A COMPARATIVE STUDY OF SOIL PROPERTIES UNDER DIFFERENT SOIL MANAGEMENT PRACTISES IN LAFIA REGION, NASARAWA STATE, NIGERIA

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ABSTRACT

Soil properties under different soil management practices (tree plantations, arable crops and natural vegetation) were studied, to highlight changes that occur in soil quality when lands are converted from natural vegetation to cultivated land. One hundred and fifty soil samples were randomly selected and analyzed for bulk density, pH, organic matter, available phosphorus, total nitrogen, exchangeable sodium, exchangeable potassium and cation exchange capacity (CEC). The results showed mean values for bulk density ranged from 1.2g/cm^3 - 1.5g/cm^3 at topsoil, the highest value was found under orange while natural vegetation had the lowest bulk density. The range of values for the bulk density increased slightly at the subsoil (1.3g/cm^3 - 1.6g/cm^3), with natural vegetation still having the lowest value. Natural vegetation had pH values that were close to neutral while other crops were slightly acidic. Organic matter (1.0% - 6.3%) was rated very low to medium, total nitrogen (0.04% -1.1%) was rated very low to very high, exchangeable sodium (0.1 cmol/kg - 0.4 cmol/kg) rated low, potassium (0.1 cmol/kg - 0.5 cmol/kg) was rated medium to high and CEC (1.9 - 8.8) was rated low to medium with natural vegetation having the highest mean values at both top soil and sub soil. While there was a general decline for values of organic matter, nitrogen, exchangeable sodium, exchangeable potassium and CEC with increased depth under natural vegetation and the tree crops, for arable crops the decline was only observed for organic matter and potassium with increased depth. Available phosphorus increased with increase in soil depth under arable crops and orange, while a decline was observed under natural vegetation and cashew. To improve soil nutrients and promote continuous farming, farmers should combine the use of crop residue, fertilizers and cropping systems such as crop rotation and agroforestry.

Key words: Arable crops, Natural vegetation, Soil properties, Tree plantations

INTRODUCTION

Land use and soil management practices are some of the major factors that impact soil properties and influences soil fertility andquality (Haynes and Williams, 1993; Amezquita et al., 2000; Kilic, Kilic, and Kocyigit, 2012). This was also corroborated by Sparling, Shepherd and Schipper (2000) who opined that soils are being adversely affected globally by present methods of land management and current practices which may not be sustainable. Agricultural development and sustainable development is dependent on soil, as it provides the basis for food, fuel, fiber, water availability, nutrient cycling, organic carbon stocks, biodiversity, and a platform for construction

(Food Agriculture Organization (FAO), 2012). With increasing world population, demand for food has risen significantly leading to increasing conversion of natural vegetation into agricultural lands (Amezquita et al., 2000; FAO, 2012).

The West Africa sub-region, which is highly dependent on agriculture in the past has relied on bush fallowing system and shifting cultivation for replenishment of soil nutrients; which was lost through removal of plant nutrients by crops. Presently, the high population density in many areas within the sub-region have led to the abandonment of the bush fallowing system and shifting cultivation altogether; and a shortening of the fallow period in the traditional shifting or bush fallow agriculture in the remaining areas within the sub-region (Amusan et al., 2006).

Within the period 2007to 2009, over 17 million persons living in Nigeria were involved in crop farming; growing a wide range of crops (National Bureau of Statistics, 2010). Agriculture alone accounts for over 40% of its Gross Domestic Product (GDP) from 2007-2009; and creates employment, provides food for human sustenance, raw materials for industry and earns foreign exchange (National Bureau of Statistics, 2010; Federal Ministry of Agriculture and Rural Development (FMARD), 2015). The large number of people involved in crop farming in Nigeria has led tolarge amount of natural vegetation been turned into agricultural lands,and continuous cropping is carried out on such lands (Ekanade, 1985; Ayuba, 1998; Phil-Eze, 2010; Afolayan and Oderinde, 2018).

