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Impact of Forest Degradation on Soil Carbon in Akure Forest Reserve in Ondo State, Nigeria

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Abstract This study was conducted to investigate the impact of forest degradation on the status of total, particulate and mineral-associated soil organic carbon content. This study was carried out in three selected sites based on the level of degradation (undisturbed, partly degraded and degraded forest parts) in Akure Forest Reserve which is geographically located in a humid rainforest zone of Akure South local government area of Ondo State, Nigeria. Four sampling plots of 25m x 25m in dimension were laid in alternate positions along the transect cut through each of the selected forest sites. Soil core samples were collected at 5 different points along the diagonal of each plot at the depths of 0-10cm, 10-20cm and 20-30cm using a soil auger. At the end of this study, it was found that total organic carbon (TOC) was highest in soil under partially degraded forest and the lowest in soil from undisturbed forest. Particulate organic carbon (POC) was highest in partially degraded forest (9.71) and lowest in undisturbed forest (7.89). In contrast, soil under undisturbed forest had the highest mineral-associated organic carbon (14.32), while soil under degraded forest had the lowest (13.21). The results of the analysis show a significant difference at $P>0.05$ among the different forest degradation type and across soil depths (0-10 cm > 10-20 cm > 20-30 cm). Soil under partially degraded forest stored significant organic carbon due to litter deposition from illegally felled trees, enhancing carbon levels. This soil also shows improved physicochemical properties. The stable fraction of organic carbon (MOC) was highest in soil under undisturbed forest, while particulate organic carbon (POC) peaks in soil under partially degraded forest. The study also assessed soil physical and chemical properties, finding that degradation led to increased bulk density and reduced porosity, potentially affecting water retention and root penetration. pH levels were slightly lower in degraded areas, while available phosphorus and total nitrogen showed marked decreases. These findings highlight the significant impact of forest degradation on soil carbon stocks and overall soil health, emphasizing the importance of forest conservation for maintaining ecosystem services and mitigating climate change.

Keywords: *Forest degradation, soil organic carbon, carbon sequestration, tropical forest ecosystems, soil properties*

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1. Introduction

Nigeria's population is currently over 140 million, with the majority of people living in rural areas. Poverty, hunger, ignorance, diseases, a lack of basic social amenities, and limited property holdings characterize rural settlements [1]. The rural people rely heavily on the forest for everyday subsistence and livelihood because of its location and the many commodities and services it can provide "for free” [2]. The increase in human population, demand for more agricultural land for food production, urbanization, and the expansion of land use activities have all put pressure on the tropical forest, resulting in a progressive shift in tree composition, cover, and structure [1]. Degradation of the forest reduces the forest's ability to act as an environmental regulator. Natural regeneration, soil and water conservation, and carbon dynamics are all affected. The influence of forest degradation on carbon dynamics is still poorly understood. Estimating variations in the forest soil carbon pool is essential for understanding carbon storage linked with different levels of degradation in different forest types [3].

Humans have been interested in soil quality and functionality since the birth of civilization (Brevik and Sauer, 2015). Soils have become one of the world's most vulnerable resources in the face of climate change, land degradation, and biodiversity loss [4]. Soil organic carbon (SOC) is the primary component of soil organic matter (SOM) and is used to assess soil health. SOC is essential for its contributions to food production, climate change mitigation and adaptation, and attaining the Sustainable Development Goals (SDGs). Soils contain almost twice as much carbon as the atmosphere and two and a half times as much carbon as all living organisms [5]. Soils are remarkable in their ability to sequester and retain huge amounts of carbon (C). Soil organic carbon is one component of the much wider global carbon cycle, which includes carbon cycling through the soil, vegetation, ocean, and atmosphere [6]. Soils contain the most terrestrial carbon store and play an important role in global carbon balance by regulating dynamic bio-geochemical processes and the exchange of greenhouse gases (GHG) with the atmosphere [7]. The majority of soil carbon is organic carbon generated from living creatures that have been preserved in deeper soil layers below 20 cm for hundreds to thousands of years [7,8]. The loss of even relatively small amounts of this soil organic carbon could exacerbate global climate change by releasing substantial amounts of greenhouse gases, such as nitrous oxide (N2O) and methane (CH4) to the atmosphere [9]. Soil is a complex mixture of minerals, organic matter, water, air, and living organisms, as well as environmental aspects like climate, parent materials, relief, organisms, and time [10]. Soil holds three times the amount of carbon (C) found in the atmosphere and 3.8 times the amount of carbon (C) found in the biotic pool [11]. Soils have the ability to act as an effective carbon sink in the atmosphere [12]. Soil carbon sequestration is the process of capturing atmospheric carbon dioxide and storing it in soil as crop residue and other organic substances [13]. This transformation has the potential to lower CO2 levels in the atmosphere, lowering global warming and mitigating climate change.

