Effects of Contrasting Agricultural Land-use Systems on Selected Soil Properties in South-West Nigeria

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Abstract

Conversion of natural ecosystems to managed ecosystems may have negative consequences on soil quality. A study was carried out in order to investigate the effects of various land-use systems on changes in selected soils properties in Derived savannah and Rain forest ecosystems in southwest Nigeria. The three land uses selected from the two agro-ecological zones were: Cashew plantation, Arable soil, and Sugarcane plantation. Selected soil properties measured were: Saturated hydraulic conductivity, bulk density, particle size distribution organic carbon, total nitrogen and exchangeable cations. The data obtained were statistically analyzed using ANOVA. Findings revealed that average soil pH in the Rainforest agro-ecology was lower in value (4.62) compared with that of the Derived savanna (5.29). The C: N was significantly higher in Sugarcane plantation under the two agro-ecological zones with 9.83 and 13.66 for Derived savanna and Rain forest respectively while Arable soil with average of 6.05 for Derived savanna and 5.63 for Rain forest was the least among the land use considered. Sugarcane plantations with higher C: N ratios can minimize the rate of organic matter decomposition and best trap carbon in the region as a technique to mitigate climate change impact on the soil. The study revealed that land management that involves proper management of soil properties can promote sustainable environment for optimal crop production.

Keywords: Land-use, Soil properties, Assessment, Management, Rain forest

Introduction

Understanding how soils respond to varied agricultural activities over time is critical to successful soil management (Kiflu and Beyene, 2013). The growing recognition that soil is a critical component of the earth's biosphere, assisting not only in the production of food and fiber but also in the preservation of local, regional, and global environmental quality, has inspired a renewed interest in assessing soil resource quality (Negassa, 2001).

Soil nutrients and related soil processes, such as erosion, mineralization, and leaching, are influenced by land use and soil management strategies (Celik, 2005; Liu *et al.,* 2010). As a result, nutrition transport and re-distribution systems are altered. Soils undergo significant alteration as a result of changes in agricultural land use (Fu *et al.,* 2000). It was also reported by (Neris *et al.,* 2012; Yakubu, 2010) that continuous cultivating previously tilled soils decreased the quality of the soil. As a result, when linking soil nutrients to environmental conditions, land use and vegetation type must be taken into account (Liu *et al.,* 2010), owing to the fact that soil can readily lose its quality in a short period of time for a variety of reasons. and sustainable agriculture necessitates long-term land use of soil resources. Agricultural activity demands basic understanding and assessment of changes in soil qualities and, consequently, their status through time, in order to determine the impact of various management measures (Oyedele *et al.,* 2014). Soil quality has long been seen as a critical component of agricultural sustainability and a goal shared by most farmers, environmentalists, and policymakers (Sherwood and Uphoff, 2000; Mallo, 2010).

Land use change impacts various soil qualities and leads to greater degradation and erosion if it is not based on good scientific inquiry (Aghasi *et al.,* 2010). Negative soil changes result in the deterioration of soil qualities, which finally leads to low production. Appropriate knowledge of the effects of various agricultural land uses on soil qualities in any particular area is essential for addressing unfavorable trends and ensuring food security and environmental sustainability in any given country. There is an urgent need to study the impact of on-going land-use on soil properties in the different agroecology in Nigeria. The effective techniques strategy for adapting to soil degradation and climate change is to develop sustainable good agricultural practices (GAP) that will maintain and develop soil physical, chemical and biological properties. However, there is a scarcity of data on the effects of land degradation and soil conservation on soil qualities across Nigeria's various agro-ecosystems. Thus the objective of this study was to assess two separate agro ecologies in south–west Nigeria on their effects of diverse agricultural land usage on selected soil physical and chemical properties

Materials and Methods

Study area

The study was conducted at Obafemi Awolowo University Teaching and Research Farm (Rain forest) and Ejigbo town (Derived Savannah) both in south western Nigeria (Fig. 1). Obafemi Awolowo University Teaching and Research Farm is within the tropical rainforest. The climate is hot humid having a distinct dry season and bimodal rainy season with maximum in June and September. The total rainfall per annum is about 1032.21 mm, with an average solar radiation of 19.2 $MJ/m^2/d^2$. The average relative humidity is 81.84 percent; the maximum temperature is 32.90 degrees Celsius; and the minimum temperature is 21.95 degrees Celsius.

