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Fertility Indicators and Selected Micronutrient Contents of Floodplain Soils Under three Land Use Types in Ohaji-Egbema, Southeastern Nigeria

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Abstract
This study was conducted in Ohaji-Egbema, Southeastern Nigeria where we investigated the fertility status and micronutrient contents of the soils. Five (5) representative soil samples were collected from (three) 3 different Land use types namely fallow Land, cassava farms and oil palm plantations at a depth of 0-30cm. Samples for bulky density were collected using core samplers. The samples were air-dried, meshed and sieved using a 2mm sieve and were subjected to standard routine laboratory analysis. Data obtained were subjected to analysis of variance (ANOVA) and means were separated using the least significant difference at (p = 0.05) probability level. The mean sand fraction ranged from 886 on cassava farm to 952 gkg^{-1} in fallow land. The mean silt and clay content ranged from 16 in fallow land to 42 gkg-¹ in cassava farms, 32 gkg-¹ (fallow and oil palm) to 52gkg-¹ (cassava) respectively. The bulk density of the soils ranged from 1.04 to 1.12gcm-³, the mean bulk density value of the soils did not differ significantly (p=0.05). Chemical properties analyzed showed that the mean pH range from 5.84 in fallow Land to 6.49 in cassava land. From the result, the pH values of the land use types did not differ significantly (p = 0.05). Organic carbon and organic matter ranged 0.97-1.19 and 1.67- 2.05 g/kg. Nutrient index and fertility rating results indicated that the location of study was generally low in their fertility status. The mean concentration of micronutrients in the study location results showed that Fe ranged from 0.8526mg/kg in fallow land, 2.3054mg/kg in cassava farms and 2.0992mg/kg in oil palm plantation land. However, Fe was significantly different among the three land use types, iron was below the critical limit (4.0) for the three land use types. Zn ranged thus; 0.0638 (fallow), 0.0525 mg/kg (Cassava and oil palm); Cu distribution in the land use types were; 0.0918 (fallow), 0.0548 (Cassava) and 0.0638 mg/kg (oil palm). Zn and Cu were also below their respective critical limits of 0.6 and 0.2 in the study area. The low level of these micronutrient content s may be due to the high sand content of the studied soil which inhibited their availability in the floodplains of Ohaji-Egbema.

Keywords: Critical limits, nutrient index, soil suitability, land use types, soil fertility

Introduction

The floodplain soils usually comprise silts, leaves and sands deposited during the period of flooding. Recently, agricultural use of floodplain soils has increased significantly in most developing nations particularly in Africa including Nigeria (Ogban and Ibia, 1998; Onyekwere *et al.,* 2001; Akpan-Idiok and Ogbaji, 2013; Akpan *et al.,* 2017). Farmers go to flooded areas for their activities because they are known to be very fertile for farming. There is an availability of water and nutrient for sustainable crop growth in these areas (Eshett, 1990). In Nigeria, there are about 4.62 million hectares of land space characterized for wetland and rice cultivation and only 11.25% of these lands are being used over the world (Olaleye *et al,* 2001). Floodplain soil is important to agricultural production as it is known to have a huge reserve of available nutrients for utilization of crops. Example rice (*Oriza sativa*) (Akpan-Idiok and Ogbaji, 2013). Many researchers have employed nutrient ratios in plant tissue to diagnose mineral nutrient deficiencies in crops (Sumner 1978). Ca/Mg, K/Mg, K/Ca, N/P, and (Ca+Mg)/K are some regularly seen ratios in the literature and are usually a reflection of some recognized nutritional antagonism. (Olaleye *et al.,* 2009; Obasi *et al.,* 2016). When the cations calcium (Ca), magnesium (Mg), potassium (K), and hydrogen (H) occupied the cation exchange sites in the exact percentages of 65%, 10%, 5%, and 20%, respectively, soil productivity was discovered to be ideal for certain crops. They calculated cation equivalent ratios of Ca:Mg 6.5:1, Ca:K 13:1, and Mg:K 2:1 using these saturation percentages. Graham (1959) later revised the saturation percentages to be 65-85% Ca, 6-12% Mg, and 2-5% K. Graham's percentage ranges are the current figures for the Basic Cation Saturation Ratio hypothesis. Recently, Loide (2002) recommended 10-20:1 (Ca/Mg) and 3:1 (K/Mg) ratios for optimum yield and productivity of crops. Many basic cation saturation ratio interpretations, however, continue to be done using the precise cation ratios of 6.5:1, 13:1, and 2:1, rather than interpreting a range of ratios that could be created from Graham's percentages, Ca:Mg 5.4:1-14:1, Ca:K 13:1 - 42.5, and Mg:K 1.2:1 - 6:1. Soil scientists that focus on soil fertility are interested in managing nutrients to improve crop production. The fertility status and properties of soils of the floodplain have not been properly evaluated in most parts of the country as in South-Eastern Nigeria, where some works have been done on the fertility status of the floodplain (Nkwopara *et al.,* 2019; Ahukaemere and Akpan, 2012). Also Onwudike *et al.,* (2016) studied the fertility status of selected soils in Mbaise, Imo State Southeastern Nigeria using the nutrient index method. However, there is a dearth of information in the literature regarding the fertility status of soils of the floodplain especially in Ohaji/Egbema area of Owerri Imo State.