The knowledge of soil health with respect to its properties and the need to evaluate sustainability of land that are being continuously cultivated is essential. Lafia Local Government Area (LGA) of Nasarawa state is associated with extensive farming practices which include cultivation of mono plantations (Nasarawa State Agricultural Development Project (NADP), 2010). Thus, this study assesses soil properties under natural vegetation and cultivated lands (tree plantations and arable crops) in Lafia LGA of Nasarawa state to know the nutrients on the decline and the extent of nutrient depletion as a result of conversion from natural vegetation into agricultural lands.

STUDY AREA

The study area is located in Lafia LGA of Nasarawa state. It is found between Latitudes 8^{o} $20^{'}$ to 8^{o} $38^{'}$N and Longitudes 8^{o} $20^{'}$ to 8^{o} $40^{'}$E (Figure 1). It has a land area of 2,797.5sq.km. The area is largely an undulating plain which is drained by the Benue River and River Mada. It has distinct dry and wet seasons, which are features of the tropical continental climate. The dry season extends from November to middle of April, while the wet season commences from middle of April and terminates in October (Yusufu, 2017; Audu et al., 2018).

The study area is within the southern Guinea Savanna vegetation belt. It is characterized by open forest dominated by trees and tall grasses with some undergrowth. Gallery forest occurs along rivers and streams that drain the area (Lyam, 2000). The major soil units of the region belong to the category of oxides or the tropical ferruginous soils. Laterite crust occurs in extensive areas on soils of the basement complex while hydromorphic soils are common along the Benue trough and flood plains of major rivers. Other soil types in the area include: ultisols, alfisols, entisols, inceptisols, vertisols and oxisols (Lyam, 2000).

