Distribution Of Soil Organic Carbon of Selected Land Use Types in Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

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Abstract
The contributions of soil to tree growth are very significant and it stores more carbon than the atmosphere and terrestrial vegetation together. The effects of land-use on the Soil Organic Carbon (SOC) in different land use types were examined in this study. The soil samples were collected at two depths (0-30cm and 30-60cm) from four sites namely; *Gmelina arborea*, *Tectona grandis*, *Leucaena leucocephana* plantations and secondary natural forest. The samples were analysed for Soil Organic Carbon (SOC), Labile Organic Carbon (LOC), Microbial Biomass Carbon (MBC) and Dissolved Organic Carbon (DOC). The data were subjected to one-way Analysis of Variance and Duncan's Multiple Range Test was adopted for the separation of means at 5% level of probability. The result shows that there were significant differences in the distribution of soil organic carbon between depths. At depth 0-30cm, highest SOC (8.59±0.55) and MBC (6.97±0.47) were recorded while the least values were obtained for LOC and DOC. With respect to land use types, there were significant differences in SOC, LOC, DOC and MBC ($P<0.05$), the highest SOC (10.04±0.10) was recorded in *Leucaena plantation* at 0-30cm, followed by (9.64±0.63) in secondary forest at depth 0-30cm. However, the least SOC was recorded in *Tectona grandis* plantation (4.09±0.08) at depth 30-60cm. Highest LOC (12.91±0.20) was recorded in *Leucaena* plantation at depth 30-60cm while the least (6.59±0.07) at depth 0-30cm. was recorded in *Tectona* plantation. The highest DOC recorded was (11.81±0.05) in Secondary forest at depth 30-60cm while the least was obtained in *Tectona* plantation (6.75±0.08) at depth 0-30cm. Highest MBC (8.20±0.00) at depth 0-30cm in Secondary forest while the least (2.91±0.01) was recorded at depth 30-60cm in *Tectona* plantation. The high DOC in the secondary forest could be a reflection of the high level of species diversity and the high level of SOC in *Leucaena* may be due to the abilities of the species which tend to increase SOC storage in long term. The study inferred that soil organic carbon and its fractions showed a significant spatial variation among the sites examined.

Keywords: Soil organic carbon, fractions, depth, land use, plantation, secondary forest

Introduction

Soil is the loose surface material consisting of inorganic particles and organic matter that covers most of the land surface. Soil provides the structural support and the source of water and nutrients for plants to growth. It is the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants (Schoonover and Crim, 2015). In the presence of environmental change, land degradation and biodiversity loss, soils have become one of the most vulnerable assets on the planet. Soils store more carbon than the atmosphere and terrestrial vegetation together. Globally, SOC stocks are assessed at an average of 1500 PgC in the main meter of soil, in spite of the fact that their distribution is spatially and temporarily variable (FAO, 2017).

Soils are the biggest terrestrial pool for organic carbon in the biosphere. Large scale changes in land utilize like deforestation and farming exercises, including biomass burning, furrowing, drainage, and low-input farming have brought about significant changes in soil natural carbon (SOC) pools (Lal, 2003; Lorenz and Lal, 2005). Soil Organic carbon (SOC) is one of the most significant components of the soil system. SOC is the substantive and vigorous basis of all natural soil procedures and along these lines it is the basis of the most beneficial and non-beneficial soil function Barančíková *et al.*, 2016). The direction of changes and conversion of SOC is impacted by human actions and land use.

SOC plays significant role in the determination of soil quality, crop production, and ecological quality (Bauer and Black, 1994; Robinson *et al.*, 1994). This is because of their impacts on soil physical, chemical, and biological properties (Kussainova *et al.,* 2013). Land use system is very important in the control of SOC levels. Change in land use and management practices impact the sum and rate of soil organic carbon losses (Guggenberger *et al*., 1995). Many research results have affirmed that soil organic carbon is related with various land uses and varies significantly at the provincial or catchment scale (Dengiz *et al.,* 2015). The changes in land use imply changes in total stock of soil organic carbon. SOC is got from a convoluted mixture of fresh organic materials from plants, soil fauna, root exudates, microbial deposits and chemically or physically secured substrates (Davidson and Janssens, 2006), which comprise of labile and recalcitrant pools (Xia *et al.,* 2010). Land cover changes influence litters, plant root, soil fauna, soil microorganisms and, soil condition, which can radically change the soil carbon stock (Lv and Liang, 2012). SOC is extraordinarily susceptible to environment change, particularly to changes in vegetation cover (Wang *et al*., 2011; Lv and Liang 2012). Soil microbial biomass carbon and dissolved carbon and are generally used to portray the movement of soil organic carbon. Regarding energy cycle and nutrient transfer, soil microbial biomass carbon is incredibly sensitive and reflects little changes in soil organic (Yang *et al.,* 2016).