Micronutrients are very important nutrient elements needed by crops in very low amounts for their growth and development. Although micronutrients are needed in small quantities, they are however not less important in crops nutrients requirement. Micronutrients include manganese, boron, copper, molybdenum, iron, zinc and chlorine. Rengel (2003) pointed out the significant roles of micronutrients in plants to include; carbohydrate and lipids metabolism through their activities alongside certain enzymic systems, biosynthesis of nucleic acids and proteins as well as involvement with other physiologically active molecules. Owolabi and Oiganji (2019) stated that information on the micronutrient content of Nigerian soils is scanty and sporadic whereas widespread deficiencies in most tropical soils have been reported by Abera and Kassa (2017). Mustapha and Loks (2005), suggested that the use of certain new and high-yielding varieties of crops has revealed the deficiency status of most Nigerian soils. The need for initial micronutrient content of Nigerian soils to be known will enhance its management through the integration of judicious soil fertility management systems such as the appropriate use of organic matter and inorganic fertilizers. This is an achievable approach which has been used in conquering soil fertility challenges (Kazemeini *et al.,* 2010). The objective of this study was to investigate nutrient status as well as micronutrient contents of floodplain soils under three land use types in Ohaji/Egbema location of southeastern Nigeria.

Materials and Methods

The study was conducted at Ohaji-Egbema in Owerri, Imo State Southeast Nigeria. Ohaji lies between Latitude 5° 19' and 5° 32' N and between Longitude 6° 45' and 6° 59' E. Orajaka (1975) reported that Ohaji-Egbema soils are formed from a parent material largely known to be Coastal plain sand otherwise known as Benin formation and had rather been classified as Alfisols or Ultisols (Obasi *et al.,* 2015). Ohaji Egbema located in the humid tropical rainforest region has a mean monthly temperature of about 27°C, and a mean annual rainfall of about 1700-2400mm. The area has a bimodal rainfall distribution with peaks in July and September and a short break in the month of August known as the August break (NIMET, 2020). The dominant socio-economic activity in Ohaji-Egbema is agriculture dominated with food crops such as yam *(Dioscorea spp)* cassava *(Manihot spp)*, Fluted pumpkin *(Tefeira ocedentalis)*, maize *(zea maize)* all at a substantial level.

Field Study

The study was conducted on a floodplain consisting of different agricultural land use types. Three land use types; 2-year continuously cultivated cassava farmland, fallow land (secondary forest), and oil palm plantations were randomly selected for the study. Soil auger was used to collect soil samples from each of the land use types at a depth of 0-30cm. From each of the land use types, five (5) soil samples were collected at an equal distance of 5 meters apart. A total of 15 soil surface samples were collected. Core sampler was used to collect soil samples for soil bulk density determination. Soils collected were bagged and transported to the laboratory for analysis. Soil samples were air-dried at room temperature, crushed and sieved using 2mm mesh sieve.

Laboratory Analyses

Physical properties

The hydrometer method was for particle size determination (Gee and Or, 2002). Bulk density (gcm^{-3}) was determined using the method described by Grossman and Reinsch (2002) and calculated using the equation;

$$Pb = \frac{M_s}{V_s}$$

Where Ms = Mass of Oven dry soil, Vs = Volume of core sampler (obtained using the relation $v = \pi r^2 h$, where r and h are radius and height of the core sampler. Total porosity was calculated from particle and bulk densities of the soils as follows:

$$T_p = (\frac{1 - P_b}{P_s}) \text{ x } \frac{100}{1}$$

Where Pb = Bulk density, Ps = Particle density (Assumed to be 2.65 g/cm^3 for tropical soils). Moisture content was determined using the gravimetric method (Obi, 1990). It will be calculated as follows;

$$\%MC = \frac{W_2 - W_3}{W_2 - W_1} \text{ x } \frac{100}{1}$$

W_1= Weight of moisture can, W_2= Weight of air-dried soil + moisture can, W_3= Weight of oven-dry soil + moisture can. The silt clay ratio was calculated by dividing the value of silt with the value of clay -