Soil biodiversity increases the reservoir of organic carbon in the soil. In the absence of additional circumstances, high biodiversity ecosystems store more carbon in soil and biota than low biodiversity ecosystems [14]. Carbon sequestration from the atmosphere has the potential to benefit both the environment and the economy. Environmental benefits include CO2 removal from the atmosphere, enhanced soil quality, and increased biodiversity [15]. As a result, soils play an important role in maintaining a balanced global carbon cycle. Soils store around 1500 Pg of carbon in the form of organic matter globally, which is roughly double the atmospheric carbon pool [16]. Consequently, the soil organic-carbon pool and its loss through emissions have a significant influence on the CO2 concentration in the atmosphere, and thus on global climate change driven by the greenhouse effect [17].

Land use and soil management practices can have a significant impact on soil carbon dynamics and carbon flux from the soil (Smith, 2008). The carbon content of soil varies substantially throughout space, depending on land use and soil depth [18]. Land use and vegetation type influence soil erosion and carbon dynamics, which affect SOC concentration, CO2 flow, and dissolved organic carbon (DOC) leaching from soil. Land use changes and management strategies have a significant impact on the dynamics of soil aggregation and SOC. These alterations may have an impact on soil structural stability, SOC storage, and nutrient turnover [19]. Many studies have found that converting forest land to other land uses, such as agricultural ecosystems, has an impact on soil attributes, particularly soil organic carbon concentration and stock. The extent and nature of soil changes after forest degradation may be influenced by soil type and extent of degradation. Therefore, the extent and nature of the changes in the properties of a degraded and non-degraded soil of forest reserves in Ondo State was evaluated.

A significant amount of forest conversion is due to agricultural land usage [1]. Agricultural operations can alter the chemical, physical, or biological aspects of the soil. Cultivation, tillage, weeding, deep ploughing, fertilizer treatments, liming, draining, irrigation, and biocide application on cultivated crops can all have an impact on soil parameters [10]. Deforestation has been the major issue in Nigeria’s forestry sector [20]. However, there are suggestions that forest conservation measures may lead to soil conservation as well as improvement in soil properties [21]. In addition, anthropogenic activities continue to increase, resulting in disturbances in the earth’s ecosystem to produce food and fiber, which will place greater demand on soils to supply essential nutrients. Intensive and continuous cropping for enhanced crop yield removes substantial amounts of nutrients from soil [1]. Land without proper management results in a decline in soil physical, chemical, and biological properties, which aggravates crop yield reduction and food insecurity [22].

According to [23], forests play a crucial role in carbon sequestration and maintaining ecosystem health. However, many forest reserves in Ondo State, Nigeria, are facing increasing degradation due to factors such as deforestation, illegal logging, farmland expansion, and urbanization [24]. This degradation has the potential to significantly impact the soil carbon levels within these forests. Despite the recognized importance of soil carbon for both climate change mitigation and ecosystem sustainability, there is a notable lack of comprehensive studies that assess the specific impact of forest degradation on soil carbon content in Ondo State. This research aims to address this critical knowledge gap and provide insights into the extent and consequences of forest degradation on soil carbon in Akure Forest Reserve in Ondo State. By doing so, it seeks to compare degraded and non-degraded parts of a forest reserve, inform conservation efforts, and sustainable land management practices, while contributing to the broader understanding of the consequences of forest degradation for global carbon cycles. Therefore, the objectives of the study are to assess and evaluate the impact of forest degradation on soil carbon levels in Akure Forest Reserve in Ondo State, Nigeria.