Variety in SOC mass is firmly identified with the equalization of contribution from net primary production and microbial decomposition. Dissolved organic carbon is a delicate indicator of the adjustments in soil environment. It gives the energy that can be used legitimately by microorganisms Along these lines, the study of soil microbial biomass carbon and dissolved organic carbon is very importance for vegetation restoration.

This study was carried out to determine and compare the distribution of soil organic carbon fraction at different depths in different land use management (*Gmelina* plantation, *Tectona* plantation, *Leucaena* plantation and secondary forest). This is essential in the management of soil organic carbon in the study area.

Materials and Methods

Study area

This study was carried out at the Federal University of Agriculture, Abeokuta, Nigeria. The university lies approximately between Longitude 7.23" – 7.58" N N and Latitude 3.25" - 3.43" E within Abeokuta, Ogun state. Four different land use types were selected within the university premises namely; *Gmelina arborea* plantation, *Tectona grandis* plantation, *Leucaena leucocephana* plantation and Secondary natural forest.

Two points were randonmly located in each stand and the natural forest for soil sample collection. The samples were collected from two depths (0-30 cm and 30-60 cm) in each site The samples from two different depths were separately collected into sterile bags. The materials used are distilled water, digestion tubes, sieve, sample bags, 66.7mm $K_2Cr_2O_7$ (p.a.; 19.6125 g 1^{-1}), concentrated H_3PO_4 (85% p.a.) concentrated H_2SO_4 (98% p.a.), 40.0 mm ferrous ammonium sulphate $[(NH_4)_2Fe(SO_4)_2$ X $6H_2O]$, 25 mm 1, 10-phenanthroline-ferrous sulphate complex solution.

Soil Analysis

Determination of Soil organic carbon (SOC)

SOC was determined by the procedure of Walkley and Black (1934) using the dichromate wet oxidation method (Nelson and Sommers, 1996). Soil organic carbon was determined by the procedure of Walkley and Black (1934) using the dichromate wet oxidation method (Nelson and Sommers, 1996). In a 50 ml digestion tube, 0.4 g of finely ground soil was mixed with 5.ml of potassium dichromate solution and 7.5 ml sulphuric acid. The tube was placed in a preheated block at 145-155^{0}C for 30 minutes. The tube then was removed and allowed to cool. The digest was transferred to 100 ml volumetric flask and 0.3 ml of the indicator solution was added. The mixture was mixed thoroughly, titrated with Ferrous Ammonium Sulphate Solution and the end point colour change from greenish to brown.

Determination of Labile Organic Carbon (LOC)

LOC was determined by placing 4g of the soil in a 50ml glass test tube after which 10ml Potassium dichromate solution was added. The soil was mixed with the solution by shaking the tube. Concentrated sulphuric acid (8ml) was added and slowly on side wall of the test tube. This was followed by adding 20 ml of distilled water. The top colour solution was mixed with a glass rod without disturbing the settled soil. Similarly, 0.44, 0.66, 0.88, 1.11, 1.32, 1.54, 1.76, 1.98 g of glucose in 100ml distilled water as to be dissolved and develop colours. Instead of soil samples, 4ml of this solution was used for determining the

Determination of Microbial Biomass Carbon (MBC)

MBC was determined by using dichromate oxidation (Kalembasa and Jenkinson 1973). The mixture of 2ml of 66.7 mm (0.4 $_N$) $K_2Cr_2O_7$ and 15 ml of the H_2SO_4/H_3PO_4 were added to 8ml of the filtered extract in a 250 ml round-bottomed flask. The whole mixture was gentle refluxed for 30 minutes, cooled and diluted with 25 ml water, which was added through the condenser as a rinse. The residual dichromate was measured by back titration with 40.0mm Ferrous Ammonium Sulphate Solution using 25mm 1,10-phenanthroline-ferrous sulphate complex solution as an indicator.

Determination of Dissolved Organic Carbon (DOC)

The transferring of 4ml of the sample extract into a digestion tube was carried out. Addition of 1ml 0.0667M Potassium Dichromate was also carried out after which 5ml concentrated sulphuric acid was added.

