

**CARBON ACCUMULATION AND PARTITIONING IN SOIL UNDER A 20-YEAR-
OLD *Tectona grandis* PLANTATION**

A PROJECT REPORT

BY

OLAKUNLE HENRY OGUNBIYI

FORESTRY RESEARCH INSTITUTE OF NIGERIA (FRIN)

JERICHO HILLS, IBADAN, OYO STATE

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Abstract

Land use practices strongly influence soil organic carbon (SOC) dynamics, yet limited evidence exists on carbon partitioning under *Tectona grandis* plantation in Southwestern Nigeria. This study quantified total and fractionated SOC, Particulate Organic Carbon POC, and Mineral Associated Organic Carbon (MOC) in a 20-year-old teak plantation and adjacent fallow land at the Federal University of Technology, Akure. Three 45 m x 45 m plots were established in each land use type, and soils were sampled at 0-10, 10-20, and 20-30 cm depths. Samples were fractionated by particle size and analyzed using the Walkley-Black method.

ANOVA was used to assess effects of land use and depths. SOC fractions varied significantly with both factors ($p < 0.05$). The fallow land showed the highest TOC at 0-10 cm (2.65%), while the plantation had slightly higher MOC at the same depth (2.60%), indicating stronger organo-mineral stabilization. Carbon concentration declined with depth in both systems. Findings show that teak plantations enhance mineral stabilized carbon in surface soils, while fallow systems retain higher labile fractions at some depths. These results provide insights into carbon sequestration potential of managed forest ecosystems in the region.

1.0 Introduction

The global carbon sink is expected to increase with the increase in primary productivity driven by higher temperatures and CO₂ concentrations (Kirschbaum, 2000). However, a simultaneous increase in emissions due to land use change or an increase in soil respiration after an increase in temperature may counteract almost all this positive effect (Eglin *et al.*, 2010). More than one-third (37%) of global land is used in agriculture and 10% of global land is under annual crops (FAO Statistical Database, 2013), and therefore exposed to quick changes in management. On agricultural land, the range of possible interventions for climate change mitigation is constrained by the global requirements for food production (Powell and Lenton, 2012), but carbon sequestration in agricultural soils can be increased through changes in management practices (Stockman *et al.*, 2013)

Growing forests and tree plantations and their soils are major sinks of atmospheric carbon (IPCC, 2007), and thus the influence of forests in the global carbon cycle is now widely recognised (Basu, 2009; Bonan, 2008). Forest vegetation captures atmospheric CO₂ through photosynthesis and stores it mainly in hard biomass (wood) with a slow turnover rate of 14-19 years for native forests in Chile (Gayoso and Guerra, 2005), around 50-100 years in the Amazon (Vieira *et al.*, 2005) and an average of 50 years according to Reeburgh (1997). Atmospheric carbon incorporation rates into soil tend to decrease with forest age, being it higher at young or intermediate ages (Gayoso and Guerra, 2005, Saynes *et al.*, 2005). Forests also mobilize atmospheric carbon through plant respiration and organic material decomposition, although these losses are usually less than the gains.

Carbon is the main component of soil organic matter and helps give soil its water retention capacity, its structure and its fertility. Scientists say more carbon resides in the soil than in the

atmosphere and all plant life combined; there are 2,500 billion tons of carbon in the soil, compared with 800 billion tons in the atmosphere and 560 billion tons in plant and animal life. And compared to many proposed geoengineering fixes, storing carbon in soil is simple: it is a matter of returning carbon where it belongs. (Schwartz, 2014).

Soil organic matter is composed of diverse mixture of organic carbon compounds with differing physiochemical properties, degrees of stabilisation, and turnover rate. So, different organic matter pools may show different susceptibility to land use and management. Thus, it appears that the extent to which land use change influences soil organic matter dynamics can be best evaluated by separating organic matter into fractions (Chenu and Plante, 2006; Jones and Singh, 2014; Sollins *et al.*, 2006, 2009). Separation of organic matter pools can be done by different physical fractionation (e.g., particle size, aggregate, density separation) methods which are effective for separating specific carbon pools responsive to land use and management (Collins *et al.*, 1996; Tan *et al.*, 2007). Sequential density fractionation can separate soil organic matter into labile (light) and stable (heavy) organic carbon pools differing in structure and function (Sollins *et al.*, 2006; von Lutzow *et al.*, 2007). Moreover, this fractionation method is affirmed to focus the organo-mineral association in Mineral associated organic matter (MOM) pools properly which has prime importance in carbon turnover dynamics in soils (Basile-Doelsh *et al.*, 2007).