$$SCR = \frac{\% \text{ silt}}{\% \text{clay}}$$

Chemical properties

Using a glass electrode pH meter, soil pH was evaluated in a 1:2.5 soil-to-liquid ratio in water and 0.1N KCl (Hendershot *et al*., 1993). Nelson and Sommers' chromic acid wet oxidation method was used to detect organic carbon (1982). Organic matter was calculated by multiplying organic carbon by 1.724. (Van Bemmelen factor). The micro Kjeldahl method was used to determine total nitrogen (Bremner and Mulvaney, 1982). C: N ratio was obtained by dividing the value of organic carbon by the value of total Nitrogen. Total exchangeable bases (TEB) were calculated by summing all the exchangeable bases(Ca^{2+}, K^+, Mg^{2+}, Na^+). Total exchangeable acids (TEA) were calculated by summing all the acidic cations (H^+&Al^{3+}). Effective Cation Exchange Capability (ECEC): This was determined by summing all the basic (Ca^{2+}, K^+, Mg^{2+}, Na^+) and acidic cations (H^+&Al^{3+}). ECEC= TEB+ TEA. Percent base saturation was determined by multiplying the total exchange capacity and multiplying by 100. This was calculated as follows:

$$\%BS = \frac{TEB}{ECEC} X \frac{100}{1}$$

and Available phosphorus was determined using Bray II solution (Olsen and Sommers (1982). Exchangeable calcium and magnesium were determined by the complexometric titration method using ethylene Diamine Tetra Acetic Acid (EDTA), and Sodium and potassium were determined by the flame photometer method (Jackson, 1962).

Fertility Evaluation

The fertility status of the soils was determined using the elemental ratios; Ca:Mg ratio was determined by dividing the value of exchangeable Calcium by the value of exchangeable Magnesium. C: N ratio was determined by dividing the value of organic carbon by the value of the total Nitrogen. K: Mg ratio was determined by dividing the value of exchangeable potassium by the value of exchangeable magnesium whereas. **Sodium Adsorption ratio (SAR):** this was determined using the equation as follows:

$$SAR = \frac{(Na^+)}{\left(\frac{(Ca^{2+})+(Mg^{2+})}{2}\right)^{\frac{1}{2}}}$$

While Na^+, Ca^{2+}, and Mg^{2+} are concentrations of sodium, calcium and magnesium ions in milimoles (mmols) of charge per liter

Exchangeable Sodium Percentage (ESP): this was obtained using the equation below;

$$ESP = \frac{\text{exchange } Na^+}{ECEC} X \frac{100}{1}$$

Where ECEC = Effective cation exchange capacity.

Aluminium saturation: this was calculated as follows;

$$Al\ sat = \frac{Al^{3+}}{ECEC} X \frac{100}{1}$$

Determination of Available Micronutrients

Available Iron, zinc and copper will be determined by the double acid extraction method described by Udo *et al.,* (2009). This was done by extraction, with 25ml of 0.05m HCl in 0.125m H_2S0_4 for 15 minutes using 5g of soil. After extraction, available Fe, Zn, Cu in the soil solution were determined using atomic absorption spectrophotometer (AAS).

Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) and significant means were separated using Least Significant Difference (LSD) at 0.05 probability level (Wahua 1999). The relationship among soil properties was determined using correlation analysis and scattered diagrams. Variations among soil properties were determined using the coefficient of variation (CV) according to Wilding (1996) where CV <15 =Low, 15 - 35 = Medium and >35 = High.

Results and Discussion

Physical Properties of the Studied Locations

The results of selected soil physical properties of the study location are shown in Table 1 Particle size distribution was dominated by the sand fractions. The mean sand content ranged from 886-952g/kg. From the results, the sand contents of the soils differed significantly (p=0.05) with fallow land having the highest mean. Similarly, significantly different (p=0.05) were recorded in the silt and clay contents of the varying land use types which ranged from 16-22g/kg and 32-52g/kg in the land use types of fallow land, cassava farm and oil palm plantation respectively. But fallow and oil palm have the same clay. However, the soils of the cassava farm had significantly the highest silt and clay contents. The geology of the area could explain the high percentage of sand seen in all land use schemes. The geology of the area includes coasted plain sands with sandy soils spread across a large area of land (Akamigbo and Ukaegbu, 2003). Bulk density ranged from 0.91-1.25 g/cm^3 for fallow land, 1.08 –1.19 g/cm^3 cassava farm and 0.96 – 1.16 g/cm^3 in oil palm plantation. Cassava farms had the largest bulk density among the land use patterns evaluated, according to the mean values. The bulk density result is consistent with Osuji *et al*. (2011) observations on soils in South Eastern Nigeria. Total porosity (TP) ranged from 52-65% in fallow land, 55-59% cassava farm and 56-63% in oil palm plantation. The mean values of the TP indicated that oil palm plantation had the highest (60.20%) while the cassava farm had the least (57.60%). From the results of the Total porosity of the soil, the soils are dominated by a high sand fraction with low total porosity and moisture content. These soils, therefore, require proper management practices that could improve the physical qualities of the soil.