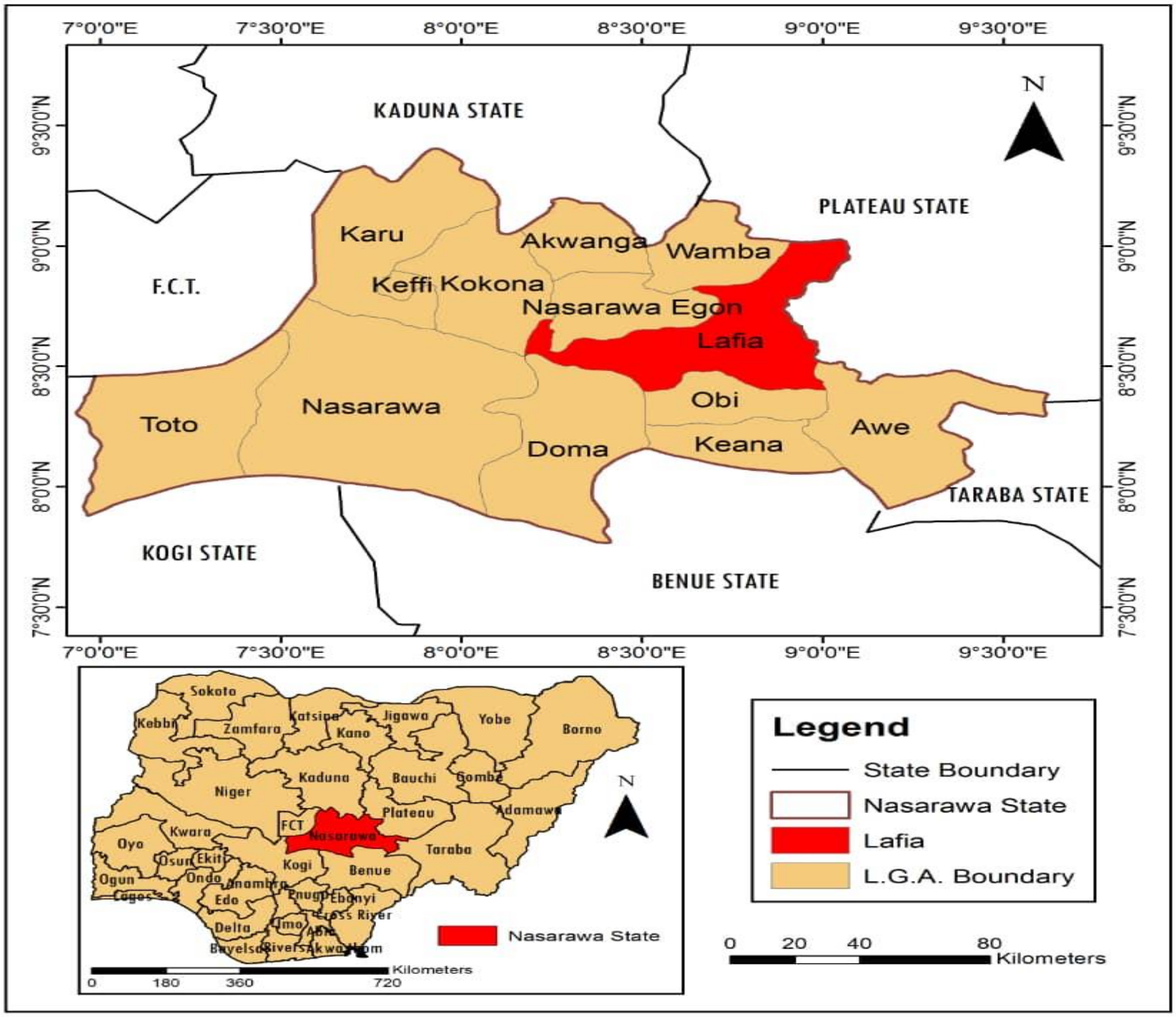

Figure 1: The Study Area
Source: Adapted from the Administrative Map of Nasarawa State

MATERIALS AND METHODS

There are majorly two geological formations in Lafia LGA, namely: basement complex rocks and sedimentary formations. The areas sampled in this study are areas characterized by the basement complex rock formation. This was to ensure that the difference in the soil characteristics are due to differences in the soil management systems. In addition, the soils were on the same slope class and their characteristics before use were similar.

To eliminate the catenary effect, study sites were confined to the upper slope positions of the catena, on flat locations where the slope angle was less than 2^{o}. This ensured that sample plots are exposed to about the same degree of nutrient loss. While there are diverse soil management systems in the area, the study was confined to investigate planted trees (orange and cashew), arable crops (maize and guinea corn) and the natural vegetation system.

To demarcate sample plots, a baseline was established to lay out a quadrat size of 30m by 30m ($900m^2$). The 3, 4 and 5 method of field layout was used as advocated by Akinsanmi (1981) in laying the quadrats. In this method, lengths of 3m and a width of 4m were measured on the field; this gave a hypotenuse of 5m so that a perfect right angle triangle was obtained in laying out quadrats. A straight line was then taken from right angle so that quadrats are laid out in straight lines. Thereafter, within each quadrat grids of 5m by 5m were then pegged which produced 36 grids.

According to the Natural Resources Conservation Service (2009), soil sampling on very large fields will require 12 sample points for areas measuring $9000m^2$. In this study the quadrants were $900m^2$, to increase the accuracy of describing the values of the soil properties, a total of 5 sample points were selected randomly from the intersect of the 36 grids within each of the 3 quadrants, for planted trees (orange and cashew), arable crops (maize and guinea corn) and the natural vegetation system. From each sample point, soil samples were taken from both topsoil (0-20cm) and subsoil (20-45cm). Five (5) samples from topsoil and 5 from subsoil were collected from within each quadrat, making a total of 10 samples per quadrant for each vegetal type. A total of 150 samples were collected in all from the study area; with the aid of a core sampler (Table 1) and analysed in the laboratory for bulk density, pH, organic matter, phosphorus, total nitrogen, sodium, potassium and cation exchange capacity (CEC). Bulk density was the physical soil property selected as it is an indicator of aeration status and water filtration capability. Bulk density is influenced by soil management practices, unlike soil texture which determines a number of physical and chemical properties of soils but which White (1997) opines is less affected by management practices. The pH, organic matter, phosphorus, total nitrogen, exchangeable sodium, exchangeable potassium and cation exchange capacity (CEC) were selected as they are important in determining soil fertility and are affected by soil management practices.

