(0.07)	1.19(0.02)	1.11(0.08)
Soil Porosity	29.22(15.98)	12.29(7.58)	11.7(5.39)	19.45(6.83)
Moisture Content	2.22(0.54)	4.76(2.18)	1.56(0.31)	2.19(1.07)
pH (H_2O)	6.73(1.16)	7.83(0.12)	6.80(1.57)	7.40(0.10)
pH ($Cacl_2$)	5.70(1.10)	6.87(0.12)	5.87(1.50)	6.70(0.10)
Organic Carbon	0.91(0.46)	1.04(0.15)	0.66(0.17)	0.72(0.10)
Organic Matter	1.57(0.80)	1.50(0.25)	1.13(0.29)	1.25(0.17)
Nitrogen	0.20(0.10)	0.22(0.04)	0.14(0.04)	0.16(0.02)
Phosphorus	19.38(19.75)	6.12(1.80)	4.46(0.45)	4.00(1.59)
Potassium	0.30(0.14)	0.17(0.02)	0.57(0.75)	0.23(0.15)
ECEC	13.72(5.52)	9.91(1.20)	14.01(6.95)	10.21(1.44)
Clay	5.33(2.31)	8.67(1.15)	8.67(1.15)	10.00(2.00)
Silt	15.33(3.06)	17.67(2.52)	17.67(3.21)	19.67(3.51)
Sand	79.33(4.16)	73.67(1.53)	73.67(3.79)	70.33(4.93)

The mean bulk density is highest in Ginger farm with 1.52gcm^{-3} and 1.49gcm^{-3} at the surface and subsurface respectively followed by Maize farm with 1.46gcm^{-3} and 1.43gcm^{-3}. For Mango and Oil palm, the bulk densities are 1.08, 1.11 and 1.26, 1.19 for the surface and the subsurface respectively (Fig. 2). The lowest bulk density was observed in Mango and there is inverse relationship between bulk density and depth.

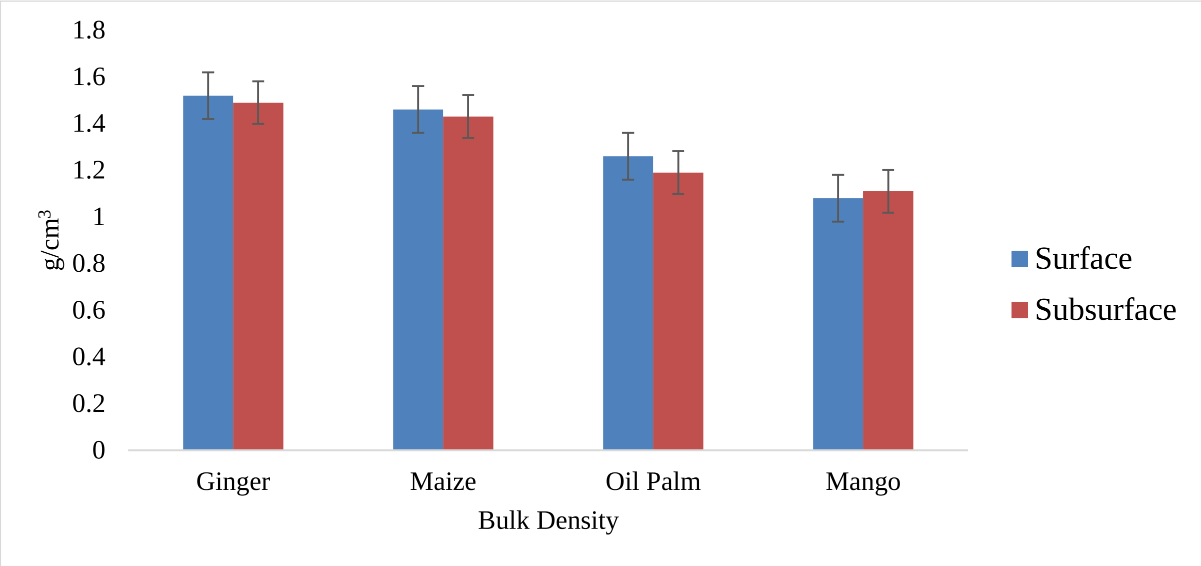

Fig. 2: Mean Bulk Density of Soil under different Cropping Systems

The soil pH was determined for H_2O and $CaCl_2$ at the surface and the subsurface levels for all the crop farms investigated. The result indicated a general increase in soil pH value with depth (Fig. 3) with highest values observed on Maize plot with average value of 7.60 and 7.83 under H_2O and 6.80 and 6.87 under $CaCl_2$ respectively for the surface and subsurface soil levels. Whereas, lowest values were recorded on Ginger farms with values of 6.40 and 6.73 under H_2O and 5.60 and 5.70 under $CaCl_2$. Increase in soil pH in all the croplands investigated particularly with depth might be due to leaching of exchangeable cations (Magaji *et al.*, 2019) and reduction of organic matter with depth (Oladoye, 2015).