Data Analysis

The data collected were analyzed using two-way analysis of variance (ANOVA) and the Means were separated using DMRT (Duncan Multiple Range Test).

colour. The samples were compared in between standards if matching, and Carbon percentage was determined accordingly.

Results

Depth and distribution of soil organic carbon and fractions under the different types of land use

The highest soil organic carbon concentration of 8.59±0.55 was recorded in 0-30cm depth, followed by 7.45±0.60 in 30-60cm depth. The result shows that there was a significant difference between the depths (Table 1).

There was a significance difference between the concentration of Labile Organic Carbon in the 0-30cm and 30-60cm depths. The highest labile organic carbon (10.99±0.59) was observed in the 30-60cm depth and the least in 0-30cm depth (9.74±0.65).

Depth of 30-60cm had the highest dissolved organic carbon (10.07±0.40). There was a significant difference in dissolved organic carbon between depths (Table 1).

Highest Microbial biomass carbon concentration was recorded in 0-30cm depth with a value of 6.97±0.47 and the least in the 30-60cm depth (5.78±0.51). Microbial biomass carbon showed a significant difference in concentration between depths (Table 1).

Table 1: Effect of depth on Distribution Characteristics of soil organic carbon and its fractions under different types of land use

Depth	Soil Organic Carbon	Labile Organic Carbon	Dissolved Organic Carbon	Microbial Biomass Carbon
0-30cm	8.59 ± 0.56^a	9.74 ± 0.66^b	8.51 ± 0.41^b	6.97 ± 0.48^a
30-60cm	7.45 ± 0.61^b	10.99 ± 0.60^a	10.07 ± 0.41^a	5.78 ± 0.51^b

Mean values with the same superscripts in each column are not significantly different P<0.05.

3.2 Land use and distribution of soil carbon and its fractions

The highest SOC was recorded in *Leucaena* plantation (9.68±0.20), followed by (8.96±0.30) in secondary forest. The least SOC was recorded in the *Tectona grandis* plantation (4.76 ± 0.30) There was a significant difference in soil organic carbon between *Leucaena* plantation and the Secondary Forest, Leucaena plantation and Gmelina plantation, Gmelina plantation and Tectona plantation. While there was no significant difference between secondary forest and *Gmelina arborea*.

There was no significance difference in the LOC concentration between *Leucaena leucocephana* and the Secondary forest, while there was significant difference in LOC between *Leucaena leucocephana* plantation and *Gmelina arborea*, secondary forest and *Gmelina arborea*, *Leucaena leucocephana* and *Tectona grandis* and *Gmelina arborea* and *Tectona grandis* plantation. The highest LOC was recorded in *Leucaena leucocephana* (12.14±0.38) while the least LOC was recorded in *Tectona grandis* plantation (7.23±0.28).

The DOC concentration revealed significantly differ when all the locations were compared. The secondary forest has the highest DOC of (11.16±0.30), followed by 9.80±0.48 in *Gmelina arborea*. The least DOC (7.62±0.40) was recorded in the *Tectona grandis* plantation.

The highest MBC was observed in the secondary forest (7.72±0.21) and the least (3.61±0.33) in the *Tectona* *grandis* plantation. There was no significance difference in MBC between Leucaena and Gmelina plantations. However, there was a significance difference in MBC between the following pairs; *Leucaena leucocephana* and secondary forest, *Leucaena leucocephana* and *Tectona grandis* plantations, secondary forest and *Gmelina arborea* and *Gmelina arborea* and *Tectona grandis* plantations (Table 2).

Table 2: Effect of land use on Distribution of soil organic carbon and its fractions under the different land use types

Land use	Soil Organic Carbon	Labile Organic Carbon	Dissolved Organic Carbon	Microbial Biomass Carbon
Leucaena leucocephana	9.68 ± 0.21[a]	12.14 ± 0.38[a]	8.59 ± 0.24[c]	7.25 ± 0.29[b]
Secondary Forest	8.96 ± 0.31[b]	11.94 ± 0.34[a]	11.16 ± 0.30[a]	7.72 ± 0.23[a]
Gmelina arborea	8.67 ± 0.28[b]	10.13 ± 0.57[b]	9.80 ± 0.50[b]	6.93 ± 0.29[b]
Tectona grandis	4.76 ± 0.30[c]	7.23 ± 0.29[c]	7.62 ± 0.41[d]	3.61 ± 0.34[c]

Mean values with the same superscripts in each column are not significantly different P<0.05.