Moisture Content (MC) ranged from 94.25 – 98.25% in fallow land, 91.82– 95.49% in cassava farms, 95.38 –

96.54%, and11.33-13.02% in oil palm plantations. The mean Moisture Content values showed that fallow land had the greatest (96.79%) and cassava farm had the lowest (94.25%). The high MC value of the Fallow land could be attributed to the poorly drained nature of the soil and the area's flooded status, which can be remedied with a sufficient drainage system. Moisture content differs amongst land use types depending on textural class, land use system, soil structure, and vegetation. The findings are consistent with Brady and Weil's (2007) claim that soil physical parameters and soil quality influence soil moisture content. In land use categories, the silt clay ratio (SCR) ranged from 0.31 to 1.25, 0.09 to 2.5, and 0.31 to 1.25 in fallow land, cassava farmed land, and oil palm plantation order. The SCR values of the investigated land use types are consistent with the findings of Hassan *et al*., (2016), who reported that SCR values less than one (1) suggested that the soils were severely worn and pedologically ferralitic in character.

Soil Chemical Properties under different land use Types

The chemical characteristics of the soil (Table 2) revealed that the analyzed land use types were generally acidic. The mean pH value of the three land use types ranged from moderately acidic (5.84) in fallow land and oil palm plantation to slightly acidic (6.49) in cassava farms Acidic situations in diverse land use types could be linked to heavy leaching caused by excessive tropical rainfall (IITA, 1995; Ojanuga and Lekwa, 2005). The average organic carbon content of the examined land use types was 0.97%, 1.19%, and 1.01% for fallow land, cassava farmland, and oil palm plantation, respectively. When compared to FDALR values (<4%), the organic carbon concentration of the examined land use types was low (1985). The mean organic matter content of the examined land use systems was (1.67%, 2.05%, and 1.74%) for fallow land, cassava farmland, and oil palm plantation, respectively. When compared to FAO rates (2-4%), the O.M content of the analyzed land use systems was low (2004). The findings show that the organic carbon levels of the four land use categories evaluated coincided with the findings of Ufot *et al.,* (2016) of soils under vegetative cover in southeastern Nigeria.

The change in TN could be due to a significant buildup of organic material on the surface horizon, the rate of decomposition, and the rate of alluviation and illuviation. Several researchers' findings in soils with comparable agro-ecology (Hassan *et al*., 2016; Chude *et al*., 2011; Ufot *et al*., 2016) corroborate the findings. Total nitrogen mean ranged (0.12%, 0.13%, and 0.12%) for fallow land, cassava farm land, and oil palm plantation, respectively, in the analyzed land use systems. The mean levels of T.N in all land use types were less than the threshold value of (0.15%) for Nigerian soils (FDALR, 1985, Chude *et al*., 2011). Low N concentrations in soils could be attributed to the quick mineralization of soil organic matter, as well as severe leaching caused by heavy tropical rainfall (Howeler, 2002; Ojanuga and Lekwa, 2005). On fallow ground, cassava agricultural land, and oil palm plantation, the available phosphorus had mean values of 1.92 mg/kg, 2.83 mg/kg, and 3.99 mg/kg, respectively. The FDALR grade (<6, <5) indicated that the available phosphorus in all of the land use systems investigated was low (1985). The low accessible phosphorus value could be owing to a high sorption reaction. Low accessible phosphorus levels have been ascribed to soil weathering, clay type, severe leaching, rainfall, and absorption reaction by soil elements (Hillocks, 2002). The effects of fixation and erosion might also contribute to a decrease in accessible P. The available phosphorus increased with increasing soil organic matter and cation exchangeable capacity under diverse land use regimes.

The exchangeable bases; Sodium (Na), Potassium (K), and Magnesium (Mg) levels in the fallow land were low when compared to Calcium (Ca) levels. On cassava farmland, potassium (K) and magnesium (Mg) have equivalent means. Ca, Mg, K, and Na mean values are (2.80 cmol/kg, 1.08 cmol/kg, 0.80 cmol/kg, and 0.94 cmol/kg) for oil palm plantation land, (3.46 cmol/kg, 1.18 cmol/kg, 1.18 cmol/kg, and 0.79 cmol/kg) for cassava farmland, and (3.28 cmol/kg, 0.98 cmol/kg. Exchangeable bases results revealed that Sodium (Na), Potassium (K), and Magnesium (Mg) levels were low in comparison to Calcium (Ca) levels in fallow land. On cassava farmland, potassium (K) and magnesium (Mg) have equal mean values. Ca, Mg, K, and Na mean values are (2.80 cmol/kg, 1.08 cmol/kg, 0.80 cmol/kg, and 0.94 cmol/kg) in oil palm plantation soil (3.46 cmol/kg, 1.18 cmol/kg, 1.18 cmol/kg, and 0.79 cmol/kg) for cassava farmland (3.28 cmol/kg, 0.98 cmol/kg.

