DOI:10.5152/forestist.2023.23008
Forestist 2024: 74(1): 35-43

ISTANBUL UNIVERSITY
CERRAHPAŞA

Original Article

Tree Species Composition and Soil Properties in a Disturbed Rainforest Ecosystem, South-West Nigeria

Farhan Jimba Moshood, Samuel Olalekan Olajuyigbe

Department of Forest Production and Products, University of Ibadan Faculty of Renewable Natural Resources, Ibadan, Nigeria

ABSTRACT

This study assessed the tree species composition and soil properties in a disturbed tropical rainforest (Osho Forest Reserve) in Nigeria. A systematic sampling method was adopted for tree species enumeration. Five line transects 1000 m long and 500 m apart were evenly distributed in the forests. Four plots (50 m × 50 m) were laid alternately and at 250 m intervals along each transect. Soil samples were collected at five points from two depths in the different land use types in the forest reserve. Twenty-four tree species belonging to 13 taxonomic families were identified. Lamiaceae had the highest tree population (190 trees). The Simpson, Shannon–Wiener, and Margalef's indices were 0.788, 2.052, and 4.016, respectively. In the 0–15 cm depth, farmland had the highest bulk density (1.75 ± 0.33 g/cm^3), while the secondary forest had the least (1.32 ± 0.12 g/cm^3). Secondary forest had the highest organic carbon content (2.80 ± 0.49%) while farmland had the least (0.95 ± 0.33%). The soil organic carbon content of secondary forest was significantly different from other land uses. In the 15–30 cm depth, farmland had the highest bulk density (1.79 ± 0.65 g/cm^3), while *Tetrapleura tetraptera* plantation had the least (1.41 ± 0.54 g/cm^3). Secondary forest had the highest organic carbon content (2.12 ± 0.75%), while farmland had the least (0.65 ± 0.10%). However, organic carbon did not significantly differ across land use types, except for secondary forest. The textural class in all the land use types was loamy sand. The study concludes that Osho Forest Reserve requires an immediate, intensive, and encompassing intervention to achieve restoration and rehabilitation.

Keywords: Osho Forest Reserve, secondary forest, soil organic carbon, systematic sampling, tree species diversity

Introduction

Forests are essential to the world, covering around 30.6% of the planet's total land area (FAO, 2018). They provide essential ecosystem services, which range from provisioning, regulating, cultural, and supporting (MEA, 2005). Tropical forests contain many of the global biodiversity hotspots in the world (Mittermeier et al., 2004). In Nigeria, lowland rainforests are characterized by dense vegetation, high annual rainfall, and high species diversity. They are home to a variety of tree species such as *Lophira alata*, *Entandrophragma angolense*, *Holoptelea grandis*, *Milicia excelsa*, *Triplochiton scleroxylon*, and *Lovoa trichiloides*, among others (Olajuyigbe, 2018; Olajuyigbe & Adaja, 2014). Despite the abundance of biodiversity, human activities such as farming and urbanization have caused damage to these forest ecosystems (Boboye & Jimoh, 2016).

Trees play important roles in ecosystems by providing habitat and food for animals, contributing to the cycling of nutrients and water, and sequestering carbon. Soil properties are the key components of soil and play vital roles in the carbon cycle by providing energy for soil organisms, influencing water retention and availability of nutrients, and affecting soil fertility (Gerke, 2022). In recent years, the lowland rainforest in Nigeria has experienced a significant amount of deforestation and degradation due to land use changes, illegal logging, and the expansion of agricultural activities (Fasona et al., 2018; Oluwajuwon et al., 2021). This has led to a decrease in tree species composition and fluctuation of soil properties in the forests.

The loss of forests and trees is occurring at a disturbing rate due to numerous socioeconomic changes, such as infrastructure growth, the commercialization of agricultural production, and the rapid development of cities (Wajim, 2020). Replenishing these forests and planting new ones is proving to be difficult due to a lack of knowledge concerning most species and their growth requirements (Etuk et al., 2013). Ecologists often consider a high level of species diversity to be a desirable state since it allows them to study how disturbances affect biotic

Cite this article as:
Moshood, F. J., & Olajuyigbe, S. O. (2024). Tree species composition and soil properties in a disturbed rainforest ecosystem, South-West Nigeria. *Forestist*, 74(1), 35-43.

Corresponding Author:
Farhan Jimba Moshood
e-mail:
moshoodfarhan@gmail.com

Received: February 21, 2023
Revision Requested: April 19, 2023
Accepted: May 6, 2023
Publication Date: December 8, 2023

life as well as the stability of the ecosystem (Moses & Anthony, 2015). The diversity of life forms may be either directly or inversely connected to tree species diversity, depending on the type of forest being studied, with transitional forests having diversity patterns across a variety of geographic scales.