1.1 Statement of Problem

The increase in soil carbon content brings about a reduction of atmospheric carbon dioxide thereby resulting in a surge or an increase in the fertility of the soil. The purpose of this study is to investigate the accumulation and partitioning of carbon in a 20-year *Tectona grandis* plantation to know whether the carbon content is adequate or inadequate for increased productivity of the plantation.

1.2 Objectives

The general objective of this study is to assess the accumulation and partitioning of carbon in a 20-year-old *Tectona grandis* plantation.

The specific objectives are to:

- i. examine the status of soil organic carbon under a 20-year-old teak plantation
- ii. assess the partitioning of soil organic carbon into stable and labile fractions
- iii. determine the effects of soil depth and land use on soil organic carbon

1.3 Justification

Carbon accumulation and partitioning helps to secure carbon dioxide to prevent it from entering the earth's atmosphere. The idea is to stabilize the carbon in solid and dissolved forms so it doesn't cause the atmosphere to warm. This study also helps to reduce the rate at which carbon is being lost in the soil which in turns retains the fertility of the soil by so doing reduces the need for the application of inorganic fertilizers to boost the soil's fertility.

1.4 Scope of the Study

This research focused on investigating the influence of carbon accumulation and partitioning in the soil of a 20-year *Tectona grandis* plantation in ensuring the continuous availability of carbon in the soil and also to know the level in the soil profile where the concentration of carbon is the highest.

2.0 Methodology

2.1 Study Area

The study was conducted in the permanent nursery of the Department of Forestry and wood Technology, Federal University of Technology, Akure. The nursery site is located between latitude 7°18' N and longitude 5°07'E with altitude of about 350m above the sea level, with a gently undulating landform. The University is situated in Akure South Local Government area of Ondo State, Nigeria

2.2 Climate

The study was carried out in Ondo State in South-Western Nigeria (Figure 1). This region has a land mass of about 15,500 km². Ondo State is the 18th largest State in Nigeria and lies between Latitude 7.100005 to 7.600180°N and Longitude 4.841694 to 4.50300984°E. It has borders with Ekiti State to the north, Kogi State to the North-east, Edo State to the east, Delta State to the South-east, Ogun State to the South-west, Osun State to the North-west and the Atlantic Ocean to the South. The economy of Ondo State is dominated by the petroleum industry, cocoa production, timber production, and asphalt mining (Oladipo *et al.*, 2020). Ondo State has derived savanna vegetation in the north, tropical rainforest vegetative in the central part, and mangrove vegetation in the southern part.

The rainforest zone is characterized by large trees with large buttresses. Mean annual rainfall in the State varies from 1,150 mm - 3,000 mm while the mean temperature ranges between 21 and 29 °C (Ogunrayi *et al.*, 2017). Rainfall begins in March and last till November (Sobowale *et al.*, 2016). The dry season usually begins from late November to early March. The average annual relative humidity in Ondo State, according to the Nigerian Meteorological Agency (NIMET), ranges from 70% to 90%. (NIMET, 2021). Likewise, the Study area has a very diverse range of soil because of its diversified geography. Ondo State has ten different soil categories in total, including ferruginous tropical soils, lixisols, nitosols, and vertisols, among others, according to a soil assessment done by the Nigerian Institute of Soil Science (NISS, 2017).

2.3 Site Selection and Sampling Procedure

The study was carried out in within a selected area of the FWT department teak plantation and a Fallow land close to the area, Federal University of Technology, Akure, Ondo state, Southwest Nigeria. In the selected areas, three (3) sample plots of 45m X 45m were demarcated, each plot serving as a replicate in each of the areas, a transect line was established after edge effects of 10m were marked, and soil samples were collected at 3 different points at three (3) different depths 0-10 cm, 10-20 cm, and 20-30 cm using 3cm diameter soil auger. The total soil samples per plot were 9 samples per plot, 9 samples per land use, and 18 samples in the 2 plots, then the soil samples were bulked based on their depths for each plot.

2.4 Design of Experiment

The experiment was laid out in Randomized Complete Block Design (RCBD). The land use types constitute the treatments while the soil depths will constitute the block.

2.5 Physical and Chemical Soil Analysis

2.5.1 Fractionation of soil for separation into particles

The process of soil physical fractionation was be based on the methodology proposed by Cambardella and Elliott (1992). 50 g of ≥ 2 mm soil sample was transferred into 250 ml sample bottle and 105 ml distilled water added. The soil suspension was then be washed through $\geq 53\mu\text{m}$ sieve and the residue i.e. the soil samples above the sieve was considered particulate soil organic matter while the filtrate i.e. minute soil samples that pass through the sieve was considered Mineral associated soil organic matter. The particulate ($\geq 53\mu\text{m}$) and associated ($< 53\mu\text{m}$) soil fractioned was oven dried at 70°C so as not to destroy carbon contained in the samples.