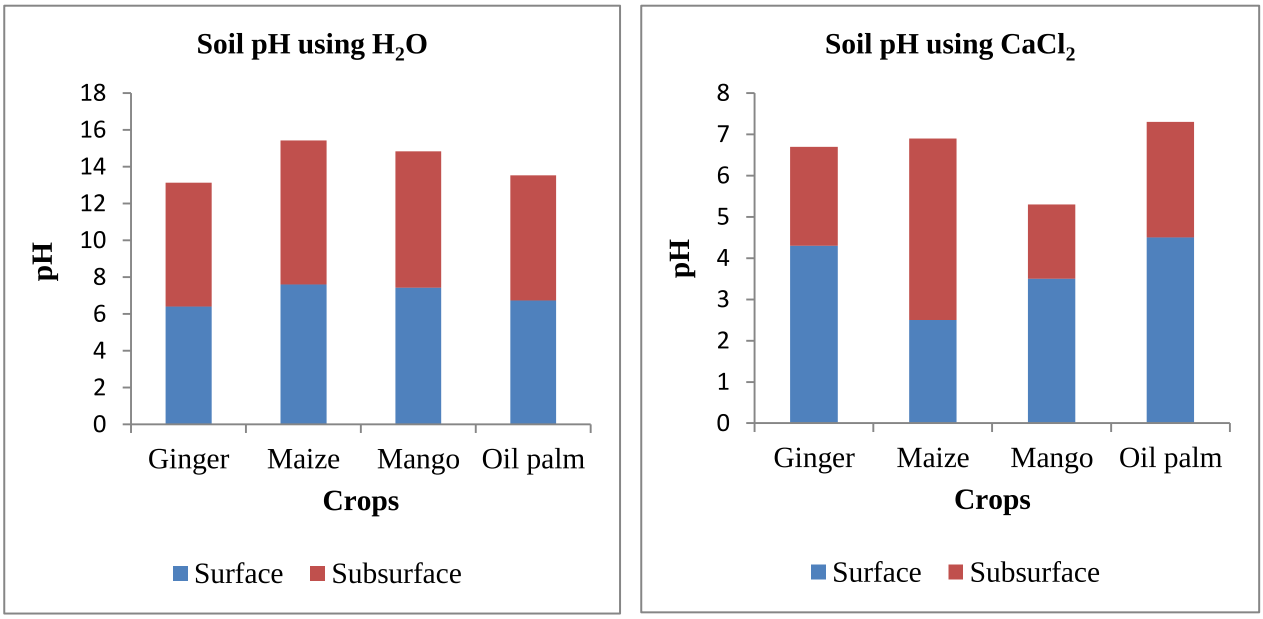

Fig. 3: Mean Soil pH under different Cropping Systems

For all the croplands investigated there were decrease in organic carbon with depth. Although, the values for the subsurface Organic Carbon fall within the moderate (0.48% and 1.15%) range (Umeri *et al.*, 2017), For instance, the results for the surface and subsurface organic carbon are Ginger (1.42% and 0.91%), Maize (1.34% and 1.04%), Mango (1.19% and

0.72%) as well as Oil palm (1.24% and 0.66%), (Tables 2 - 3 above and Fig. 4). The high Organic Carbon content most especially at the surface soil level may be due to the accumulation of organic matter over years (Ogeh and Osiomwan, 2012; Loria *et al,* 2016) and low mineralization (Osujeike *et al,* 2017).

The results for Organic Matter showed an inverse relationship with increasing soil depth. For example: values 2.45% and 1.57%; 2.30% and 1.50%; 2.06% and 1.25% and 2.14% and 1.13% were obtained for Ginger, Maize, Mango and Oil palm at the surface and the sub surface levels respectively, (Tables 2 - 3 and Fig4). These observed values were within moderate (1.7% - 2.6%) range described by (Oriola and Atiyong, 2020). The high level of Organic Matter in the surface soil could be due to the humus formed by fallen leaves (Yahaya, et al., 2014). Highest level of Organic Matter recorded on Ginger farm could be due to the use of organic manure by the farmers in the study areas.