The immense amount of human activity in Nigerian rainforest has had a great impact on its biodiversity. Despite this, the species composition in many gazette forests has not been properly documented (Adeyemi et al., 2013). For example, there are limited data on the condition of the trees in the Osho Forest Reserve, making it difficult to manage the forest effectively. Furthermore, sections of the forest reserve have been converted to monocultures of both indigenous and exotic tree species. This has created disturbances in the ecological balance of the reserve.

Soil stability has numerous benefits including provision of nutrients to plants and improving water availability, which leads to enhanced soil fertility and increased food productivity as well as acting as a carbon reservoir. However, global issues such as climate change, biodiversity loss, and land degradation have led to soils becoming vulnerable (Lal, 2013). Consequently, enhancing the soil properties remains a challenge, particularly impoverished and depleted soils in tropical climates (Smaling et al., 1997). Anthropogenic activities cause changes to the soil structure, texture, aggregation, and soil organic carbon (SOC). These changes vary along the depths of the soil and should be considered in the Osho Forest Reserve.

Having reliable and accurate data is essential for a successful forest management strategy. Without such information, it is impossible to plan for the sustainable management of the forest (Al-Bakri et al., 2013). This research on a disturbed rainforest ecosystem is of great importance to the local and global community because it provides insight into the complex interactions between tree species composition and soil properties in the Osho Forest Reserve. Previous research in the Osho Forest Reserve focused on agroforestry practices (Azeez et al., 2017) and carbon stock estimates (Olayode et al., 2015). Hence, this research provides essential information on the tree species, diversity, and richness as well as the soil properties in the Osho Forest Reserve. In addition, the research provides an invaluable baseline for future studies, which could evaluate the effect of land use on the environment and measure the effectiveness of conservation efforts.

Material and Methods

Study Area

The study was carried out in the Osho Forest Reserve, which is located in the Ido Local Government Area of Oyo State, Nigeria (Figure 1). It is situated between latitudes 7°00′ and 7°45′N and longitudes 3°00′