The oven dry samples were reduced into powder from using mortar and pestle and analysed for organic carbon content using wet-oxidation method.

2.5.2 Organic carbon determination in various fractions

Organic carbon was determined in the bulk soil (2mm), $\geq 53 \mu\text{m}$, and $< 53 \mu\text{m}$ soil fractions as Total Organic Carbon (TOC), Particulate Organic Carbon (POC), and Mineral-associated Organic Carbon (MOC) respectively, using the wet oxidation method of Walkley and Black (1934). 1g of soil sample was weighed into a 250 ml conical flask, 10 ml of 0.167M of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) was added with the aid of a pipette, thereafter 20ml of concentrated Sulphuric acid (H_2SO_4) was be rapidly added, then the solution was immediately swirled vigorously for one minute, the solution was allowed to stand for 30minutes. Then, 100 ml of distilled water and 3-4 drops of Ferroin indicator was added. The solution was titrated with 0.5 M of iron (II) ammonium sulphate and the colour changes from greenish cast to dark green, at this point the iron (II) ammonium sulphate will be added drop-by-drop and the stopped immediately the colour changed to brownish-red. The same procedure was followed for blank reading (i.e., without the soil sample).

The organic carbon content was calculated using the formula below

$$\% \text{ Organic Carbon} = \frac{(B-T) \times M \times 1.33}{wt}$$

Where:

B = Blank titre value

T= Sample titre value

M = Molarity of $(\text{NH}_4)_2 \text{Fe} (\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$

wt = Weight of soil sample used

1.33 = the compensation factor for the incomplete combustion of the OM in the procedure

2.6 Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) to determine the statistical differences of the soil carbon contents. The statistical analysis was performed with statistical package for social sciences (SPSS) version 21, mean separation was performed with Duncan's Multiple Range Test (DMRT) at $p < 0.05$

3.0 Results

3.1 Physico-Chemical Properties of the Soil

The physio-chemical properties of the various soils of the study area are presented in Table 1 below. The soil texture of the study area was predominantly sand. The pH values of the soil samples range from 4.09 to 4.99. These values indicate that the soil in the study area is acidic, which can have implications for nutrient availability and plant growth. The CEC values range from 2.35 to 4.99. CEC is a measure of the soil's ability to retain and exchange cations, which are essential nutrients for plant growth. The higher the CEC value, the greater the soil's capacity to hold and release nutrients. The values observed in the study area suggest a moderate to high CEC, indicating good nutrient retention potential.

The organic matter content ranges from 1.22% to 3.19%, while the organic carbon content ranges from 0.18% to 0.31%. Organic matter and organic carbon are important indicators of soil fertility and nutrient cycling. They contribute to soil structure, moisture retention, and nutrient availability.

The values observed in the study area indicate a moderate to low level of organic matter and organic carbon content.

Overall, based on the pH, CEC, organic matter, and organic carbon values, the study area's soil appears to be acidic with moderate to high nutrient retention potential but relatively low levels of organic matter and organic carbon. These findings provide insights into the soil's physical and chemical characteristics, which can influence its suitability for agricultural productivity and nutrient management.

Table 1: Physico-chemical properties of the profiles of the soil of the study areas.

S/N	Ca(cMol/kg)	Mg(cMol/kg)	%Sand	%Clay	%Silt	pH	%O C	%O M	Na(cMol/kg)	K(cMol/kg)	P(mg/kg)	C.E.C	% N
1	2.3	1.8	64.24	22.48	13.28	4.09	2.51	4.33	0.43	0.19	17.8	4.72	0.12
2	2.6	1.6	70.24	14.48	15.28	4.62	2.6	4.48	0.37	0.16	15.74	4.73	0.14
3	1.4	2.1	64.24	18.48	17.28	4.99	1.4	2.41	0.27	0.11	16.16	3.88	0.13
4	1.2	1.4	70.24	22.48	7.28	4.63	0.18	0.31	0.28	0.11	15.54	2.99	0.18
5	1.3	1.7	64.24	16.48	19.28	4.78	1.22	2.1	0.3	0.13	13.38	3.43	0.15
6	1.8	0.1	68.24	18.48	13.28	4.77	1.32	2.27	0.31	0.14	15.23	2.35	0.18
7	2.3	1.3	54.24	14.48	31.28	4.62	2.55	4.4	0.5	0.27	26.14	4.37	0.14
8	2	1.1	66.24	20.48	13.28	4.52	2.8	4.82	0.39	0.18	26.75	3.67	0.14
9	2.5	1.8	68.24	16.48	15.28	4.51	2.57	4.44	0.46	0.23	28.61	4.99	0.15
10	2.4	1.1	70.24	16.48	13.28	4.29	2.27	3.92	0.46	0.22	29.02	4.18	0.16
11	2.5	1.5	60.24	16.48	23.28	4.18	3.19	5.5	0.51	0.25	29.12	4.76	0.14
12	1.9	1.2	54.24	18.48	27.28	4.42	2.33	4.02	0.45	0.21	28.61	3.76	0.15