Table 1: Number of Samples Selected from 3 Quadrats A, B, C for Each Soil Management System in the Study Area

Vegetal type	Topsoil Quadrat A	Topsoil Quadrat B	Topsoil Quadrat C	Total topsoil	Subsoil Quadrat A	Subsoil Quadrat B	Subsoil Quadrat C	Total Subsoil
Cashew	5	5	5	15	5	5	5	15
Orange	5	5	5	15	5	5	5	15
Maize	5	5	5	15	5	5	5	15
Guinea corn	5	5	5	15	5	5	5	15
Natural vegetation	5	5	5	15	5	5	5	15
Total				75 Topsoil				75 Subsoil

Laboratory Analysis

Soil samples were air dried and sieved through a 2mm diameter sieve. Thereafter, they were put into polythene bags that were assigned laboratory numbers. The methods used in testing the soil properties at the Nasarawa State University Agronomic Research Laboratory are shown in Table 2.

Table 2: Soil Parameters and Methods of Laboratory Testing

Soil Parameter	Methods of Laboratory Testing
Bulk density	Volume displacement
Soil organic matter	Walkey and Black (1934) titration method multiplied by 1.724
pH	pH meter (glass-calomel combination electrode)
Total nitrogen	The macro-Kjedahl method (Black, 1965).
Available phosphorous	Used a spectrophotometer in the soil samples leached with Bray P- 1extracting solution (0.025 N HCL+0.003 N NH_4F).
Exchangeable sodium	Flame photometry
Exchangeable potassium.	Flame photometry
Cation exchange capacity	Titration method by distillation of ammonium that would be displaced by sodium from NaCl solution

RESULTS AND DISCUSSION

Table 3 presents the results of the soil parameters from standard laboratory analysis. The soil properties were derived from different soil management practices in Lafia region of Nasarawa state.

Table 3: Soil Properties under various Soil Management Practices in Lafia Region

Soil Properties	Natural Vegetation		Cashew		Orange		Maize		G/Corn	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Bulk density g/cm^3	1.2	1.3	1.3	1.5	1.5	1.6	1.4	1.5	1.4	1.6
pH	6.6	5.8	6.0	5.0	5.1	4.8	5.6	4.9	5.4	4.8
Organic matter %	6.3	3.7	4.8	2.4	2.4	1.3	1.1	1.8	1.0	1.7
Avail phosphorus (ppm)	7.5	4.7	4.8	3.9	3.1	3.7	3.5	4.8	3.5	4.3
Total Nitrogen %	1.1	0.7	0.5	0.3	0.2	0.1	0.2	0.04	0.1	0.03
Na^+ cmol/kg	0.4	0.3	0.3	0.2	0.3	0.2	0.2	0.1	0.2	0.1
K^+ cmol/kg	0.5	0.4	0.4	0.2	0.3	0.2	0.1	0.2	0.1	0.2
CEC	8.8	4.2	5.8	3.4	2.8	2.0	2.5	1.9	2.5	1.9

Bulk Density

The measure of bulk density is required for the determination of soil compactness, it is also used as an indicator of aeration status and water filtration capability. Natural vegetation had the lowest bulk density at the top soil (1.2g/cm^3) as compared to cashew (1.3g/cm^3), orange (1.5g/cm^3), maize (1.4g/cm^3) and guinea corn (1.4g/cm^3) as shown on Table 3. Slight increases were observed at the sub soil under all the vegetal systems studied in the order: orange and guinea corn > cashew and maize > natural vegetation (Table 3). Similar values were obtained in a study carried out in Zaria and the increase in clay with depth and decrease in organic carbon with depth was observed as factors responsible for increase in values of bulk density (Jimoh et al., 2016). The findings of higher values of bulk density on cultivated lands compared to natural vegetation corroborated that of Lal (1995) and Ekanade (1985); who studied bulk density of soil which had been converted from forest to cultivation arable and tree crops. The higher the bulk density, the higher the degree of compaction of the soil. The critical value of bulk density for restricting root growth varies with soil type (Hunt and Gikes, 1992) but in general, bulk density greater than 1.66 g/cm^3 tends to restrict root growth (Mackenzie, Coughlan and Cresswell, 2002). The cultivation of tree crops (cashew and orange) and arable crops (maize and guinea corn) resulted in increased soil bulk density values more than what was obtained under the natural vegetation soil, but all the values were below the 1.66g/cm^3. Hence problems of high bulk density which can hinder root penetration is currently not evident in the study area.