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Little organic matter and high weathering could explain the low amount of ECEC in the terrain types (Akamigbo and Asadu, 1983). In all land use types, the ECEC increased in an uneven fashion with soil depth. The percentage base saturation (%BS) in fallow land, cassava farm and, and oil palm plantation land use types range from (90.54-94.84%), (85.02-91.72%), and (84.10-93.80%), respectively According to FAO (2004) assessments, the percentage base saturation mean suggested that all land use types were all high. The %BS results show that basic cation dominates cation exchange capacity in all land use types. The fallow land use type had the highest mean value (92.52%) and the cassava farmland use system had the lowest (89.90%) among the land use kinds. The findings on percentage base saturation of the analyzed land use systems contradict Igbokwe's (1990) work on soil fertility and land use patterns in Nigeria's eastern states. Nevertheless, parent material, weathering rate, and global climate change may have contributed to the variation shown by the findings of (Onweremadu *et al*., 2011;Wang *et al*., 2001).

Some Fertility Indicators of Soils in the Study Area

The results in Fig. 1 which shows some of the fertility ratios indicated that all the elemental ratios are not significant. In all land use classifications, the median of C:N ratios indicated fertile, ranging from 8.29 to 9.21.

When the C: N ratio is between 1 and 15, fast mineralization and N release occurs, making N accessible for plant uptake. The lower the C: N ratio, the faster nitrogen is released into the soil for immediate crop utilization. (Watson *et al.,* 2002). A C: N ratio > 35 results in microbial immobilization. Ca: Mg showed that fallow land and palm plantation were unfertile with means of 2.80 and 2.78 respectively. According to Johnstone (2011), the Ca: Mg ratio in fertile soils is typically in the range of 3:1-7:1. Landon (1991) also said that a Ca: Mg ratio less than 3:1 is indicative of infertile soils. Except for barren land, which had a mean of 0.70, the K:Mg values suggested fertile land. It has been reported that the ideal K: Mg ratio in fertile soils is in the range of 0.2-.0.35 and K: Mg ratio greater than 2:1 may inhibit the uptake of Mg (Udo *et al*., 2009). Sodium adsorption ratio (SAR) indicated fertile in all the land use types with means of 0.37, 0.51 and 0.73 in the fallow land, Cassava farmland and oil palm plantation respectively. When the sodium adsorption ratio (SAR) is >13, the soil contains sufficient sodium to interfere with the growth of most crop plants, meaning it's infertile (Brady and Weil, 2010). The ESP of the fallow land and Cassava farm is fertile while oil palm plantation is infertile with a mean of 15.96. If exchangeable sodium percentage (ESP) is >15 it is associated with severely deteriorated soil physical properties and pH values of 8.5 and above, making the soil infertile.

Relationship between fertility indicators and soil physicochemical properties

The relationship between fertility indicators and soil physicochemical properties is presented in Table 3. C/N was significantly negatively correlated with MC (r = -0.654), negatively highly correlated with Sand (r = 0.701) and positively highly correlated with OC (r = 0.781), OM (r = 0.791) as well as K (r = 0.795). Ca/Mg negatively correlated with ECEC (r = -0.555) and TEB (r = -0.590) but highly negatively correlated with Mg (r = -0.752). K/Mg was significantly negatively correlated with BD (r= -0.576), ECEC (r= -0.624) and TEB (r= -0.638) but highly negatively correlated with BD (r= -0.765), Ca (r= -0.823) and Mg (r= -0.762) while it correlated positively with MC (r= 0.511) and TP (r= 0.598). SAR was highly negatively correlated with BD (r= -0.721) and negatively correlated with Ca (r= -0.606) and clay (r= -0.565) but highly positively significant with Na (r= 0.762). ESP negatively correlated with BD (r= -0.523) and clay (r= -0.500) but highly negatively correlated with BD (r= -0.822) and Ca (r= -0.762) while positively significant with MC, Na and TP at (r= -0.610), (r= 0.572) and (r = 0515) respectively. Al sat was negatively significant with BD (r= -0.505) and TN (r= -0.596) but positively significant with TP (r= 0.515). This relationship could be attributed to Differences in the land use systems, such as cropping, fertilization, tillage and also the flooding conditions and activities of some organisms.