2. Materials and Methods

2.1. Study Area

The study was carried out in Akure Forest Reserve. Akure Forest Reserve is geographically located in a humid rainforest zone of Akure South Local Government Area of Ondo State, Nigeria. It lies between latitudes 7°10’0’’ and 7°27’30’’N of the Equator and longitudes 4°52’30’’ and 5°12’30’’E of the Greenwich Meridian with a total land area cover of 6993 ha. It shares border with Osun State in the Northeast [25]. The climate of the study area is characterized by dry season which lasts from November to March while the wet season commences from April and ends in October with the highest rainfall records between July and August. Average annual temperature is 27°C. The mean annual rainfall is about 4000mm with relative humidity of 80–85% annually [26]. The soils are predominantly ferruginous tropical soils and are typical of the variety found in the intensively weathered areas of basement complex formations in the rainforest zone of southwest in Nigeria [27]. It is slightly neutral; pH of 6.7–7.3 and sandy-loam in nature. The soils are of high agricultural value for both tree and arable crops.

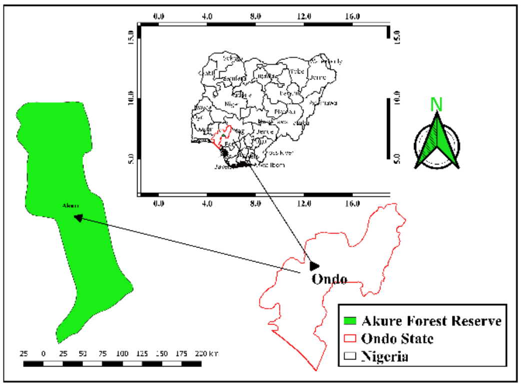

Figure 2.1. Map of Akure forest reserve

2.2. Soil Sample Collection

The laying of plot for soil sample collection was carried out using the systematic line transects. Two parallel transects of 200m distance apart was used in each of the study sites. 50 m offset was laid in each of the study sites, thereafter four sample plots of 25 m x 25 m each was alternately laid on each transect to represent one hectare. On each sample plot, soil core samples were collected at 5 different points along the diagonal of each plot at three different depths of 0-10cm, 10-20cm and 20-30cm using a soil auger. Samples from each plot at each depth was bulked separately to form composite soil samples. Composite soil samples were well labelled and stored in polythene bags which was taken to the Department of Forestry and Wood Technology laboratory for analysis. The collected soil samples from each categorized area were air-dried at room temperature 32^{0}C, gently crushed to reduce heterogeneity and passed through a 2mm sieve to obtain fine earth separates.

2.3. Soil Analyses

A representation of each of the soil samples collected was separated into particulate and mineral sized fractions to determine, analyzed organic carbon, particle size distributions, pH, available phosphorus, total nitrogen.

2.3.1. Fractionation of Soil for Separation Into Particulate and Mineral Size Fractions

The physical fractionation of the soil samples collected was done based on the method proposed by [28]. 50 g of ≥2 mm soil sample was transferred into a 250 ml sample bottle and 105 ml distilled water was added to it. The soil suspension was washed through a ≥53 µm sieve and the residue (the soil samples that are above the sieve) was considered Particulate soil organic matter while the filtrate (minute soil samples that passes through the sieve) was considered Mineral associated soil organic matter. The particulate (≥ 53µm) and mineral associated (< 53µm) soil fractions was first air-dried and then oven-dried at 40C in order to avoid destroying any carbon in the samples. The oven-dried samples were ground into powder form using mortar and pestle, and then analyzed for organic carbon content using the wet-oxidation method.