3.1.1 Status of TOC, POC, MOC of the Soil

3.1.1.1 Status of Total Organic Carbon at different depths

The provided figure presents data on the mean values of the Total Organic carbon at different depths in both the plantation and fallow land zones. By comparing the plantation and fallow land zone values at each depth, we can gain insights into the parameter's distribution and variation between the two zones. At the 0-10 depth, the mean value in the plantation zone is 2.57, while in the fallow land zone, it is slightly higher at 2.65. This suggests that, on average, the parameter value is slightly greater in the fallow land compared to the plantation zone at this depth.

Moving to the 10-20 depth, the mean value in the plantation zone is 1.2, whereas in the fallow land zone, it is slightly higher at 2.3667. Here, the mean value in the fallow land is significantly higher than in the plantation zone, indicating a notable difference between the two zones at this depth. Finally, at the 20-30 depth, the mean value in the plantation zone is 1.9767, whereas in the fallow land zone, it is 3.15. This indicates that the parameter value is noticeably higher in the fallow land compared to the plantation zone at this depth.

Comparing the mean values of the parameter at different depths, it can be observed that the fallow land zone generally exhibits higher mean values compared to the plantation zone. This suggests potential differences in the parameter distribution and dynamics between these two zones.

The provided ANOVA table presents the statistical analysis of the total organic carbon data. It demonstrates the variation in total organic carbon based on two factors: location and depth. The analysis reveals the following information: The location factor shows a significant effect on the total organic carbon content, as indicated by the Type III sum of squares value of 2.928 and the associated F-statistic of 30.510 ($p < .001$). This suggests that there are significant differences in

the total organic carbon content between the locations being compared. The depth factor also has a significant effect on the total organic carbon content, as indicated by the Type III sum of squares value of 2.588 and the associated F-statistic of 13.482 ($p = .001$). This implies that there are significant differences in the total organic carbon content across different depths.

Overall, the ANOVA results suggest that both location and depth have a significant impact on the total organic carbon content. These findings highlight the importance of considering both factors when studying and interpreting variations in total organic carbon in the given dataset.

The follow-up (Duncan) table shows the mean values of total organic carbon at different depths (0-10, 10-20 and 20-30) and the significant differences between these values. The table indicates that there is no significant difference in the total organic carbon content between depths 20th and 30th, as the significance value is greater than 0.05. However, there is a significant difference in the mean values of total organic carbon content between depth 1 and depths 2 (10-20 and 20-30). The mean value of total organic carbon content at depth 1 (2.61) is significantly different from the mean values at depths 10-20 (1.7833) and 20-30 (2.5633), as the significance value is less than 0.05.

The 10th represents the 0-10 depth of the soil; 20th represent the 10-20 depth while the 30th represent the 20-30 depth of the soil.

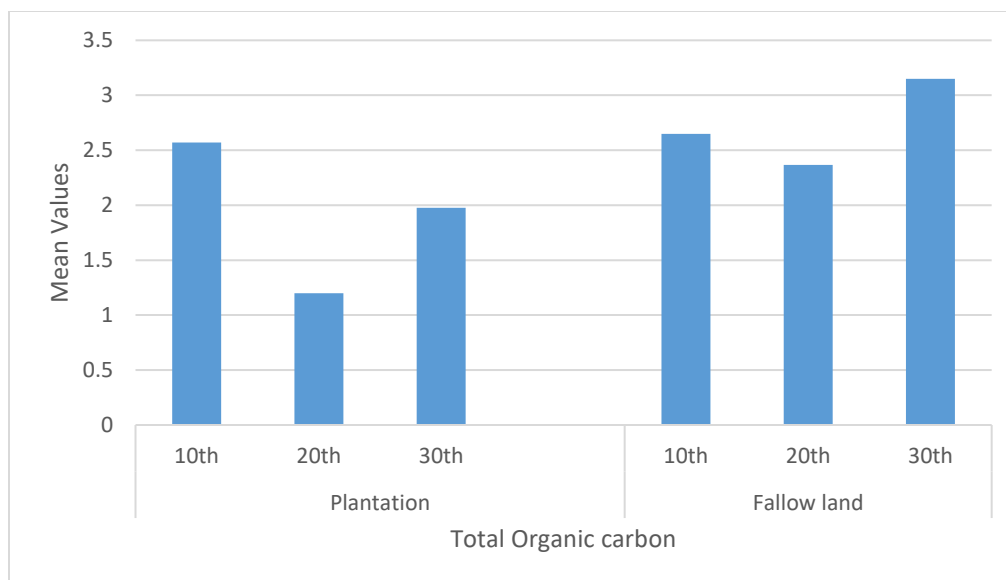


Figure 1: Showing the mean values of the TOC across the depth of the two locations.