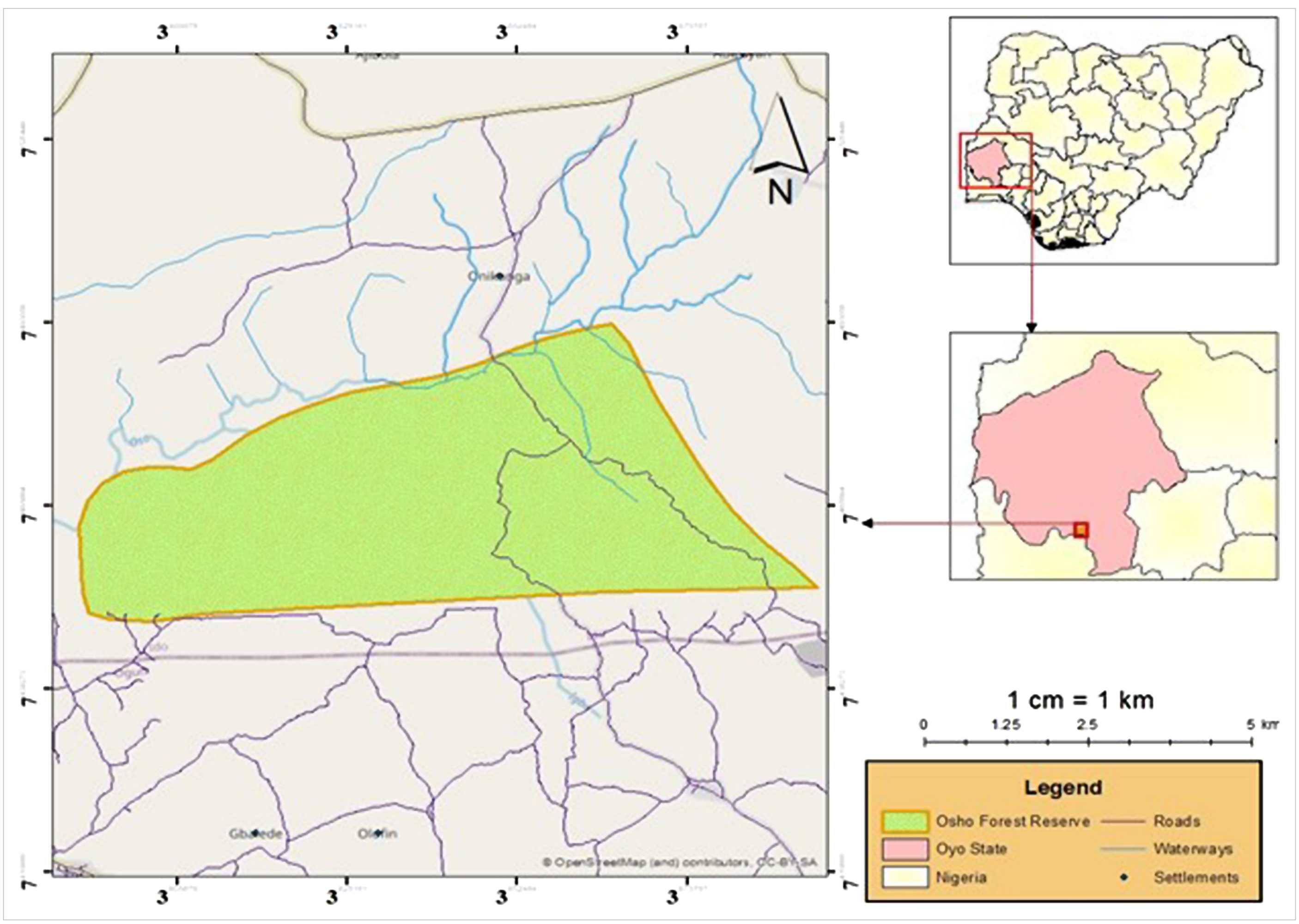

Figure 1.
Map of Osho Forest Reserve (inset map of Nigeria and map of Oyo State)

and 3°25′E. The ecological zone is the derived savanna, and the reserve had an original land area of 5180 ha, which was reduced to 3500 ha through the 1951 Amendment Order. The tropical climate of the Osho Forest Reserve is characterized by two seasons, namely dry and wet seasons. Two distinct wet seasons occur in the reserve—May to July and September to November—apart from the break in August. The major dry season occurs between December and March and is usually accompanied by northeast trade winds. The average annual rainfall is 1257 mm, while the relative humidity ranges from 84.5% between June and September and 78.8% between December and January. The annual maximum and minimum temperatures are 31.3 °C and 21.0 °C, respectively (Azeez et al., 2017). The Osho Forest Reserve harbors important indigenous and exotic tree species which were planted under the Taungya farming system. The exotic species found in the forest reserve include *Tectona grandis* and *Gmelina arborea*. Some of the indigenous species are *Terminalia* spp., *Treculia africana*, and *T. scleroxylon*.

Sampling Procedure

A systematic sampling technique was adopted for sample plot allocation. Five line transects, 1000 m (1 km) long and 500 m apart, were evenly distributed across the forests. Along each transect, four plots (50 m × 50 m) were laid alternately at 250 m intervals (Figure 2). A total of 20 sample plots were used in the study, implying that 1 ha was sampled along each transect (i.e., four plots of 50 × 50 m = 1 ha).

Tree Species Measurement and Identification

In the sample plots, all living trees with diameter at breast height (Dbh) ≥ 10 cm were enumerated. Tree growth variables (Dbh and total height) were measured using a diameter tape and Spiegel Relaskop. An experienced taxonomist was employed to identify trees to species level. Leaves, barks, flowers, and fruits of trees that could not be identified on the spot were collected for identification at the Forestry Herbarium of the Forestry Research Institute of Nigeria, Ibadan, Nigeria.

Soil Sample Collection

From the line transects, six land use types (secondary forests, *T. grandis* plantation, *G. arborea* plantation, *Anogeissus leiocarpus* plantation, *Tetrapleura tetraptera* plantation, and farmland) were identified in the study area. In each land use type, soil samples were collected at five different points (i.e., North, East, West, South, and center) from two different depths (0–15 cm and 15–30 cm). The samples were collected using a soil auger and stainless-steel soil cores.

Data Analysis

Frequency

This is the dispersion of individual tree species in the study area and was determined using Equation (1).

$$\text{Frequency} = \frac{\text{Number of plots in which the species occurs}}{\text{Total number of plots studied}} \quad (1)$$

Relative Frequency

This is the degree of dispersion of individual tree species in the study area relative to the number of all species occurring in the study area.

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of individual species}}{\text{Total frequency of all species}} \quad (2)$$

Relative Density

This is the numerical strength of a species in relation to the total number of individuals of all species in the study area.