Relationship between depths and land use types on the distribution of soil organic carbon and its fractions

In relation to the land-use, the highest SOC (10.04±0.10) was recorded in *Leucaena leucocephana* at 0-30cm, followed by 9.64±0.63 in secondary forest at the depth of 0-30cm. However, the least SOC was recorded in *Tectona grandis* (4.09±0.08) at the depth of 30-60cm (Table 3).

The results of the SOC show a significance difference *in Leucaena leucocephana*, secondary forest, *Gmelina arborea* and *Tectona grandis* plantations with the two depths.

The highest LOC (12.91±0.20) was recorded in *Leucaena leucocephana* at 30-60cm, 12.03±0.05 in the secondary forest at the depth of 0-30cm, while the least LOC was recorded in *Tectona grandis* plantation (6.59±0.07) at the depth of 0-30cm. There was a significant difference in LOC in *Leucaena leucocephana*, secondary forest, *Gmelina arborea* and *Tectona grandis* plantation between depths (0-30cm and 30-60cm) (Table 3).

The highest DOC recorded was (11.81±0.05) in secondary forest at the depth of 30-60cm, followed by 10.88±0.13 in *Gmelina arborea* plantation at the depth of 30-60cm. DOC of 6.75±0.08 was recorded in the *Tectona grandis* plantation at the depth of 30-60cm. There was significance difference in soil DOC from *Leucaena leucocephana* plantation, secondary forest, *Gmelina arborea* plantation and *Tectona grandis* plantation across the depths.

The highest MBC (8.20±0.00) was recorded in the secondary forest at the depth of 0-30cm and the lowest (2.91±0.01) in the *Tectona grandis* at the depth of 30-60cm. There is significance difference in *Leucaena leucocephana*, secondary forest, *Gmelina arborea* and *Tectona grandis* plantation between the depths.

Table 3: Interactive effect between land use and depths of distribution characteristic of soil organic carbon and its fractions under different types of land use

Land Use	Depth	SOC	LOC	DOC	MBC
Leucaena leucocephana	0-30cm	10.04 ± 0.11[a]	11.37 ± 0.31[b]	8.07 ± 0.09[e]	7.88 ± 0.13[ab]
	30-60cm	9.33 ± 0.29[b]	12.91 ± 0.20[a]	9.11 ± 0.15[c]	6.63 ± 0.16[d]
Secondary forest	0-30cm	9.64 ± 0.06[ab]	12.03 ± 0.05[ab]	10.51 ± 0.21[b]	8.20 ± 0.00[a]
	30-60cm	8.28 ± 0.03[c]	11.85 ± 0.76[ab]	11.81 ± 0.06[a]	7.24 ± 0.10[c]
Gmelina arborea	0-30cm	9.25 ± 0.18[b]	8.94 ± 0.392[c]	8.73 ± 0.09[cd]	7.50 ± 0.22[bc]
	30-60cm	8.09 ± 0.15[c]	11.32 ± 0.28[b]	10.88 ± 0.13[b]	6.37[d] ± 0.25[d]
Tectona grandis	0-30cm	5.42 ± 0.11[d]	6.59 ± 0.078[e]	6.75 ± 0.09[f]	4.30 ± 0.28[e]
	30-60cm	4.09 ± 0.08[e]	7.87 ± 0.03[d]	8.50 ± 0.23[d]	2.91 ± 0.01[f]

Mean values with the same superscripts in each column are not significantly different P<0.05.

Discussions

Soils are major Carbon stores in tropical areas and about 36–60% of ecosystem Carbon in forests are stored in soils (FAO, 2006; Don *et al.*, 2011). This research has indicated the distribution status of soil organic carbon and its fractions in Gmelina plantation, Teak plantation, Secondary forest and Leucaena plantation at two different depths; 0-30cm and 30-60cm. There were significant differences in soil organic carbon at the two depths and for the different locations.

Soil organic carbon at depth 0-30cm recorded the higher amount of soil organic carbon value than the depth 30-60cm. The upper part of soil at depth 0-30cm tend to be rich in soil organic carbon. This may be due to the fact that soil surface of the plantation has less disturbance which allowed soil organic carbon fraction to gather at the surface of the soil. SOC also appears to gain importance with increasing depth across the soil profile as reported by Zhao et al., (2015) in Stratification and Storage of Soil Organic Carbon and Nitrogen as affected by tillage Practices in the North China Plain.