Ejigbo is a town in Osun State that is part of the Derived savannah agro-ecological zone in south-west Nigeria. Derived Savannah is defined as a zone with length or growing period between 7 and 9 months (Salako, 2003). The climate is hot humid having dry and rainy seasons, with the total annual rainfall of about 950 mm, and the average value for humidity is 70.30 %; the maximum temperature is 32.80 °C with 20.83 °C as the minimum temperature. The soils of the two agro-ecological zone are developed from crystalline Basement Complex rocks (granites,

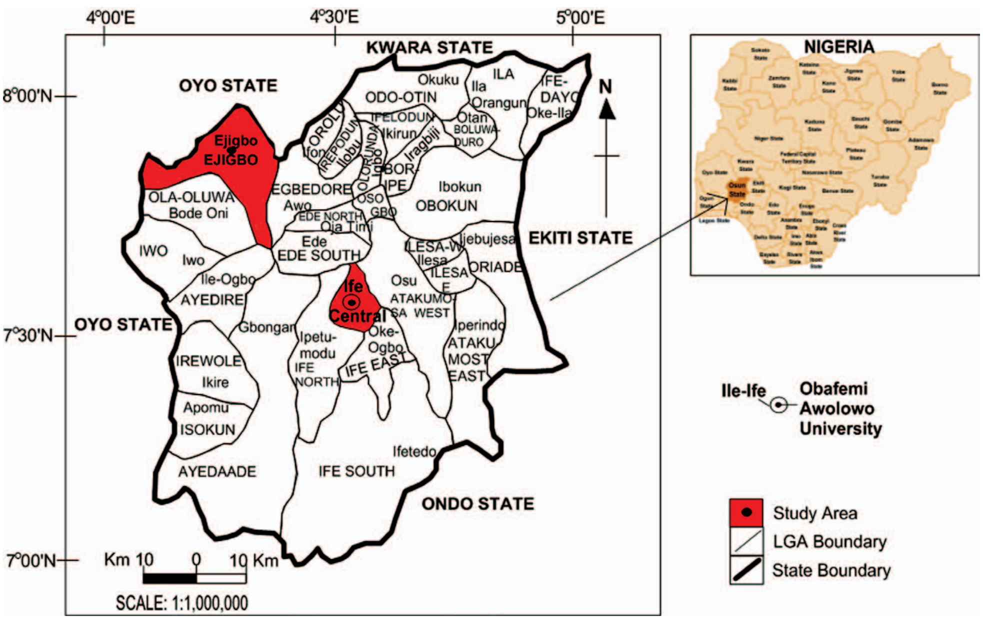

Figure 1: Map of Osun State showing the location of the study areas: Ejigbo and Obafemi Awolowo University, Ile-Ife

gneisses and schists) (Bennet, 1980) which is the dominant parent material in Nigeria.

Land use selection

The two locations where the research was carried out were selected because they distinctly represent the two major agro ecological conditions in the region where the research was carried out and the three land uses selected in both Agro-ecologies were: Cashew plantation that has been in place for more than 20 years, Arable land occupied with cassava and maize and yearly tractorized; Sugarcane plantation located in valley bottom land and usually flooded with water.

Sampling technique

In each agro-ecological zone, soil samples were collected at random from the three different forms of land use type. Each land-use type was approximately 0.5 hectares in size. Six soil samples were taken at depths of 0-15 cm and 15-30 cm from each land use category. Due to the homogeneity of the study area, each land use was treated as a unit. The undisturbed soil samples (using core sampler) were carefully collected on the field and transferred immediately to the laboratory for processing while disturbed soil samples were obtained at random from each of the two soil depths from various land use types, they were bulked, thoroughly mixed and a representative sub-sample was taken, air dried, passed through a 2 mm sieve, and stored in plastic bags for laboratory analysis. Table 1 presents experimental sites and their description.