2.3.2. Organic Carbon Determination

The determination of Organic Carbon (Equation 1) in the bulk soil (2mm), ≥53µm, and <53µm soil fractions as Total Organic Carbon (TOC), Particulate Organic Carbon (POC), and Mineral-associated Organic Carbon (MOC) respectively, was carried out using wet oxidation method [29]. Each representative sample was crushed with pestle and mortar and then passed through 0.5mm mesh sieve. 1g was weighed into a 250ml flask and 10ml of 0.167M potassium dichromate (K2Cr2O7) was added using a pipette, and swirled gently to disperse the soil. 20ml of concentrated sulphuric acid(H2SO4) was added and swirled vigorously for a minute and left to stand for 30 minutes before 100ml distilled water was added. Three drops of phenonthroline indicators were added and titrated against 0.5M of Iron (II) ammonium sulphate. As the end point approached, the solution will take on a greenish cast and then changed to a dark green. At this point, the Iron (II) ammonium sulphate was added drop by drop until the color changed sharply to brownish-red (Maroon color). The same procedure was followed for blank reading (i.e. without soil sample).

The organic carbon content was calculated using the formula below:

$$\%\text{Organic Carbon} = \frac{(B - T)\,xMx1.33}{wt} \qquad \text{Equation 1}$$

Where:
B = Blank titre value
T = Sample titre value
M = Molarity of (NH4)2 FE(SO4)2 6H2O
wt = Weight of soil sample used
1.33 = the compensation factor for the incomplete combustion of the OM in the procedure

2.3.3. Estimation of Soil Organic Carbon Pool

Soil organic carbon (SOC) pool was determined using soil samples collected at 0-10, 10-20, and 20-30 cm depth, calculated using the following equation.
C – Pool = d x BD x SOC
Where, C-pool = soil carbon pool in (t/ha),
D = sampling depth (cm)
BD = bulk density (g/m^3)
SOC = soil organic carbon (%)

2.3.4. Particles Size Analysis

The analysis was carried out using Bouyoucos hydrometer method. 50g (< 2mm) of each air-dried soil samples were treated with 50ml of 5% calgon (Sodium hexametaphosphate) along with 100ml of distilled water in clean plastic bottles. The samples were stirred with multi-mix machine for 15minutes. The suspension was transferred to the glass cylinders and topped with distilled water to 1,000ml mark. The top of the cylinder was covered and inverted several times to ensure complete suspension. The cylinder will then be placed on a table and the hydrometer was inserted immediately and the reading was taken after 40 seconds. After the hydrometer reading, the temperature was taken using a thermometer. The second reading was then be taken after 2 hours. Also, the temperature of the suspension was taken after the second hydrometer reading. The first reading measured the percentage of silt and clay in suspension. The second reading indicated the percentage of total clay in the suspension. Thus, the percentage composition of sand, silt and clay was calculated using the formula below (Equation 2 - 5).

$$(clay + silt)\% = \frac{40 \text{ seconds hydrometer reading} - \text{correction for temperature} \times 100}{\text{Oven dry mass of sample}}$$

Equation 2

$$(clay)\% = \frac{2 \text{ hours hydrometer reading} - \text{correction for temperature} \times 100}{\text{Oven dry mass of sample}}$$

Equation 3

(Silt) % = (Equation 2) – (Equation 3) Equation 4

$$(Sand)\% = \frac{\text{oven dry weight of particles retained on } 45\mu\text{m sieve} \times 100}{\text{Oven dry mass of sample}}$$

Equation 5

2.3.5. PH of the Soil

Measurement of soil pH using a potentiometer to determine the degree of acidity or alkalinity in soils was carried out. The pH of the soil samples was determined using a glass electrode pH meter. A 1:1 soil to water ratio suspension was prepared by measuring 20g (< 2mm) of air-dried soil into a beaker followed by adding 20ml of distilled water and stirred with a glass rod occasionally. The electrode was inserted in the partly settled solution after allowing the suspension to stand for 30 seconds and the pH was measured [30].

2.3.6. Soil Bulk Density Determination

Soil bulk density was determined using a 2.5 cm diameter cylindrical core sampler. The cylinder was hammered into the soil to collect bulk density samples which was placed in the oven at 650C until a constant weight was attained. The weight of empty cylinder, diameter, radius and height will also be determined to get the volume.