Relationship between some fertility indicators of soils in the area

From the results in Figures 2a-d, the graphs are showing a positive relationship between Ca/Mg (0.650) and C/N (-2.611) at (R^2= 1), SAR (-0.048) and K/Mg (0.634) at (R^2= 0.463) and Al sat (0.131) and C/N (1.909) at (R^2= 0.902) which simply indicated that an increase in each of the elemental ratios leads to an increase in another. But Al sat (-0.162) has a negative graph showing negative relationship with ESP (4.926) at (R^2= 0.902). This indicated that increase in Al sat will cause a decrease in ESP and vice versa.

Concentration of Micronutrients in the studied locations

The concentration of micronutrients in the study location is presented in Table 4. Results showed that iron ranged from 0.8526mg/kg in fallow land, 2.3054mg/kg on cassava farms and 2.0992mg/kg in oil palm plantation land. However, iron had a significant difference in the three land use types. Furthermore, comparing the iron content of the study area and the critical limit of iron in the soil, it was observed that iron content in the study area was below the critical limit (4.0) for all three land use types. This could be due to the leaching away of soil micronutrients in the floodplain soils. The zinc content of the study area ranged from 0.009 – 0.0638mg/kg and there was a significant difference in the zinc content of the study area. However, compared to the critical limit (0.6), the zinc content was very low in the study area. This deficiency is a result of the organic carbon content of the study area.The copper content of the study area range from 0.0548 – 0.0918mg/kg, however, a significant difference was recorded. Though copper content was also below the copper critical limit of 0.2. This deficiency can be attributed to the high sand content of the study soil which inhibits the available copper content in the soils. Conversely, it can be seen that iron, copper and zinc were all below their critical limits in the soils of Ohaji-Egbema for the three land use types and this is largely attributed to the leaching action of the floodplain soil.

Relationship between micronutrients with soil physicochemical properties

The relationship between the micronutrients with soil physicochemical properties is shown in Table 5. Copper had a negative relationship with total nitrogen at a 5% level of probability, hence, an increase in copper content in the soils of the study area reduces the availability of total nitrogen and vice versa. Furthermore, iron had a negative relationship with hydrogen and silt/clay content of the soils of the study site at a 5% level of probability as such, an increase in silt clay content and hydrogen decreases the amount of iron available in the soils of the study area. Also, there was a negative relationship between zinc and hydrogen at a 5% level of probability. As such an increase in hydrogen decreases zinc by 5%.

Conclusion

The results demonstrated that sand dominated other soil fractions across the three land use categories tested. When compared to other land use types, Cassava farmland had a high bulk density. Overall porosity was high, with the greatest mean observed in oil palm plantations. The moisture content was high, with fallow land having the most moisture. All land use types had low levels of organic carbon, organic matter accessible phosphorus, and total nitrogen. The exchangeable cation ranges from low to moderate to high, but the effective cation exchange capacity was low. The percentage of base saturation was very high. C/N Elemental ratios indicated fertile soil in all land use types, Ca/Mg indicated unfertile in fallow land and palm plantation, K/Mg indicated infertile in fallow land, and SAR indicated fertile in all land use types. Yet, as compared to the critical level (0.6 mg/kg), the zinc content in the research area was quite low. This shortage is caused by the study area's organic carbon level. The copper concentration of the studied area differed significantly. Despite the fact that the copper concentration was below the threshold limit of 0.2 mg/kg. This shortage can be linked to the study soil's high sand content, which restricts the available copper content in the soil. Generally, iron, copper, and zinc were all found to be below their critical limits in the soils of Ohaji-Egbema for the three land use categories, which can be attributed to the leaching effect of the floodplain soil.

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Table 1: The means of the soil physical properties of the study location