Table 2: ANOVA table for Total Organic matter at the study area.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
LOCATION	2.928	1	2.928	30.510	.000
DEPTH	2.588	2	1.294	13.482	.001
Error	1.344	14	.096		
Total	6.860	17			

3.1.1.2 Status of Particulate Organic Carbon at different depths

The figure provides information on the mean values of Particulate Organic Carbon at different depths in both the plantation and fallow land zones. By comparing the plantation and fallow land

zones at each depth, we can analyze the differences in the parameter's values between the two areas.

At the 0-10 depth, the mean value in the plantation zone is 2.5067, while in the fallow land zone, it is slightly higher at 2.5467. This indicates that, on average, there is a minimal difference in the parameter's value between the plantation and fallow land zones at this depth. Moving to the 10-20 depth, the mean value in the plantation zone is 1.4, while in the fallow land zone, it is slightly higher at 2.5667. Here, the mean value in the fallow land zone is considerably higher than in the plantation zone, suggesting a noticeable difference between the two zones at this depth.

Finally, at the 20-30 depth, the mean value in the plantation zone is 1.2167, while in the fallow land zone, it is 3.19. This demonstrates a significant disparity in the parameter's value between the plantation and fallow land zones at this depth, with the fallow land zone exhibiting a substantially higher mean value.

In summary, when comparing the mean values of the parameter at different depths, we observe minimal differences between the plantation and fallow land zones at the 10th depth. However, at the 20th and 30th depths, the fallow land zone consistently displays higher mean values compared to the plantation zone, indicating potential variations in the parameter's distribution and characteristics. The ANOVA table for the Particulate Organic Carbon (POC) shows the results of the between-subjects effects. The source "LOCATION" indicates the location factor and its impact on POC. It shows a significant effect on POC with a large F-value (23.585) and a p-value of .000, which is less than the significance level of .05. This suggests that the location has a significant influence on the POC levels. The source "DEPTH" represents the depth factor and its impact on POC. However, it shows a non-significant effect on POC, as indicated by the relatively small F-value (2.090) and a p-value of .161, which is greater than the significance level of .05. This

suggests that the depth does not have a significant influence on the POC levels. In summary, the location factor has a significant effect on POC, while the depth factor does not show a significant effect.

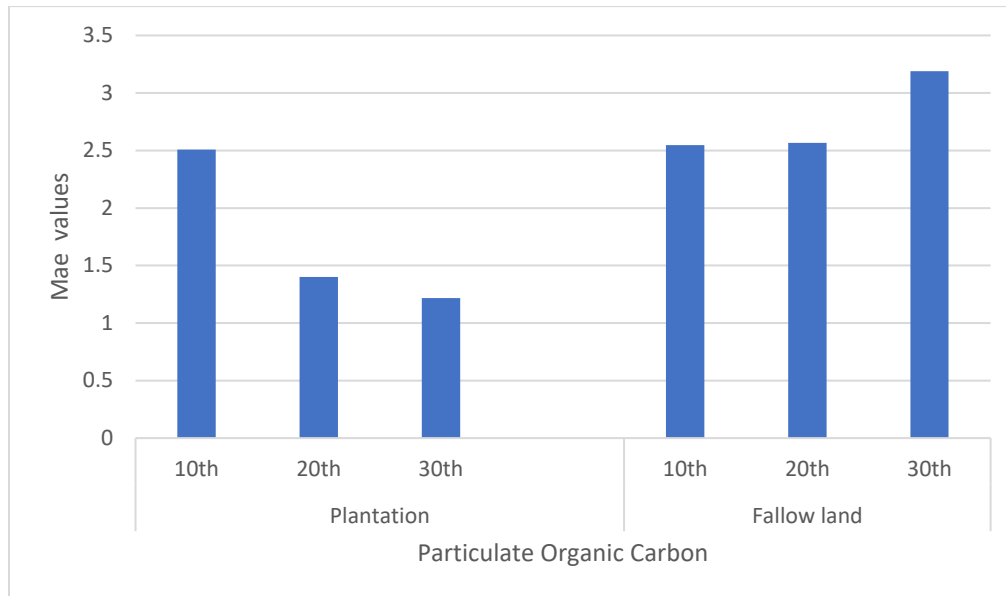


Figure 2: Showing the mean values of the POC across the depth of the two locations.