Table 1: Geographical and land use type of the two stations

Experimental sites	Rain forest (Obafemi Awolowo University)		Derived savannah (Ejigbo)	
	Longitude	Latitude	Longitude	Latitude
Cashew plantation	N 07° 32'47"	E 004° 32' 51"	N 07° 52'42"	E 004° 18' 0"
Arable soil	N 07° 33'10"	E 004° 33' 21"	N 07° 52'19"	E 004° 18' 28"
Sugarcane plantation	N 07°32' 40"	E 004° 32 20"	N 07°52 15"	E 004° 18' 29"

Laboratory analysis

Physical and chemical analyses were carried out at the Obafemi Awolowo University's Soil Science Laboratory in Ile-Ife, Nigeria. For soil physical properties, particle size distribution was determined by hydrometer method (Okalebo *et al.,* 2002). For soil bulk density determination, a cylindrical core with a diameter of 5 cm and a height of 10 cm was utilized to take undisturbed soil samples from 0 to 10 cm deep at three distinct sampling points per experimental plot (Grossman and Reinsch, 2002).

The Blake and Hartge (1986) method was used to calculate bulk density in equation 1 as:

$$Bulk\ density(bd) = \frac{Mass\ of\ oven\ dried\ soil(g)}{Volume\ of\ core\ sampler(cm^3)} \quad (1)$$

The soil total porosity was obtained by the relationship between bulk density and soil particle density (2.6 Mg m^{-3}). Saturated hydraulic conductivity (Ksat) was measured by the constant head soil core method (Reynolds *et al.,* 2002). The volume of leachate was recorded over time until flow was steady, at which point the ultimate rate of flow was calculated using equation 2 as follows:

$$Ksat = \frac{Q}{AT} \times \frac{L}{\Delta H} \quad (2)$$

where Ksat = saturated hydraulic conductivity (cm h^{-1}), Q = volume of water that flows through a cross-sectional area (cm^3), A=cross sectional area of core (cm^2), T=time(s), L=length of core (cm), and ΔH=hydraulic head difference (cm).

The pH of the soil was determined in distilled water using a glass electrode pH meter in 1:1 soil: water ratio as described by Thomas (1996). Total nitrogen was determined by the macro-Kjeldahl method (Bremner, 1996); Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with neutral 1.0 M NH_4OAC solution of. The K^+, Ca^{2+} and Na^+ concentrations in the extract were determined using the flame photometer while Mg^{2+} was determined using the atomic absorption spectrophotometer (AAS). For the determination of soil organic carbon, the

Walkley-Black wet oxidation method (Nelson and Sommers, 1996) was adopted.

Data analysis

The data was subjected to analysis of variance (ANOVA) to determine the influence of the treatments. The Duncan Multiple Range Test was used to differentiate differences in the means. (DMRT) ($p \leq 0.05$) (SAS 2013)

Results and Discussion

Selected physical parameters of the study sites

Derived savanna soils had higher percent sand while Rain forest soils had higher percent silt and clay content (Fig. 2) if the two agro-ecologies are compared. Sand was significantly higher by 24% under Derived savanna soils compared to Rain forest soils. Also, clay content decreased by more than 2.0 folds in soils under derived savanna compared to rain forest agro-ecological zones. The higher clay content in the Rain forest soils might be as a result of washing down of clay particles due to heavy downpour in this zone. This shows that the study area's soil texture was influenced by different land-use types and agro ecology. The particle size of soil and texture are important factors in determining the fertility status of soils that supports the cultivation of different crops, Hartley (1988).