Bulk density calculated as: $$\frac{Weight\ of\ Oven-dry\ soil}{Volume\ of\ Oven-dry\ soil}$$

2.4. Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) using Randomized Complete Block Design (RCBD) to determine statistical differences of selected soil properties. The statistical analysis was performed using GraphPad prism (Version.10) at $p<0.05$. (The choice of GraphPad Prism (Version. 10) for statistical analysis was based on its user-friendly interface, precision, and suitability for handling experimental designs like Randomized Complete Block Design (RCBD). It is highly effective for performing ANOVA, detecting subtle statistical differences, and visualizing data through clear, high-quality graphs. The software's compatibility with complex datasets and its support for rigorous testing at $p<0.05$ ensures credible and reproducible results. Its widespread acceptance in scientific research further reinforces its reliability for this study)

3. Results and Discussion

3.1. Effect of Forest Degradation on Soil Organic Carbon in Akure Forest Reserve

Table 1 indicated that soil degradation alters the particle size distribution of the soil, though the soil texture generally remained within similar categories (sandy clay loam, clay loam, and loam) across degradation levels. Undisturbed forest soils had higher silt content, particularly in deeper layers (20-30 cm), whereas degraded soils exhibited more clay content, notably at the 20-30 cm depth. Forest degradation typically causes soil compaction and loss of structure due to the removal of vegetation, which exacerbates soil erosion and increases clay content. The texture changes observed align with findings by [30], who noted that forest degradation contributes to increased clay content, particularly in deeper soil layers, due to the higher erosion of finer particles. The bulk density also varied significantly with degradation levels, with undisturbed soil having the lowest values, particularly in the upper 0-10 cm depth (0.746 g/cm³). The bulk density increased progressively in partially degraded (0.873 g/cm³) and degraded soils (0.916 g/cm³). Increased bulk density is a sign of soil compaction, which typically follows vegetation removal [31]. High bulk density is also associated with reduced pore space and infiltration rates, which can hinder plant root growth and water percolation, further exacerbating degradation effects [32]. The pH of the soil increased significantly with forest degradation, as indicated by the values in Table 1. Undisturbed soils exhibited more acidic conditions (pH 4.24-4.48), while degraded soils had relatively neutral to mildly acidic pH levels (pH 6.03-6.25). Increased pH in degraded areas can be attributed to the reduction in organic matter and litter cover, which otherwise would help buffer soil acidity. Organic matter decomposition typically releases organic acids that lower pH in undisturbed systems [33]. This shift to higher pH with degradation has been observed in various studies, such as [34], who found that deforestation led to reduced organic matter and increased soil pH in tropical forests.

From the study's results, it is evident that forest degradation, particularly due to deforestation and logging activities, alters the soil's physical and chemical properties. Degraded soils exhibited increased bulk density and reduced porosity, which can be directly attributed to the removal of vegetation cover and increased exposure to rainfall, leading to soil compaction. These changes disrupt the natural water retention capacity of the soil, making it more prone to erosion, especially during heavy rainfall, and diminishing its ability to sequester carbon. For example, undisturbed soils exhibited lower bulk density and higher organic carbon pools compared to degraded soils, which had a more compact structure. The increased bulk density in degraded soils, coupled with altered soil texture (e.g., increased clay content), connote that higher rainfall intensities may wash away finer particles, leaving heavier, less fertile soil behind, this corroborated with the assertion of [35] who noted that less fertile soil can be caused by washing of finer particles during heavy rains. Also, these soils exhibit lower pH levels, indicating the loss of organic material that normally buffers the acidity in the soil. Moreover, the study found that partially degraded soils, where illegal logging activities had occurred, contained higher amounts of particulate organic carbon (POC) due to the accumulation of organic residues such as tree bark and leaves left behind after logging. This means that, while forest degradation negatively impacts carbon sequestration, partial degradation could still retain some carbon if the area is not subject to intense agricultural use. This is an important insight when considering forest management strategies and the potential for regeneration in partially degraded areas. The impact of temperature and precipitation on these dynamics cannot be overstated. According to [36]. increased temperatures could further exacerbate the degradation of soils by accelerating organic matter decomposition and reducing the moisture content of soils, which directly affects plant growth and carbon sequestration. Similarly, erratic rainfall patterns, particularly intense rainfall, can accelerate soil erosion, leaching of nutrients, and disruption of the carbon cycle, making soils less effective in carbon storage as stated by [37].