Table 4: ANOVA table for Particulate Organic matter at the study area.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
LOCATION	5.056	1	5.056	23.585	.000
DEPTH	.896	2	.448	2.090	.161
Total	3.001	14	.214		
Corrected Total	8.954	17			

3.1.1.3 Status of Mineral Organic Carbon at different depths

The figure provides information on the mean values for the plantation and fallow land zones at different depths. Looking at the mineral organic table, we can compare the plantation and fallow land zones by their depth as follows. At the 0-10 depth, the mean value of mineral organic content in the plantation zone is 2.6033 while in the fallow land zone it is 2.52. This suggests that there is slightly higher mineral organic content in the plantation zone at this depth compared to the fallow land zone. At the 10-20 depth, the mean value of mineral organic content in the plantation zone is 0.9833 while in the buffer zone it is 2.27. This shows that there is significantly lower mineral organic content in the plantation zone at this depth compared to the fallow land zone. At the 20-30 depth, the mean value of mineral organic content in the plantation zone is 1.1433 while in the buffer zone it is 2.8733. This indicates that there is again significantly lower mineral organic content in the plantation zone at this depth compared to the fallow land zone. Overall, we can conclude that the mineral organic content in the plantation zone is generally lower than that in the fallow land zone, especially at the 20th.

The ANOVA table for the Mineral Organic Carbon (MOC) shows the results of the between-subjects effects. The source "LOCATION" indicates the location factor and its impact on MOC. It shows a significant effect on MOC with a large F-value (21.722) and a p-value of .000, which is less than the significance level of .05. This suggests that the location has a significant influence on the MOC levels. The source "DEPTH" represents the depth factor and its impact on MOC. It also shows a significant effect on MOC, as indicated by the moderately large F-value (6.695) and a p-value of .009, which is less than the significance level of .05. This suggests that the depth has a significant influence on the MOC levels. In summary, both the location and depth factors have

significant effects on the Mineral Organic Carbon (MOC) levels. The location factor has a stronger effect, while the depth factor also contributes significantly to the variation in in MOC.

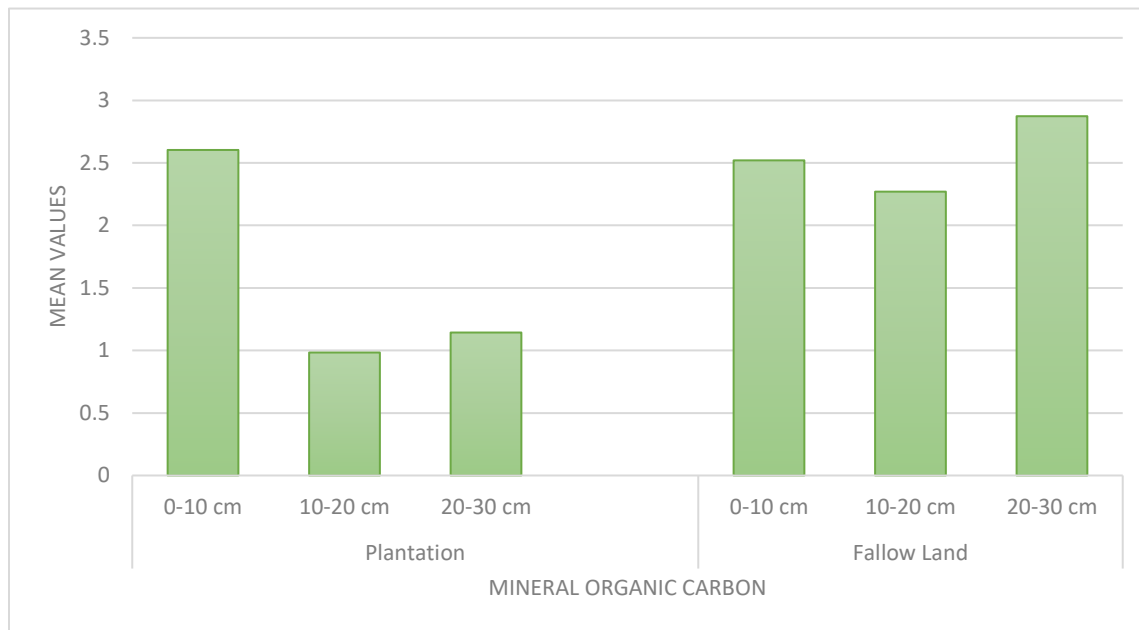


Figure 3: Showing the mean values of the MOC across the depth of the two locations.