Soil pH

Soil pH is a measure of the hydrogen ion concentration in the soil. It affects the solubility of nutrients in the soil solution and the absorption of nutrients elements by the root plants. The mean pH values at the top soil and subsoil in the study area were generally lower under arable crops (maize and guinea corn) compared to values under tree crops and natural vegetation. The values at the topsoil range from 5.4 – 6.6 in the order: orange < guinea corn < maize < cashew < natural vegetation (Table 3). The pH level increased under the sub soil in all the five vegetal systems (Table 3). The subsoil values ranged from 4.8 -5.8 with the order of values as: orange and guinea corn < maize < cashew < natural vegetation. Natural vegetation had values that were closer to neutral. The soil in the study area are slightly acidic and with increasing soil depth, the level of acidity also increased. The use of inorganic fertilizer in the study area to boost productivity could be responsible for increased acidity in the subsoil.

Many crops grow best when pH is close to neutral (pH 6 -7.5). It promotes the availability of plant nutrients for optimal yield. Also, bacteria that decompose soil organic matter are hindered in strong acidic soils (United States Department of Agriculture, 2011). Where pH is low, the nutrition, growth and yield of crops decreases negatively affecting crop production; for instance, the pH levels for optimum yield of maize and guinea corn was placed at 6.8 by Smith and Doran (1996). The pH level under maize and guinea corn in the study area, which is lower than 6.8 could affect the yield of the crops.

Organic Matter

Organic matter in soil protect the soil surface from rain drop impacts, resist wind action, and thus, greatly aid in erosion control (Yusufu, 2017). The arable crops (maize and guinea corn) had the lowest mean value (1.0 % -1.1%) of organic matter at the top soil but the values rose (1.7 % - 1.8%) with increased soil depth (Tables 3). The slight increase at the subsoil might be due to soil organic matter incorporation from the topsoil layer to the sub soil layer as a result of the mixing effect of tillage activities, and its downward movement due to its higher sand content. Similar observations were made by Tilahun (2007) in the study of variability of soil nutrients. Comparatively the tree crops (cashew and orange) had higher mean values of organic matter (2.4% - 4.8%) while the highest value (6.3%) was under natural vegetation at the topsoil in the study area. With increased soil depth, the values of organic matter decreased under natural vegetation, cashew and orange, while a different observation was made under the arable crops studied. The decrease observed under natural vegetation, cashew and orange is an indication that the values of organic carbon, which is used in the determination of organic matter, also decreased lowering the soil quality.

The rating of organic matter by Landon (1991) showed that it is very low when values are < 2%, low when it is 2-4%, medium when it is 4-10%, high when 10-20% and rated very high when it is above 20%. The organic matter in the soils studied are rated from very low to medium. The result in the study area shows that soil organic matter was degraded after the opening up of natural vegetation for cultivation, be it tree plants or arable crops. The high difference between the values under natural vegetation and cultivated lands may have been brought on by insufficient inputs of organic substrate from the farming system, due to residue removal and lack of crop rotation. This corroborates previous reports (Duff et al., 1995; Tilahun, 2007). The values of organic matter content was also low in the soils in Sokoto State, an area within the northern region of Nigeria just as the study area, and this was attributed to continuous cultivation and removal of farm residues (Yakubu, 2001)

The value of organic matter content under cashew, which was the highest among the cultivated lands, could be due to the fact that there are lots of leaves and fruits on the soil which decompose to increase the organic matter content in the soil.