Organic matter content of the study area

Figure 3 shows organic matter distribution for the three types of land use under the two agro ecological zones considered. There was no significant difference in organic matter content for the two agro ecological zones considered under arable soils, also lower organic matter content was observed under these soils compared to the two other land uses. This result was not unexpected, as previous study had indicated that continual cropping reduced soil organic matter level (Mikha and Rice, 2004; Ashagrie *et al.,* 2007). Differences in vegetation cover may also be one of the reasons for higher organic matter content in other land uses compare with arable land. Natural vegetation in Nigeria's agro-ecological zones is constantly threatened by the removal of plant cover and indiscriminate deforestation for fuel wood, timber, shelter, food crops, and building materials. Surface runoff and soil erosion are increased as a result of these operations. There were significantly higher organic matter content in both Cashew and Sugarcane plantation in Rain forest soils compared to Derived savanna soils (Fig. 3). The

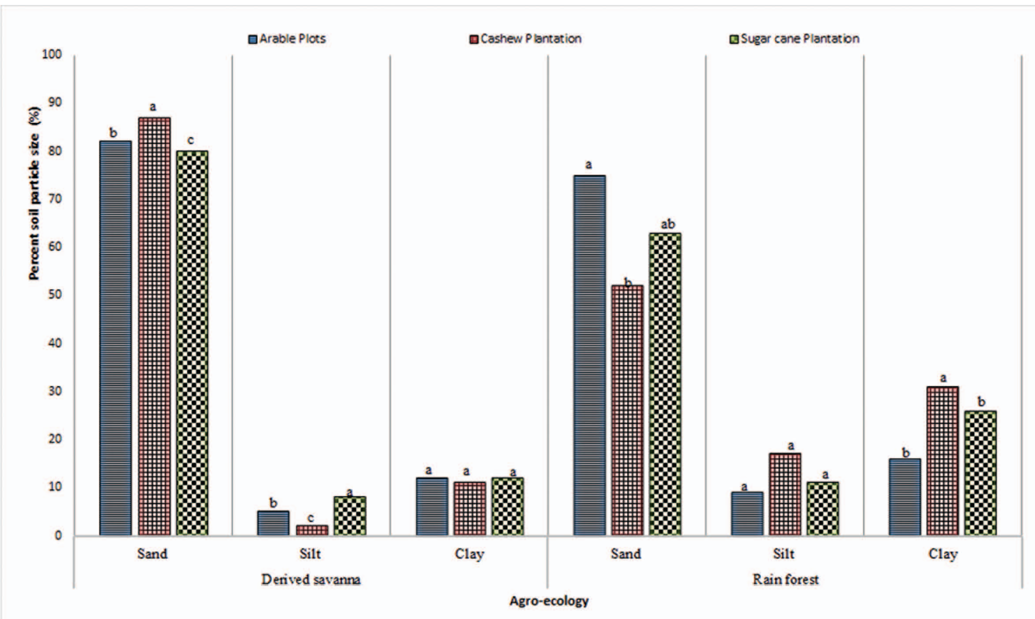

Figure 2: Particle size distribution of the three agricultural land use in Derived savanna and Rain forest

higher soil organic matter, (SOM), content of the soil in sugarcane plantation in this climatic zone might be due to high moisture content which retarded the activities of the microorganisms involved in the organic matter decomposition thereby accumulating more organic matter (Mclean and Bledsoe, 1992; Alloway and Aryes, 1997).

Accumulation of soil organic matter is beneficial to soil in relation to agriculture and also aids sequestration of carbon from atmospheric carbon dioxide (Ogunwole *et al.,* 2010).

in the Rain forest soils under the three different land uses considered. With regards to Arable soils that had the highest bulk density, soil bulk density decreased by 1.2 to 2.1 folds in soils under Cashew plantation and Sugarcane plantation.