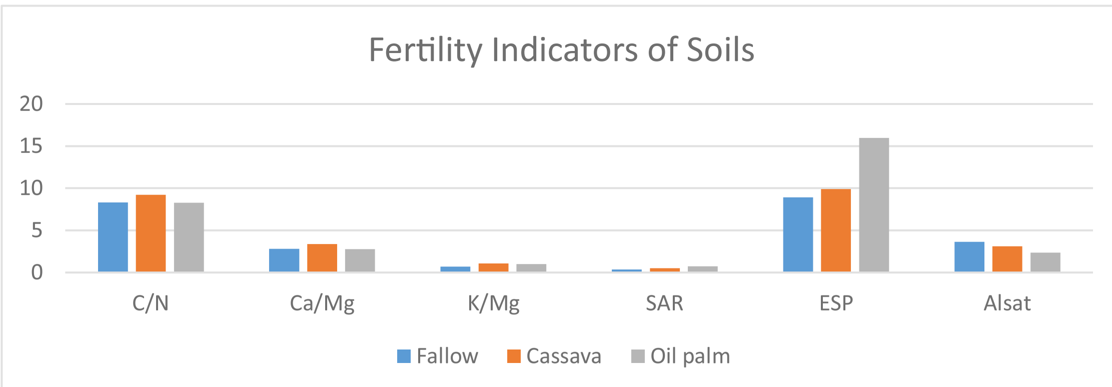
Land used	Sand gkg-1	Silt gkg-1	Clay gkg-1	TC	BD gcm-3	TP %	MC %	SCR
Fallow	952	16.0	32.0	S	1.09	58.40	96.79	0.50
Cassava	886	42.0	52.0	S	1.12	57.60	94.25	1.12
Oil palm	946	22.0	32.0	S	1.04	60.20	96.29	0.69
LSD(0.05)	2.83	2.64	3.03	S	0.18	6.68	0.820	1.57

S = sandy, TC – Textural Class, BD = Bulk density, TP= total porosity, MC = Moisture Content, LSD = Least Significant Difference

Table 2: Means of Soil chemical properties of the study location

Land used	pH	Org Carbon %	Org. Matter %	Total N %	Avail P Mg/kg	Ca	Mg	K	Na Cmolkg^{-1}	H	Al	TEB	TEA	ECEC	BS %
Fallow	5.84	0.97	1.67	0.12	1.92	3.28	0.94	0.64	0.55	0.38	0.27	5.41	0.44	5.85	92.52
Cassava	6.49	1.19	2.05	0.13	2.83	3.46	1.18	1.18	0.79	0.60	0.22	6.60	0.78	7.38	89.00
Oil palm	6.02	1.01	1.74	0.12	3.99	2.80	1.08	0.80	0.94	0.47	0.16	5.62	0.56	6.18	90.16
LSD(0.05)	0.74	0.27	0.47	0.02	2.67	1.21	0.68	0.77	0.59	0.15	0.121	2.61	0.31	2.87	3.21

ECEC = effective cation exchange capacity, BS = Base saturation, TEB = Total Exchangeable Bases, TEA = Total Exchangeable acidity



ALSAT = Aluminum Saturation, ESP = Exchangeable Sodium Percentage, SAR = Sodium Adsorption Ratio.
Fig. 1: Mean of Some fertility indicators of soils in the study area

Table 3: Relationship between fertility indicators and soil physicochemical properties

Soil property	C/N	Ca/Mg	K/Mg	SAR	ESP	Al. sat
BD	0.119	-0.371	-0.576*	-0.341	-0.523*	-0.505*
BS	0.243	-0.450	-0.765**	-0.721**	-0.822**	-0.265
Ca	0.329	-0.397	-0.823**	-0.606*	-0.762**	-0.159
Clay	0.261	0.333	0.199	-0.565*	-0.500*	0.152
ECEC	0.458	-0.555*	-0.624*	-0.260	-0.483	-0.357
H	0.132	0.041	-0.030	0.206	0.028	-0.258
MC	-0.654*	-0.006	0.511*	0.473	0.610*	-0.389
Mg	0.254	-0.752**	-0.762**	-0.279	-0.460	-0.461
Na	0.168	-0.442	0.106	0.751**	0.572*	-0.397
OC	0.781**	-0.223	0.106	-0.086	-0.282	-0.278
OM	0.791**	-0.211	0.120	-0.080	-0.275	-0.264
Sand	-0.701**	-0.043	-0.023	0.082	0.255	-0.071
Silt	0.042	0.483	0.240	0.391	0.312	0.268
TEA	0.324	0.043	-0.247	-0.024	-0.218	-0.057
TEB	0.457	-0.590*	-0.638*	-0.273	-0.492	-0.372
TN	0.291	-0.295	0.013	-0.079	-0.234	-0.596*
TP	-0.121	0.395	0.598*	0.347	0.531*	0.515*
pH	-0.307	-0.363	-0.287	0.440	0.335	-0.354
K	0.795**	-0.367	0.069	0.087	-0.154	-0.387