The organic matter content was highest in the partially degraded soils across all depths, with values of 4.54%, 2.32%, and 1.55% for the 0-10 cm, 10-20 cm, and 20-30 cm depths, respectively. The undisturbed soils had the lowest organic matter content at 0-10 cm (3.58%), 10-20 cm (1.25%), and 20-30 cm (0.88%) as seen in Table 2. The results connote that soil degradation affects the distribution of organic matter. Partially degraded soils had a higher content likely due to the accumulation of forest litter and organic residues from illicit logging activities, which led to a greater organic matter deposit compared to undisturbed soils. This supports findings by [38], which means that degradation processes such as deforestation decrease soil fertility, yet, partially degraded soils can still retain nutrients if not subjected to intense agricultural use. The accumulation of organic residues on these soils plays a key role in maintaining their organic matter content.

At the 0-10 cm depth, the partially degraded soils had the highest soil organic carbon pool (SOCP) value (22.91 t/ha), followed by the degraded soils (21.15 t/ha). Undisturbed soils had the lowest SOCP (15.56 t/ha). The same trend was observed at the 10-20 cm and 20-30 cm depths in Table 3. These results indicate that forest degradation increases the SOCP in the upper soil layers, especially in partially degraded soils. According to [39], deforestation significantly impacts the carbon stock of soils, leading to increased organic carbon in partially degraded soils, likely due to decomposition of forest litter and logging residues. This explains the higher SOCP in these soils compared to undisturbed soils.

The results in Table 4 indicated that, partially degraded soils had the highest total organic carbon (TOC) values at all depths (10.54%, 5.38%, 0.90% for 0-10 cm, 10-20 cm, and 20-30 cm, respectively), while undisturbed soils recorded the lowest values (8.30%, 2.90%, 0.51% at the same depths). This result highlights how partial degradation leads to higher TOC content, attributed to the forest litter and organic residues left behind during logging activities. The findings align with [40], who noted that partially degraded soils tend to retain more organic carbon than degraded soil due to minimal disturbance in the ecosystem, unlike undisturbed soils where organic matter decays slowly under the forest canopy.

3.2. Partitioning of Soil Organic Carbon into Stable and Labile Fractions in Akure Forest Reserve

At the 0-10 cm depth, partially degraded soils had the highest particulate organic carbon (POC) content (9.71%), followed by degraded soils (9.18%) and undisturbed soils (7.89%) as revealed in Table 5. This pattern was consistent across all depths, with partially degraded soils retaining the most POC. This could be due to the harvesting method used by the illegal loggers, in which round logs are converted into timber in the forest and leaving the residues (tree barks, leaves, branches, etc.) to decompose on the site (as seen in Appendix). In addition to this, there was no agricultural/farming practices performed on both the degraded and partially degraded forest soils in the study area thus the carbon deposits still remain in the soil. This result coincides with the studies by [41], which found that POC increases with the addition of fresh organic matter such as tree bark and leaves, which rapidly decompose. In this case, the partially degraded soils had the highest POC due to the presence of organic residues left by illegal logging.

MOC was highest in undisturbed soils at all depths, with values of 14.32%, 8.24%, and 4.48% for 0-10 cm, 10-20 cm, and 20-30 cm, respectively (Table 6). In contrast, partially degraded and degraded soils had lower MOC values, indicating that mineral-associated organic carbon is more stable and less affected by forest degradation. These findings are consistent with research by [42], who noted that MOC persists in the soil for a longer period due to its slow turnover, which explains the higher MOC in undisturbed soils compared to degraded areas.