Highest values (0.31% and 0.21%) of Nitrogen was obtained from Ginger farm in the study area at the surface and subsurface soil levels. Whereas, lowest values of Nitrogen were recorded in Mango farm (0.26 and 0.16) The highest values recorded in the Ginger farm might not be unconnected with the use of Organic Matter by the farmers in the study area. (Tables 2 - 3 and Fig. 4).

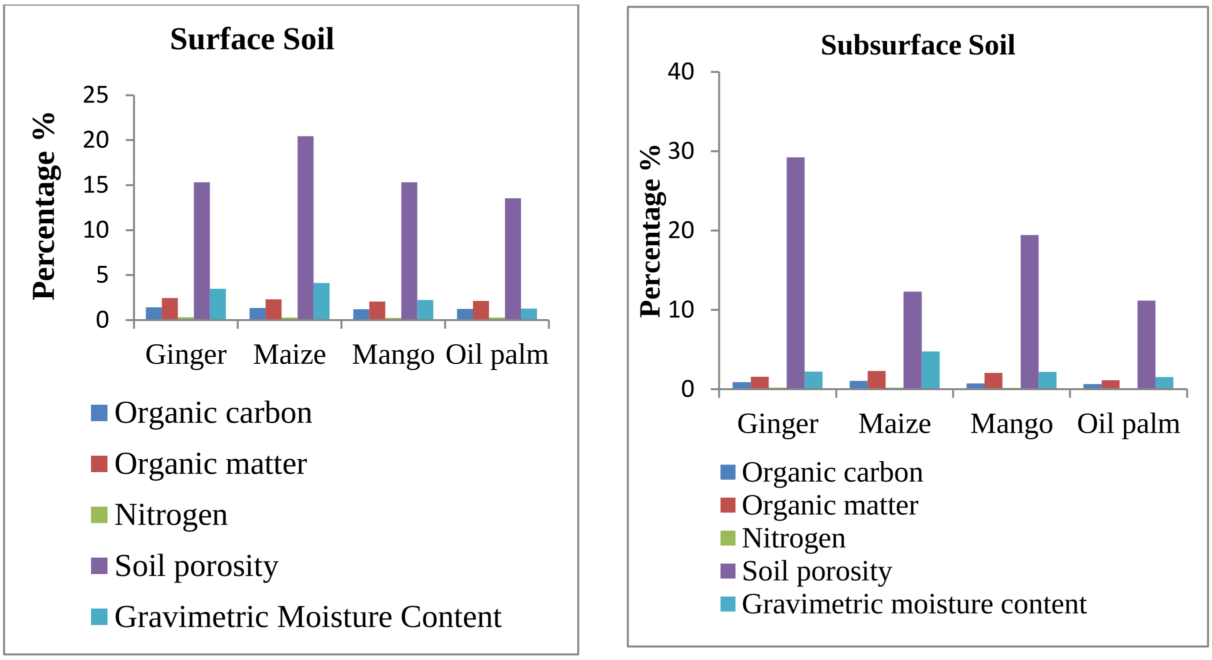

Fig. 4: Physico – Chemical Characteristics of Soils under different Cropping Systems

Soil Porosity were observed to be increasing from surface to subsurface in Ginger and Mango farms ie 15.31% to 29.31% and 15.31% to 19.45% respectively but decreasing with increasing soil depths in Maize and Oil palm farms 20.44% to 12.29% and 13.54% to 11.17% respectively (Tables 2 - 3 and Fig 4). For Ginger and Mango farms, there is an inverse relationship between soil porosity and soil depth (i.e the higher the soil depth the lower the soil porosity). Whereas, there is an observed higher soil porosity with increasing the soil depth. The higher soil porosity with increasing soil depth on Maize and Oil palm can be as a result of shallow root system of Maize and Oil palm compared to Ginger and Mango.

The results for Moisture Content in all the crops investigated and at the surface and subsurface soil levels are as follow 3.47 and 2.22; 2.22 and 2.19; 4.13 and 4.76 and 1.27 and 1.56 for Ginger, Mango, Maize and Oil palm farms respectively (Tables 2 - 3 and Fig. 4). The results indicated increase in soil Moisture Content with increasing soil depth on Maize and Oil palm farms, ie 4.13% and 4.76%; 1.27% and 1.56%. The increasing Moisture Content with soil depth on Maize and Oil palm farms is as a result of the drier soil condition due to lower Organic Matter and shallower root systems of Maize and Oil palm compared to the Ginger and Mango.