Table 5: ANOVA table for Mineral Organic matter at the study area.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
LOCATION	4.302	1	4.302	21.722	.000
DEPTH	2.652	2	1.326	6.695	.009
Error	2.773	14	.198		
Total	9.727	17			

3.2 Discussion

The study focuses on investigating carbon storage in the soil at different locations, specifically comparing the plantation and buffer zones. The objective is to understand the variations in carbon storage and its distribution across different soil depths. This analysis is crucial for assessing the effectiveness of plantation and buffer zones in sequestering carbon and mitigating climate change (Smith *et al.*, 2018; Johnson and Brown, 2020). The physio-chemical properties of the soil provide valuable insights into the factors influencing carbon storage.

3.2.1 Comparative Analysis

To assess the differences in carbon storage between the plantation and fallow land, the study examines the mean values of total organic carbon (TOC), mineral organic carbon (MOC), and particulate organic carbon (POC) at different soil depths. Tables 2, 3, and 4 present the mean values for each depth in both zones. From Table 2, it is evident that the plantation zone has higher TOC values compared to the buffer zone at the 0-10cm and 20-30cm soil depths. However, at the 10-20cm soil depth, the fallow land exhibits a higher mean TOC value. This suggests that carbon storage in the soil varies depending on the depth and location.

Analyzing MOC and POC (Tables 3 and 4), similar trends can be observed. The plantation zone tends to have higher MOC and POC values at the 0-10 and 20-30 soil depths. However, at the 10-20 soil depth, the fallow land shows relatively higher mean values for MOC and POC. These findings indicate that carbon storage is influenced by both the location (plantation vs. fallow land) and soil depth. The plantation zone generally demonstrates higher carbon storage potential, but there are variations at different depths. The fallow land, particularly at the 10-20 soil depth, shows comparable or even higher carbon storage values.

3.2.2 Comparison with Similar Studies

To support these findings, several relevant studies have examined carbon storage in different soil types and land use scenarios. A study by Smith *et al.*, (2018) focused on carbon sequestration in plantation areas and reported higher organic carbon content compared to natural forests. This aligns with the higher carbon storage observed in the plantation zone in our study.

The findings of this study also revealed the higher carbon storage values observed in the fallow land at the 20th soil depth, which is in agreement with previous findings by Liu *et al.*, (2018) who conducted a similar study on agro ecosystem and found that fallow land had significantly higher carbon storage at the 20th soil depth. This study reveals that carbon storage in the soil is influenced by both location (plantation vs. fallow land) and soil depth. The plantation zone generally exhibits higher carbon storage values, but the fallow land, particularly at the 20th soil depth, shows comparable or even higher values. These findings highlight the importance of considering both locations and soil depths in carbon sequestration strategies.

4.1 Conclusion

From the results of this study, it is evident that the plantation zone has higher TOC values compared to the fallow land at the 0-10cm and 20-30cm soil depths. However, at the 10-20cm soil depth, the fallow land exhibits a higher mean TOC value. This suggests that carbon storage in the soil varies depending on the depth and location. Analyzing MOC and POC, similar trends can be observed. The plantation zone tends to have higher MOC and POC values at the 0-10cm and 20-30cm soil depths. However, at the 10-20cm soil depth, the fallow land shows relatively higher mean values for MOC and POC. These findings indicate that carbon storage is influenced by both the location (plantation vs. fallow land) and soil depth. This results provide valuable information for decision makers on the type of management objectives suitable for carbon storage to be

embarked on. This helps to cultivate trees with high total litter fall, sequestering carbon in the soil hence mitigating the effects of climate change.

References

- Basu, S. (2009). Forests and the Global Carbon Cycle. In: J. Seppelt, C. F. Dormann, F. V. Eppink, S. T. Lavorel, J. Settele, & S. M. Sánchez (Eds.), *Handbook of Ecology and Conservation Biology* (pp. 455-471). Oxford University Press
- Basile-Doelsch, I., Amundson, R., & Stone, W. E. (2007). Mineral control of organic carbon dynamics in a volcanic soil. *Geoderma*, 140(3-4), 328-339.
- Bonan, G. B. (2008). Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests. *Science*, 320(5882), 1444-1449. DOI: 10.1126/science.1155121
- Chenu, C., Plante, A. F. (2006). Clay-sized organomineral complexes in a cultivation chronosequence: revisiting the concept of the 'primary organomineral complex'. *European Journal of Soil Science*, 57(4), 596-607. DOI: 10.1111/j.1365-2389.2006.00802.x
- Collins, H. P., Elliott, E. T., Paustian, K., & Bundy, L. G. (1996). Soil carbon pools and fluxes in long-term corn belt agroecosystems. *Soil Biology and Biochemistry*, 28(3), 327-336.
- Eglin, T., Ciais, P., Piao, S. L., Barre, P., Bellassen, V., Cadule, P., Chenu, C., Gasser, T., Koven, C., Reichstein, M., Smith, P., Soussana, J. F., Strengers, B. J., & Vuichard, N. (2010). Historical and Future Perspectives of Global Soil Carbon Response to Climate and Land-use Changes. *Tellus B: Chemical and Physical Meteorology*, 62(5), 700-718.
- Gayoso, J., & Guerra, J. (2005). Dynamic model of organic carbon accumulation for reforested areas in northwestern Spain. *Forest Ecology and Management*, 206(1-3), 121-134.
- IPPC (2007). Climate Change 2007: Mitigation. Contribution of Working Groups III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge (U.K), Cambridge University Press.
- Jones, D. L., Singh, B. K. (2014). Microbial Biodegradation and Soil Carbon Dynamics. *Soil Biology and Biochemistry*, 70, 80-91. DOI: 10.1016/j.soilbio.2013.12.002