*and ** = sig at 0.05 and 0.01 probability levels respectively

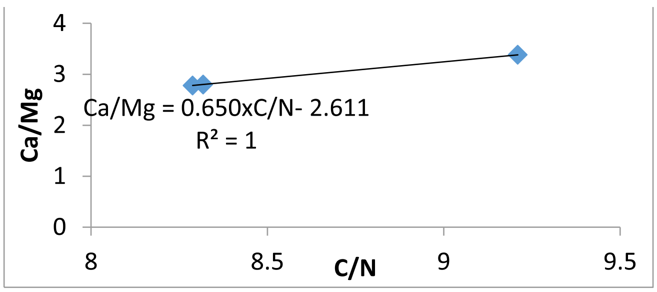


Fig. 2a

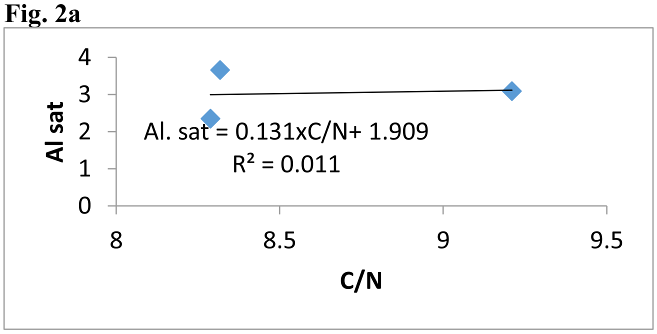


Fig. 2b

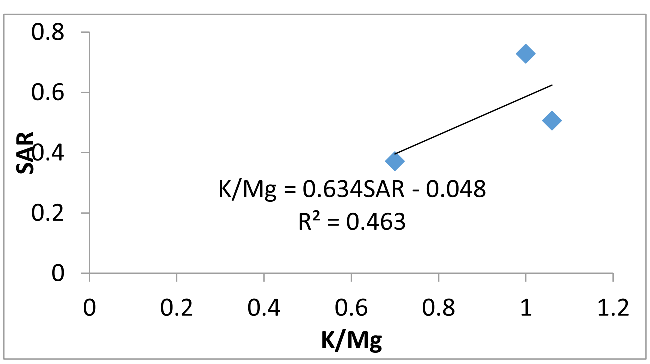


Fig. 2c

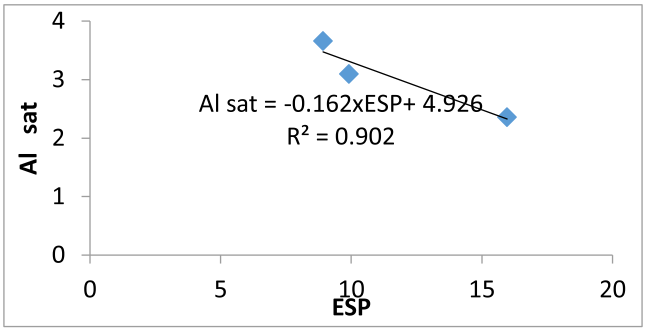


Fig. 2d

Table 4: Concentration of Micronutrients in the studied locations

LAND USE	Fe Mg/kg	Cu Mg/kg	Zn Mg/kg
Fallow land	0.8526	0.0918	0.0638
Cassava Farm	2.3054	0.0548	0.0532
Plantation land	2.0992	0.0604	0.0532
LSD(0.05)	0.009	0.038	0.009
CV	10.7	38.1	10.7

****= significant at 0.05 probability level, Fe= Iron, Zn= Zinc, Cu= Copper***

Table 5: Relationship between micronutrients with soil physicochemical properties

Soil Property	Cu	Fe	Zn
Avail P.	-0.2009	0.2752	-0.3026
Bulk Density	0.0559	-0.0399	0.2487
Base Saturation	0.1232	-0.3865	0.2786
Ca	-0.1155	-0.1887	-0.1329
Clay	-0.3071	-0.0846	-0.2279
ECEC	-0.2455	0.1698	-0.2822
H	-0.3946	0.5384*	-0.5422*
Moisture Content	-0.023	-0.2889	-0.1036
Mg	-0.2217	0.1415	-0.0789
Organic C	-0.1735	0.2987	-0.0669
Sand	0.2432	-0.4646	0.1526
Silt/ Clay	0.0322	0.6045*	-0.1361
TEA	-0.3114	0.3663	-0.4699
TEB	-0.228	0.138	-0.2475
TN	-0.5108*	0.225	-0.3237
TP	-0.1143	0.0635	-0.2933
pH	-0.3967	0.4082	-0.2383
K	-0.2064	0.3003	-0.2772

****= significant at 0.05 probability level, AP= Available Phosphorus, B.D=Bulk density, BS= Base saturation, Ca= Calcium, ECEC=Exchangeable Cation Exchange Capacity, H=Hydrogen, MC= Moisture Content, Mg= Magnesium, OC= Organic Carbon, TEA= Total Exchangeable Acidity, TEB= Total Exchangeable Base, TN= Total Nitrogen, TP= Total porosity, PH= Potential Hydrogen, K= Potassium, Fe= Iron, Zn= Zinc, Cu= Copper.***