The following results were obtained for Available Phosphorus in the study area: 27.67MgKg^{-1} and 19.38 MgKg^{-1}, 10.58 MgKg^{-1} and 6.12 MgKg^{-1}, 4.63 MgKg^{-1} and 4 MgKg^{-1}, 12.91 MgKg^{-1} and 4.46 MgKg^{-1} for Ginger, Maize, Mango and Oil palm with highest being on Ginger farm and lowest on Mango. The results also showed a decrease in Available Phosphorus with increasing depth thus agreeing with the findings of Oladoye, 2015.

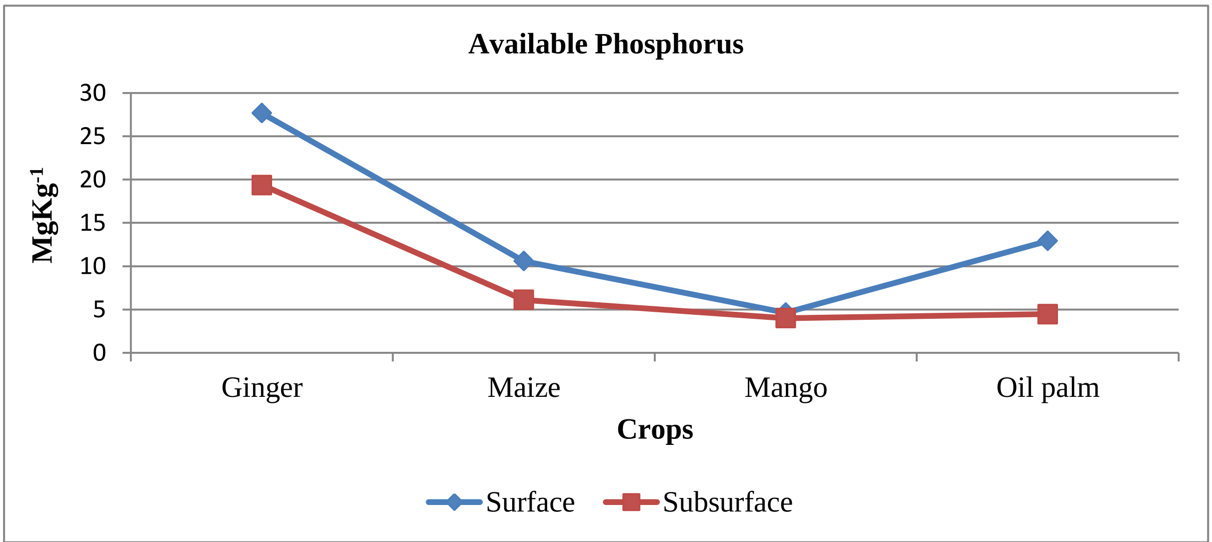

Fig. 5: Available Phosphorus in Soil under different Cropping Systems

The results of the laboratory analyses indicated that the Effective Cation Exchange Capacity was very high on Oil palm farm with 19.53M_{eq}/100g and 14.01M_{eq}/100g for surface and subsurface and low on Maize farm with 14.06M_{eq}/100g and 9.92M_{eq}/100g (Tables 2 - 3 and Fig. 6). Ginger and Mango farms have 16.04M_{eq}/100g and 13.72M_{eq}/100g and 16.07 and 10.21M_{eq}/100g at the surface and subsurface levels respectively (Tables 2 - 3 and Fig. 6). All the farms exhibited lower in ECEC at the subsurface level due lower Organic Matter content at the subsurface soil level (Oladoye, 2015)