Edward *et al.* (2015) noted that bulk density that ranged between 1.4 to 1.6 g cm^{-3} for Loamy sand, Sandy clay loams and Clay loam resulted in hindrance to root penetration and insufficient aeration due to compaction. Planting operations as well as intense precipitation in the Rain forest under this type of land use might be responsible

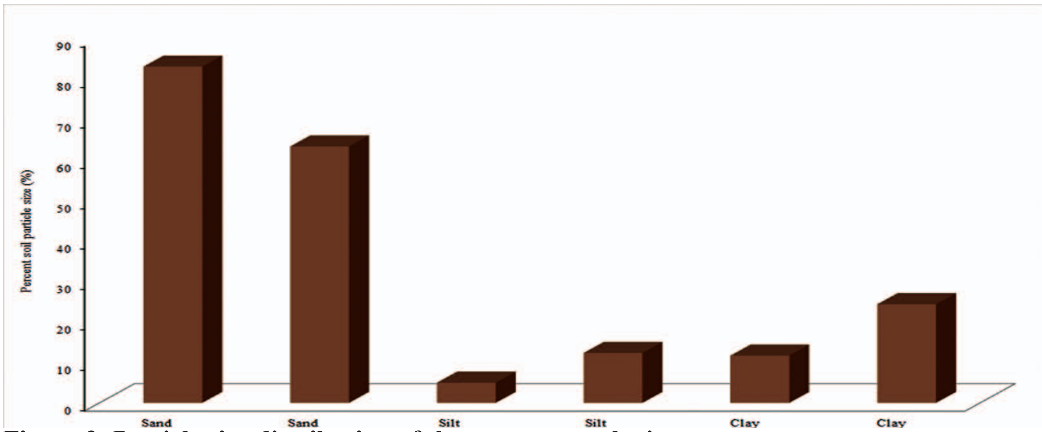

Figure 3: Particle size distribution of the two agro ecologies

Selected soil physical properties for the two locations are shown in Table 2. There were no significant differences ($p<0.05$) in bulk density, porosity and hydraulic conductivity in the different land uses considered in the Derived savanna. However, there were significant differences for the stated soil physical properties for this. High bulk density restricts water and air movement, increases plant root lodging and rotting, reduces crop emergence, disturb root development, and restricts soil exploration by roots, resulting in poor crop growth, reducing crop yield and vegetation cover available to protect the soil from surface run off (Arshad *et*

Table 2: Selected physical properties for different agro-ecologies for different agricultural land use types in two agro ecologies

Treatment	Derived savannah					Rain forest				
	BD(g cm^{-3})	Porosity (%)	HC(cm h^{-1})	Silt: Clay	Texture	BD(g cm-³)	Porosity (%)	HC(cm h^{-1})	Silt: Clay	Texture
Arable soil	1.26a	52.38a	20.53a	0.42b	Loamy Sand	1.79a	32.50c	9.78b	0.57a	Sandy loam
Cashew plantation	1.55a	41.33a	14.06a	0.19c	Loamy Sand	1.47b	44.75b	59.39a	0.50ab	Clay loam
Sugarcane plantation	1.61a	39.27a	23.11a	0.67a	Sandy loam	0.8515c	67.91a	5.56b	0.34b	Sandy clay loam

HC = Hydraulic Conducvity, BD = Bulk density *al.,* 1996; Kabiru *et al.,* 2017)

Porosity among different agricultural land-use in the Rain forest was significantly different from one another and followed this pattern: Arable soils < Cashew plantation < Sugarcane plantation (Table 2).

Cashew plantation had the highest hydraulic conductivity among the land use types considered. Saturated hydraulic conductivity decreased by 6.07 to 10.68 folds in soils under Arable land and Sugarcane plantation. Hydraulic conductivity is vital for predicting drainage and water movement within the soil matrix, whether in the form of saturation or vapour flow.

Lower hydraulic conductivity observed in these two land uses could be due to increase in land use and land cover change from bushland to other forms (continuous cultivation), which has the ability to cause soil disturbances and obstruct free movement of water through the micro-pores, leading to surface runoff, erosion, and pollution of stream (Negassa, 2001).

Silt: clay was lower in Cashew plantation under Forest and Derived savanna soils. Arable plots had significantly highest silt: clay and the least ratio was found in sugarcane plantation under Rainforest soils. Highest ratio of silt to clay was recorded for Sugarcane plantation under derived savanna soil while Cashew plantation recorded the least value. A considerably lower clay content in Arable and Sugar plantation was most likely because of preferential removal of these particles by soil erosion, Table 2.