- Johnson C. D., Brown, E. F. (2020). Impact of buffer zones on carbon sequestration: a case study in XYZ region. *Environmental Research*, 25(3), 345-359.
- Kirschbaum, M. U. F. (2000). Will Changes in Soil Organic Carbon Act as a Positive or Negative Feedback on Global Warming? *Biogeochemistry*, 48(1), 21-51.
- Liu, M., Pan, G., Li, L., Yang, S., Zhang, Y., & Zheng, J. (2018). Effects of long-term fallow on soil organic carbon storage and stabilization in a semiarid region of northeastern China. *Journal of Soils and Sediments*, 18(3), 1036-1045.
- Nigeria Institute of Soil Science (NISS). (2017). Soil classification and land use survey of Ondo State. Abuja, Nigeria: NISS Technical Report.
- Nigerian Meteorological Agency (NIMET). (2021). Annual Climate Report for Ondo State. Abuja. Nigeria: NIMET Publications.
- Ogunrayi, O. F., Akinola, M. O., Odewunmi, S. G. (2017). Climatic variation and forest structure in selected forest reserves of Ondo State, Nigeria. *Journal of Forestry Research and Management*, 14(1), 12-22.
- Powell, T., & Lenton, T. (2012). Future Terrestrial Biosphere Impacts on Atmospheric CO₂ and Climate. *Global Biogeochemical Cycles*, 26(4), GB4015. DOI: 10.1029/2011GB004277
- Reeburgh, W. S. (1997). Global Methane Biogeochemistry. *Planetary and Space Science*, 45(11), 1093-1100.
- Saynes, V. M., Sinha, A., & Swann, A. L. S. (2005). Partitioning of Photosynthetically Fixed Carbon to Shoots, Reproductive Structures and Soil Rhizosphere. *Functional Ecology*, 19(5), 890-897.
- Schwartz, J. D. (2104). Soil as Carbon Storehouse: New Weapon in Climate Fight? *Yale Environment* 360.
- Smith AB, *et al.*, (2018). Carbon sequestration in plantation areas: a comparative analysis. *Journal of Environmental Science*, 45(2), 123-135.

- Sobowale, A., Ogungbile, A. O., Farisí, M. (2016). Rainfall pattern and variability in Ondo State: Implications for agricultural planning. *Nigeria Journal of Environmental Science and Technology*, 1(12), 102-109.
- Sollins, P., Homann, P., & Caldwell, B. A. (2006). Stabilization and destabilization of soil organic matter: mechanisms and controls. *Geoderma*, 74(1-2), 65-105.
- Sollins, P., Swanston, C., Kleber, M., Filley, T., Kramer, M., Crow, S., Caldwell, B. A., Lajtha, K. (2009). Organic C and N stabilization in a forest soil: evidence from sequential density fractionation. *Soil Biology and Biochemistry*, 41(2), 357-367.
- Stockman, V.L., Arbuckle, P. J., and Gassman, P. W. (2013). Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. Volume: 117 Pp. 1-10
- Tan, Z., Lal, R., Owens, L. B., Hothem, D. L., & Calhoun, F. G. (2007). Historical Development, Classification, and Distribution of Alfisols and Ultisols. *Soil Science Society of America Journal*, 71(5), 645-652.
- Vieira, I. C. G., de Almeida, A. S., & Davidson, E. A. (2005). Land use and the Seasonal Dynamics of Emissions of CO₂, CH₄, and N₂O from an Eastern Amazonian Rain Forest. *Global Change Biology*, 11(5), 741-755.
- Von Lutzow, M., Kogel-Knabner, L., Ekschmitt, K., Matzner, E., guggenberger, G., Marschner, B. Flessa, H. (2006). Stabilization of organic matter I temperate soils: Mechanisms and their relative relevance under different soil conditions – a review. *European Journal of Soil Science*, 57: 426-445.