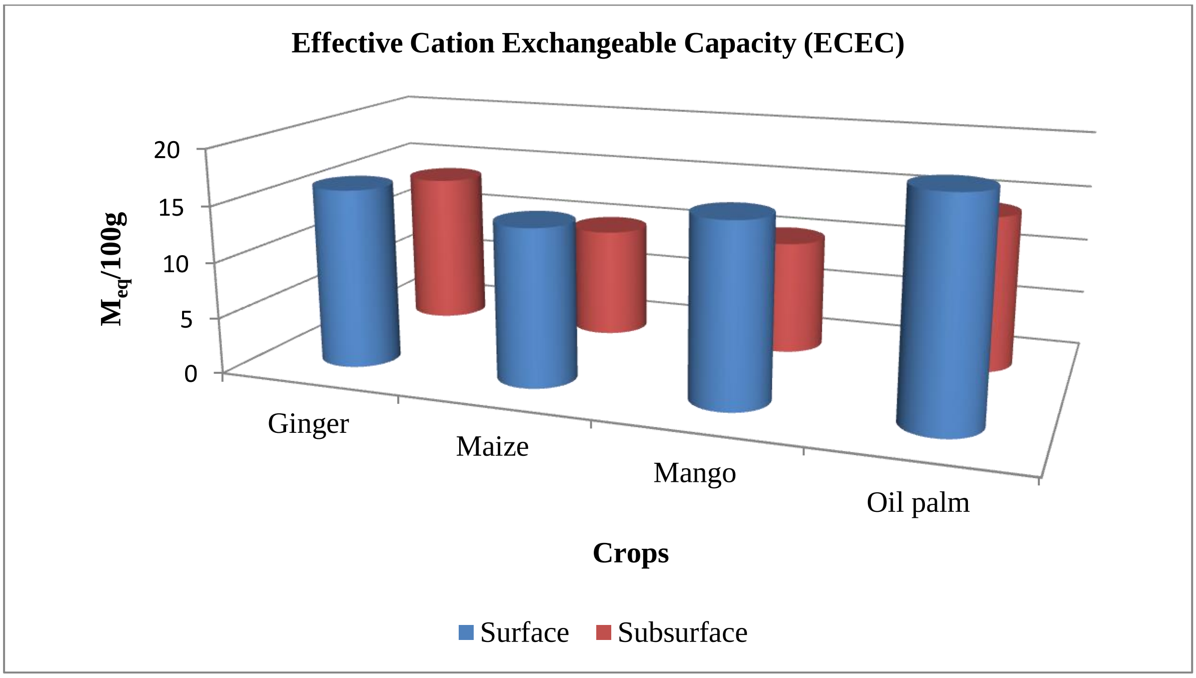

Fig. 6: Mean Effective Cation Exchange Capacity (ECEC)

Potassium showed decrease in concentration with increasing depth. The concentration of Potassium in Ginger, Maize, Mango and Oil palm from the surface and the subsurface were 0.35M_{eq}/100g and 0.30M_{eq}/100g; 0.19M_{eq}/100g and 0.17M_{eq}/100g; 0.52M_{eq}/100g and 0.23M_{eq}/100g; 1.03M_{eq}/100g and 0.57M_{eq}/100g respectively (Tables 2 – 3 and Fig. 7). The highest Potassium concentration was recorded on Oil palm farms and the lowest on Maize farm. This similar trend was also observed for Organic Matter and Organic Carbon content in the soil.

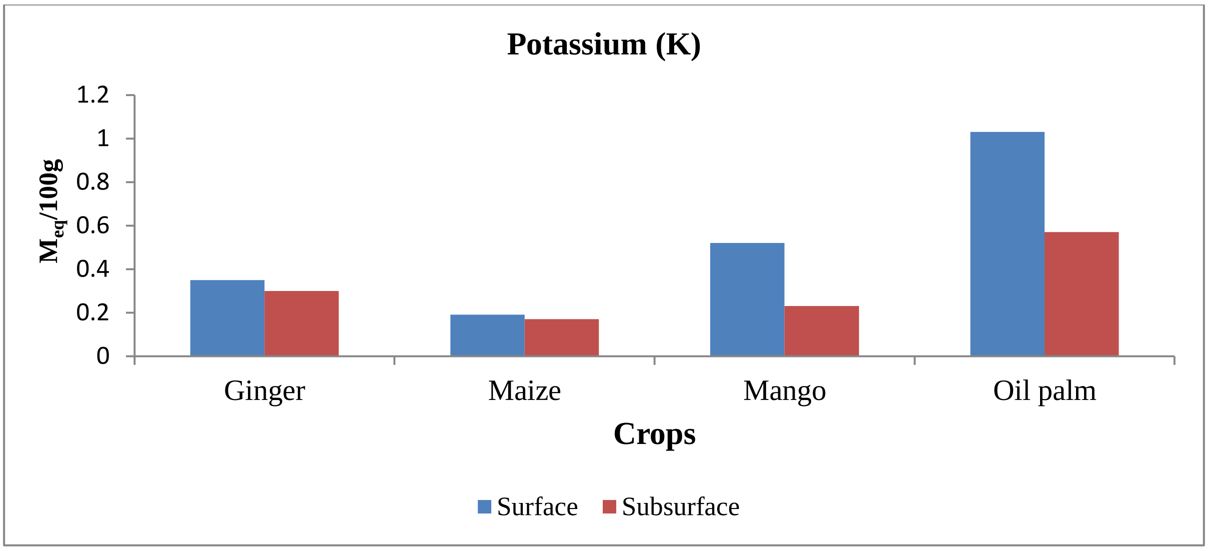

Fig. 7: Mean Concentration of Potassium in Soil under different Cropping Systems

Particle size distribution showed decreasing sand and silt with increasing depth except for clay that increased with increasing depth (Fig. 8) This finding agreed the findings of (Oladoye, 2015).