Table 1. Effects of forest degradation on soil particle size distribution in the study area

Forest Degradation Level	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	Bulk density (g/cm^3)
Undisturbed	0-10	55	19	26	Sandy clay loam	4.24^b	0.746
	10-20	48	25	27	Sandy clay loam	4.43^b	
	20-30	41	36	23	Loam	4.48^b	
Partially Degraded	0-10	53	17	30	Sandy clay loam	5.43^a	0.873
	10-20	45	24	31	Clay loam	5.63^a	
	20-30	40	33	27	Clay loam	5.72^a	
Degraded	0-10	54	18	28	Sandy clay loam	6.03^a	0.916
	10-20	48	18	34	Sandy clay	6.09^a	
	20-30	45	24	31	Clay loam	6.25^a	

Table 2. Effects of soil degradation on soil organic matter content in the study area

Soil depth	Forest Degradation Level		
	Undisturbed (%)	Partially Degraded (%)	Degraded (%)
(0-10 cm)	3.58 [b]	4.54 [a]	3.96 [a]
(10-20 cm)	1.25 [b]	2.32 [a]	2.19 [a]
(20-30 cm)	0.88 [b]	1.55 [a]	1.18 [a]

Table 3. Effects of forest degradation on soil organic carbon pool (SOCP) in the study area

Depth	Undisturbed (t/ha)	Partially Degraded (t/ha)	Degraded (t/ha)
(0-10 cm)	15.56 [b]	22.91 [a]	21.15 [a]
(10-20 cm)	5.44 [b]	11.7 [a]	11.69 [a]
(20-30 cm)	3.82 [b]	7.82 [a]	6.29 [a]

Table 4. Effects of forest degradation on Total Organic Carbon (TOC) in the study area

Soil depth	Undisturbed (%)	Partially Degraded (%)	Degraded (%)
(0-10 cm)	8.30[b]	10.54[a]	9.20[a]
(10-20 cm)	2.90[b]	5.38[a]	5.08[a]
(20-30 cm)	0.51[b]	0.90[a]	0.68[b]

Table 5. Effects of forest degradation on Particulate Organic Carbon (POC) of the study area

Depth	Undisturbed (%)	Partially Degraded (%)	Degraded (%)
(0-10 cm)	7.89[b]	9.71[a]	9.18[a]
(10-20 cm)	2.75[b]	4.85[a]	5.10[a]
(20-30 cm)	1.14[c]	2.84[b]	3.98[a]

Table 6. Effects of forest degradation on Mineral-associated Organic Carbon (MOC) of the study area

Depth	Undisturbed (%)	Partially Degraded (%)	Degraded (%)
(0-10 cm)	14.32[a]	13.33[b]	13.21[b]
(10-20 cm)	8.24[a]	7.34[b]	7.64[b]
(20-30 cm)	4.48[a]	4.13[a]	3.12[b]

Conclusion and Recommendation

The study found out that forest degradation affects SOC and related soil properties in the Akure Forest Reserve. It was established that soil degradation affected the soil texture, the bulk density, and the pH of the soil. These changes, especially the increase in the content of clay and compaction, are indicative of the impact of vegetation removal and soil erosion as a result of deforestation. However, partially degraded soils, which have accumulated organic residues from logging activities, had higher organic matter content, SOCP, and TOC than undisturbed soils. This buildup of organic matter in partially decomposed areas indicates that these soils still contain a good deal of organic carbon, thus implying that there could be some measure of regeneration of soil fertility if the area is not subjected to very heavy traffic. In addition, the study showed that forest degradation influences the distribution of SOC into the stable and labile pools. The most labile POC was found in partially degraded soils because logging left behind organic residues. In contrast, the more stable mineral-associated organic carbon (MOC) was higher in undisturbed soils, suggesting that these forests can effectively sequester carbon in the long term. Therefore, there is a need to implement policies that will help in the fight against the continued cutting of trees in the forests. Conservation of MOC in the forest should be done by preserving the undisturbed forest to retain high MOC, and the rehabilitation of the partially disturbed forest to enhance the accumulation of organic carbon and soil fertility. The conservation of SOC stocks and the overall health of the ecosystem can only be achieved through sustainable forest management practices to avoid further soil degradation.

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Appendix

Plate 1: Undisturbed part of the study area

Plate 2: Partially degraded part of the study area

Plate 3: Degraded part of the study area