Available Phosphorus

Available phosphorus is crucial to agriculture because when it is lacking in the soils it limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997).Result in Table 3 shows that available phosphorus at top soil was highest under natural vegetation (7.5 mg/kg), Cashew was 4.8 mg/kg, orange was much lower at 3.1 mg/kg; while the arable crops (maize and guinea corn) had the same mean value (3.5 mg/kg). There was an appreciable decline in phosphorus at sub soil under the natural vegetation (4.7 mg/kg) and cashew (3.9 mg/kg) while a dissimilar observation was made for arable crops (4.3-4.8 mg/kg) and orange (3.7 mg/kg), as the available phosphorus increased with increased depth (Table 3). The value of phosphorus under maize and guinea corn was higher at the sub soil probably because the fertilizers applied on the soil may have leached down, hence resulting in increased value in sub soil unlike the case of the cashew where the phosphorus decreased in the sub soil.

Landon (1991) categorized available soil phosphorus levels: values <5 mg/kg is rated as low, 5-15 mg/kg is medium and >15 mg/kg is rated high. The available phosphorus in the soils of the study area was generally low, since the phosphorus was less than 5 mg/kg in all the soil management systems except natural vegetation. The low content of phosphorus observed in the study area corroborates what some authors (Igwe, 2001; Mustapha and Udom, 2005; Shehu, Jibrin and Samndi, 2015) observed in their studies that availability of phosphorus under most soils in Nigeria declined as a result of crop harvest and erosion.

Total Nitrogen

Nitrogen is a macro-nutrients in the soil, which helps to regulate to a considerable extent the utilization of potassium, phosphorous and other soil constituents by most plants (Mesfin, 1998). Total nitrogen was highest under natural vegetation (1.1%), cashew was 0.5 %, while orange and maize was 0.2%, and the lowest was under guinea corn with 0.1% (Table 3). The relatively low values observed under arable crops were perhaps due to its low organic content and continuous tillage of the land. A similar idea was propagated by Tisdale et al., (1995) when they noted that nitrogen content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and low organic matter content. The considerable reduction of total nitrogen in the continuously cultivated fields could also be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation (McDonagh, Thomsen and Magid, 2001). The mean values of nitrogen declined at sub soil under all the vegetal systems studied, with observed values ranging from 0.03% - 0.7% (Table 3). The lowest content of nitrogen (0.03) observed for guinea corn may be attributed to its high utilization of nitrogen (FAO, 1995).

According to Landon (1991), the rating of total nitrogen > 1% is very high, 0.5-1% is high, 0.3-0.5% medium, 0.1-0.2% low, and < 0.1% as very low. In the study area, only natural vegetation was categorized as very high at the topsoil, cashew was high while orange, maize and guinea corn fell under low categorization. In the sub soil, the reduction in the values of total nitrogen under all the soil management systems resulted also in the downgrading of the categorization in the study area. Total nitrogen was higher under natural vegetation, it was medium under cashew, low under orange and very low under maize and guinea corn. The continuous decline in the total nitrogen content of the soils is likely to affect the productivity and sustainability of soil as opined by Tilahun (2007).

Exchangeable Sodium (Na^+)

Exchangeable sodium affects the population, composition and activity of beneficial soil microorganisms directly through its toxicity effects. When it is high in soils it makes the soil sodic which affects soil fertility and productivity (Grime, 2001; Wakene, 2001). The results obtained in the study area revealed the highest value of sodium was under natural vegetation with 0.4cmol/kg, the tree crops (cashew and orange) had the same value which was 0.3cmol/kg, and 0.2cmol/kg was the value for the arable crops (maize and guinea corn). There was a decline of 0.1cmol/kg under all the vegetal systems with increased depth at sub soil, these values according to United States Department of Agriculture (2011) is not high enough to make soils saline. High sodium content would adversely affect soil structure resulting in easy dispersal of soil particles. Excessive sodium levels can occur naturally or it can result from irrigation with high sodium water. In the study area, the levels of sodium fell within tolerable limits.