Selected chemical parameters of the study sites

Soil pH (H_2O) values of the soil were minimally affected by the land use types in the two different agro-ecologies, Table 3. The two agro ecologies had significant different effects on soil pH. Soil pH in the Rainforest were lower in value compared to that of the Derived savanna. Soil pH values in different land use type under Derived savanna were generally higher compared to soils under Rainforest. There was no significant difference in soil pH among different land–uses considered in derived savannah. However, soil pH varied significantly by the impact of land-use changes in Rain forest, with lowest pH (4.50) in cashew plantation and highest pH (4.70) in arable lands. Lower soil pH in Rainforest soils might be due to consequences of the leaching action of basic cations out of the soil solum and dominance of exchangeable H+ and Al3+ compared to other soils in Derived savanna (Neina, 2019). Others could be due to land use practices such as cultivation and the use of inorganic fertilizers on a long-term basis. According to Heluf and Wakene (2006), the use of acidifying mineral fertilizers and intensive cultivation increased basic cation leaching and organic matter oxidation, resulting in a reduction in soil pH, Table 3.

Table 3: Soil pH and exchangeable bases for the two agroecology

Treatments	Derived savanna					Rain forest				
	pH (water)	Ca (cmol kg^{-1})	K (cmol kg^{-1})	Mg (cmol kg^{-1})	Na (cmol kg^{-1})	pH (water)	Ca (cmol kg^{-1})	K (cmol kg^{-1})	Mg (cmol kg^{-1})	Na (cmol kg^{-1})
Arable soil	5.32a	11.10a	12.28a	4.38b	6.15a	4.70a	9.48c	2.51a	5.35a	4.20b
Cashew plantation	5.27a	9.43c	2.46b	5.30a	4.60c	4.58b	10.08b	2.08b	4.75b	3.50c
Sugarcane plantation	5.28a	10.53b	2.63b	4.20b	5.35b	4.57b	11.55a	2.23b	4.58b	5.30a
Av.	5.29	10.35	5.79	4.63	5.37	4.62	10.37	2.27	4.89	4.33

Significantly higher Ca^{2+}, K^{+} and Na^{+} contents were measured in Arable soils while the least of these cations were recorded for Cashew plantation in Derived savanna. Also, Mg^{2+} and K^{+} were significantly higher in Arable soils compare to Cashew and Sugarcane plantations in Rain forest soils. Similarly, Ca^{2+} was significantly higher by 12.72 to 17.92 % in soils under sugarcane plantation compared to lowest in other land use types in Rain forest agroecology. The increase in exchangeable bases in Arable soils may be attributed to input management practices that might occur as a result of incorporation of organic and inorganic fertilizer into the soil Lal (1997) reported increased concentration of exchangeable bases with organic and inorganic amendment compared to plant debris left on the surface as mulch, Table 3.

Table 4 presents carbon and total nitrogen content for different land-use types in the two agro ecological zones. Total carbon and nitrogen were influenced by the treatments in the two agro ecologies. In Derived savanna, Total carbon was significantly higher by more than 32 % in soils under Sugar plantation compared to lowest in Arable soils. Similarly, Total nitrogen was significantly higher by 18.52 % in soils under