Labile Organic Carbon at depth 0-30cm was lower than that of depth 30-60cm. This could be a reflection of the difference in the plantation sites that have a significant effect on LOC through the difference in moisture content, temperature and the decaying litter fall (Xia, *et al.*,2010).

Higher Dissolved Organic Carbon was obtained at depth 30-60cm. Dissolved Organic Carbon moves with both surface water and ground water and this could contribute to its increase in concentration with depth. Kalbitz *et al.*, 2000; Laik *et al.*, (2009) reported that litter and humus were the two important sources of Dissolved Organic Matter (DOM). The composition of the leaf litter and the decaying roots might be playing an important role in determining the concentration of DOC in soils.

Soil Microbial Biomass plays important role in soil fertility. The highest Microbial Biomass Carbon was recorded at depth 0-30cm of the Secondary Forest. This may indicate the concentration of microbial biomass in the humus layer of the soil. Kaiser and Heinemeyer (1993), reported that increase in amount of MBC in soil depends on the abundance, quality and distribution of the carbon input factors that contributes to it. The decrease in Microbial Biomass Carbon in the subsurface layer of *Tectona Grandis* revealed a decreasing percentage of fresh plant material in the soil organic matter as a result of the decreasing carbon input rate of roots which (Meyer *et al*., 1996).

With respect to types of land use, *Leucaena* plantation has the highest amount of SOC compared to the other land use types. This may be due to the age of the plantation that can affect the level of SOC in a plantation area. Guo and Gifford (2002) and Eclesia *et al*. (2012), reported that some increase in SOC content with increasing age in plantations and different land use changes that could determine geographical patterns of SOC accumulation. The more the age of a plantation, the tendency of the SOC content to be more (Berthrong *et al*., 2012).

Leucaena plantation has the highest amount of Labile Organic Carbon (LOC), followed by the Secondary forest while *Gmelina* plantation and teak plantation has the least. Strosser (2010) reported that the quantity and characteristics of LOC fraction differ depending on the direction of land use change and the fractionation approach used, which means land use activities may determine the level of LOC.

The secondary forest has more Dissolved Organic Carbon content than the other sites. This could be attributed to the vegetation of the area and also the parent material of the soil of this location. It could also be related with both the high and low rate of microbial respiration (Don and Schulze, 2008). Depending on the types of vegetation and parent material through their direct and indirect effects on availability of nutrient and texture of soils, the DOC change in soils varies in tropical areas as reported by Fujii *et al*., (2011).

The secondary forest contains more MBC than other land use types which may be due to the different stages in secondary forest. This was also similar to the findings of Medeiros *et al.*, 2017 and Notaro *et al*., 2014 who reported that there are different succession stages in secondary forests which showed increased MBC in a secondary forest.

In all the locations, *Leucaena* plantation at depth 0-30cm had the highestSOC which may be due to Carbon storage which fluctuates basically because of climatic, topographical and soil structuring factors in the long term, while vegetation and changes in land use patterns affect storage in the short term. In addition, it was reported by Radrizzani *et al*., (2011) that *leucaena* stands have the potential to increase SOC storage over the long-term because of its potential to fix nitrogen. The soil organic carbon of a site varies a lot and it is determined by a lot of factors such as vegetation, depth, environmental conditions, sites and parent materials. This study shows that soil organic carbon and its fractions varied among the land use types. *Leucaena* plantation had the highest Soil Organic Carbon.

With respect to relationship between depth and the land use types on the characteristic of soil organic carbon and its fractions, *Leucaena leucocephana* had highest SOC at 0-30cm.

From the findings of this research, the soils of *Leucaena* plantation and secondary forest are richer in soil organic carbon and its fractions than the others. It is advisable that *Leucaena* plantations should be established because at long term, it increases the soil organic carbon of the site and its potential to partially mitigate climate change by removing carbon dioxide (CO_2) from the atmosphere.

Conclusion and Recommendations

The study inferred that soil organic carbon and its fractions shows a significant variation in all the locations used, soil organic carbon and its fractions are the major determinant of soil, soils which play a major role in the global carbon budget has an amount of Soil organic carbon and its fractions. This study indicates that there is a great potential with our trees to improve soil fertility by developing sustainable land use to reduce the rate of soil erosion and to ensure long-term sustainability of the farming system, as a result concerted efforts are urgently needed to protect the remaining forests.

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