Exchangeable Potassium (K^+)

Exchangeable Potassium influences plant productivity and one of the factors that affects the distribution of K^+in soil is soil management practices (Wakene, 2001). Ravikumar and Somashekar (2013) developed a rating scale for exchangeable potassium, where values are categorized as low when it is < 0.1cmol/kg, medium when it is 0.1 -0.2cmol/kg and high when it is above 0.2cmol/kg. Under natural vegetation at the top soil in the study area, the mean value for potassium was 0.5cmol/kg, cashew and orange were 0.4cmol/kg and 0.3cmol/kg respectively. Thus, they were rated as having high content of exchangeable potassium. The arable crops (maize and guinea corn) had the same value of 0.1cmol/kg (Table 3) and were rated as having medium potassium content. Although there was a decline in the values observed under natural vegetation, cashew and orange with increased depth at the subsoil, they still maintained the same high rating. However, a reverse was recorded for the arable crops (maize and guinea corn). The values at the subsoil under arable crops went up (0.2cmol/kg) and their rating therefore improved moving from medium to high.

The relatively high content of potassium recorded under natural vegetation may be associated to the high pH value observed under the natural vegetation. Similar observations were reported by Mesfin (1998) of high potassium under high pH tropical soils. The mean values, which increased with soil depth, under arable crops in the sub soil could be due to increase in clay with soil depth and inorganic fertilizer application that has leached downwards.

Cation Exchange Capacity

Cation exchange capacity (CEC) of the soil affects its capacity to supply nutrient cations for plant growth (Brady and Weil, 2002). The values for CEC at the topsoil in the study area were 2.5cmol/kg under the arable crops (maize and guinea corn), 2.8cmol/kg under orange and 5.8cmol/kg under cashew, these were all rated low (Table 3); using the Esu (1991) categorization scale where CEC values were placed into three classes: high (> 12cmol/kg), medium (6-12cmol/kg) and low (< 6cmol/kg). A medium scale rating was observed under natural vegetation (8.8cmol/kg). The findings support Igwe (2001) who also observed decrease in soil cation exchange capacity following cultivation of lands. A general decline was recorded in the values of CEC at the subsoil for all the vegetal systems studies (Table 3). Mean values for natural vegetation, cashew, orange, maize and guinea corn were 4.2cmol/kg, 3.4cmol/kg, 2.0cmol/kg 1.9cmol/kg, and 1.9cmol/kg respectively. These values placed both the cultivated and uncultivated land under low rating of CEC at the subsoil level.

At the topsoil the relatively higher value of CEC under natural vegetation revealed that the soil was less susceptible to cation nutrient loss through leaching, since CEC measures the soil ability to retain and supply nutrient ions called cations. The soils under arable crops and tree crops were more susceptible to nutrient loss, hence the relatively low CEC values. The topsoil organic matter was higher under natural vegetation than under the remaining four vegetal systems. It is known that cation exchange capacity of tropical soils largely depends on the organic fractions of the soil since their clay minerals are kaolinitic, and naturally have a low capacity to absorb nutrient cations (Nye and Greenland, 1960).

CONCLUSION

The study highlighted that soil properties in the study area, despite having the same slope class and belonging to the same parent material, were influenced by soil management practices. Differences were observed in the values of all the soil properties analyzed, between natural vegetation and cultivated lands. Soil under arable crops were the most affected because of the continual cropping compared to tree plantations; while natural vegetation showed values that were reflective of soil management that had no disturbance due to tillage. The implications of the finding show that soils under arable land are relatively more liable to soil compaction because of the high level of bulk density; which would hinder proper root growth. The relatively low levels of organic matter and CEC, particularly under arable crops, would negatively affect crop yield and also increase the incidence of erosion and leaching of nutrients in the study area. This would further deplete the phosphorus in the soil and increase the chemical constraints of the cultivated lands.

To sustain continuous farming and reduce the rate of soil nutrients decline of soils in the region, farmers in the region should be encouraged to adopt soil fertility management practices, where they combine the use of crop residues (organic inputs), fertilizers and cropping systems such as crop rotation and agroforestry. In addition, extension workers should be utilized more on the field to educate farmers on practices that would bring about soil improvement.

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