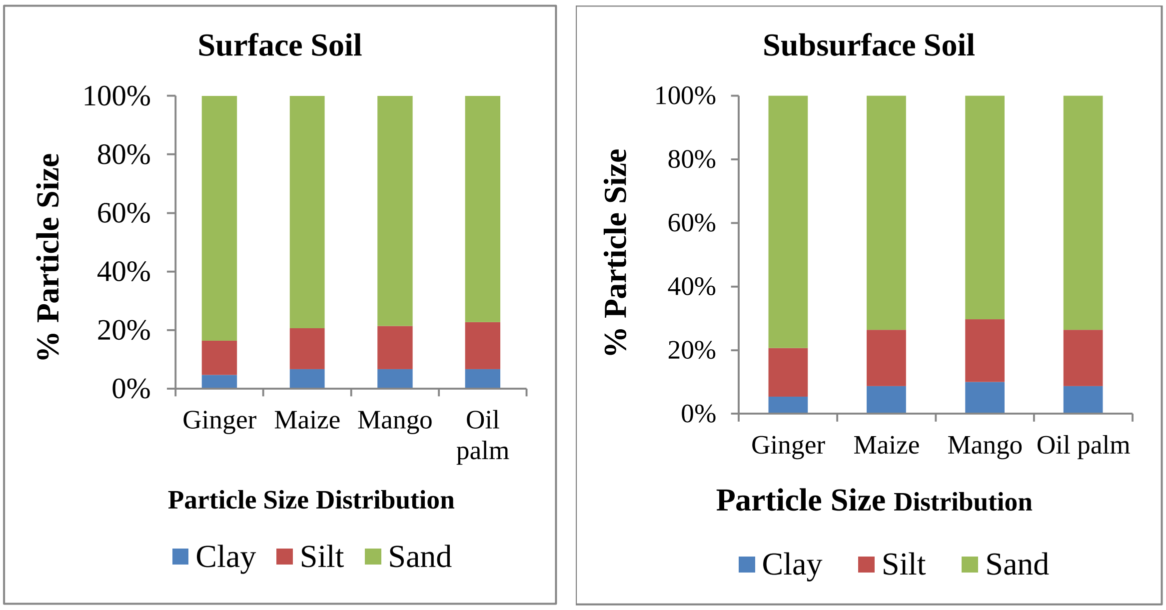

Fig. 8: Percentage (%) Particles Size Distribution in Soil under different Cropping Systems

The results of the inferential analyses using Analysis of Variance (ANOVA) indicated that of all the 14 parameters investigated, only four parameters i.e Bulk Density, Moisture Content, pH($CaCl_2$) and Phosphorus were significantly different amongst all the crops at the three study areas. So also, only Organic Carbon, Organic Matter and Nitrogen were significantly different at the surface and subsurface soil levels. Bulk Density, Moisture Content and Clay proportion showed significant differences when soil under permanent crops were compared with soil under annual crops. There were significant differences in Bulk Density and Moisture Content when soil under Oil palm and Mango were compared and the statistical analysis showed significant differences in pH and Potassium when soils under Ginger was compared with those under Maize crops.

CONCLUSION

This study assessed the physico - chemical (pH, bulk density, available Nitrogen, Phosphorus, Potassium, effective cation exchange capacity, soil texture, organic matter, organic carbon and soil structure) parameters of soil under different (Ginger, Maize, Mango and Oil palm) cropping systems from three sites (Ungwan Rana, Kurmin Kwara and Kyari) at two (surface and subsurface) levels in Daddu of Jaba Local Government Areas of Kaduna State. Of all these parameters investigated, Bulk Density; Soil Moisture Content; pH($CaCl_2$) and Phosphorus were significantly different amongst all the crops. Implying that the agricultural practices in the study area mostly impact soil Bulk Density, Soil Moisture Content, pH($CaCl_2$) and Phosphorus. Therefore, future land management practices should be such that will not impact these parameters as the Bulk Density currently recorded is above the tolerant limit for most crops cultivated in the study area.

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