Cashew plantation compared to Arable soils The decrease in soil disturbance witnessed in Sugar cane plantation and Cashew plantation in this ecological zone might have favoured the heavy concentration of C and N on the surface soil layer (Mrabet *et al.,* 2001). Also, the carbon and nitrogen in Sugarcane plantation and Cashew plantation might be more resistant to decomposition and may have longer turnover time compared to C and N in Arable soils. With reference to Sugarcane plantation, C:N decreased by 1.51 to 1.62 folds in soils under Cashew plantation and Arable soils in Derived savanna. The soil C:N ratio is usually noted as an indicator of soil nitrogen mineralization. The implication from the data gotten is that increase in soil nitrogen mineralization can occur in Arable soil compare to Sugarcane plantation but lower carbon sequestration to combat change in climate. Organic carbon was significantly higher in Sugarcane plantation and Arable soils under Rainforest Agro-ecology compared to Cashew plantation. In contrast, Total nitrogen was significantly higher by 39 % in soils under Cashew plantation compare to lowest in Arable (Table 4). Lower amount of Total nitrogen in soils under Arable soils in this agro ecological zones might be due to removal of N-enriched leafy biomass and grains during harvest and insufficient replenishment of N through manure or chemical fertilizers. The C:N was significantly higher in Sugarcane plantation under Derived savanna soils and Rainforest soils follow by Cashew plantation, Arable soils had lowest C:N under the two agro ecologies. High C:N ratios in Sugarcane plantation can reduce the rate of organic matter and organic nitrogen decomposition by decreasing the capacity of soil microbial activities, whereas low C:N ratios in other land uses could increase the process of microbial decomposition of organic matter and nitrogen, but not conducive to carbon sequestration this was also reported by Wu *et al.* (2001). The implication of this is that soils under Sugarcane plantation decrease decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activity and can best sequester carbon in the region as a means to combat climate change this observation concur with the study of Abbasi *et al.* (2007). The C:N ratio for all the sites considered were within the range of soil organic matter that can easily mineralize without serious immobilization of nitrogen (Hartley, 1988)

Organic matter distribution among different land use in two different agro-ecologies is presented in Figure 4. There was lower total organic carbon in Derived savannah soils when compared to Rain forest soils under different agricultural land-use. The lower levels of organic carbon can be attributed to climatic factors (e.g. temperature) and farming practices. Also, Lower level of organic-carbon C in Derived

Table 4: Carbon and total Nitrogen content for different land use types in the two agro ecological zones

Treatments	Derived savannah			Rain forest		
	C (%)	N (%)	C:N	C (%)	N (%)	C:N
Arable soil	1.29b	0.22b	6.05b	3.87a	0.25b	5.63b
Cashew Plantation	1.68ab	0.27a	6.51b	2.74ab	0.41a	6.66b
Sugar Plantation	1.90a	0.20c	9.83a	3.87a	0.26b	13.66a
Av.	1.62	0.23	7.46	3.49	0.31	8.65

savannah soils vis a vis Rain forest soils might have resulted over time from a combination of several factors, such as decrease in C inputs as a result of sparse vegetation and lower biomass return and rapid decomposition due to high temperatures (Mullar-Harvey *et al,* 1985; Reicosky and Forcella, 1998). Organic carbon is an important factor in crop productivity since it helps with nutrient retention, soil aggregation, soil organism nutrition, and water storage. Soil organic carbon influences soil chemical, physical, and biological properties through these roles (Chan, 2010).

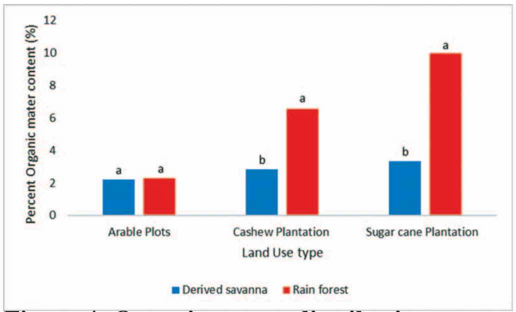

Figure 4: Organic matter distribution among different land use in two different agro-ecologies

Conclusion

Lower organic matter content observed in Arable soils for both agroecology considered can be improved by applying organic fertilizers at regular interval. Higher bulk density most especially in Arable soils of Rainforest can be addressed if activities of regular disturbance of soil particles (tractorization) is minimized. Also lower pH in this agro ecology (Rainforest) as a result of heavy downpour and management practices (like application of in-organic fertilizers and continuous cultivation that promote losses of basic cations) can be minimized, if acid forming fertilizer is avoided. This will go a long way in crop and soil sustainability. Land-use practices that resemble the natural environment in the previously existing ecology would go a long way to improve soil quality in the two agro-ecologies.

Declaration of competing interest

The authors declare that there are no competing interests regarding this work.

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