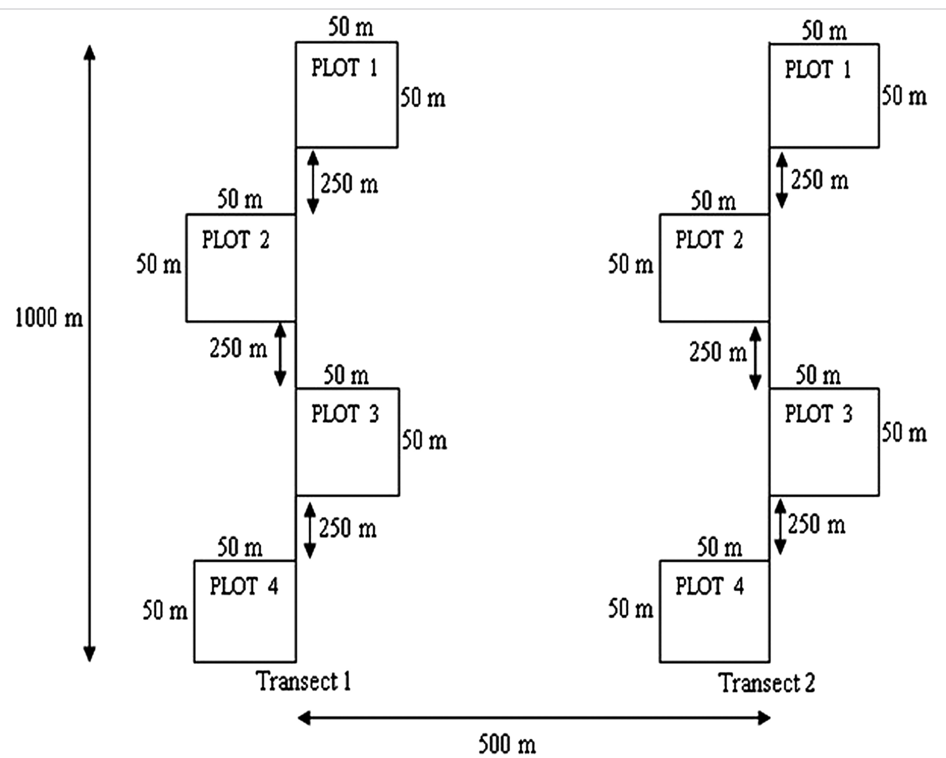

Figure 2.
Layout of sample plots in Osho Forest Reserve using systematic line transect sampling method

$$\text{Relative density}\left(\text{RD}\right)=\frac{\text{Number of individuals of a species}}{\text{Total number of species encountered in the study area}}\times 100 \tag{3}$$

Relative Dominance

This is the coverage value (basal area) of a species relative to the coverage value (basal area) of all the species in the study area. It is usually expressed in percentages.

$$\text{Relative Dominance}\left(\text{RD}_{\text{O}}\right)=\frac{\textit{total basal area of a species}}{\textit{total basal area of all the species encountred}}\times 100 \tag{4}$$

Important Value Index

It describes the overall importance of each species in the community.

Important value index (IVI) = Relative frequency + relative density + relative dominance (5)

Species Diversity

The species diversity indices were calculated using the Shannon–Wiener's index of diversity (Price, 1997).

$$\text{Shannon-Wiener's Index of Diversity}\left(\text{H}^{\text{l}}\right)=-\sum_{t=1}^{s}Piln\left(Pi\right) \tag{6}$$

where S = total number of species in the community; P_i = proportion of "S" made up of the ith species, and ln = natural logarithm.

Species Richness

Tree species richness in the area was calculated using Margalef's index of species richness (Margalef, 1958).

$$\text{Margalef's Index}\left(\text{d}\right)=\frac{S}{\sqrt{N}} \tag{7}$$

where S = the number of tree species encountered and N = the total number of individuals of all the tree species in the area.

Basal Area

The cross-sectional area of tree stems at the breast height (1.3 m above the ground level).

$$\text{Basal area}=\frac{\pi \text{Dbh}^2}{4} \tag{8}$$

where $\pi=\frac{22}{7}$ and Dbh = diameter at breast height.

Soil Bulk Density

The bulk density of the soil samples was determined using the core method (Grossman & Reinsch, 2002). The undisturbed core soil samples were taken to the laboratory and oven dried until a constant weight was attained. Soil samples were weighed on an oven-dry basis; the bulk density was calculated by dividing the weight of the oven-dried soil by the volume of the soil core, which is the volume of the steel tube.

$$\text{Bulk density}\left(\text{g/cm}^3\right)=\frac{\text{Mass of oven-dried sample}}{\text{Volume of soil sampe}} \tag{9}$$

Soil Organic Carbon

Soil organic carbon was determined using the wet oxidation method (Walkley & Black, 1934). Sub-samples (1 g) of the soil aggregates were oxidized using 10 mL of 1 N $K_2Cr_2O_7$ solution and swirling the flask gently to disperse the soil in the solution. Concentrated H_2SO_4 (10 mL) was added into the suspension, and the solution was left for 30 minutes. Distilled water (100 mL) was added to stop the reaction. Ferroin indicator (three to four drops) was added and titrated with 0.5 N $FeSO_4$. The organic carbon of the soil was calculated using the formula:

$$\text{Organic Carbon}\left(\%\right)=\frac{\left(\text{blank value}-\text{titre value}\right)\times \text{N of FeSO}_4\times 1.33\times 0.003\times 100}{\text{weight of sample}} \tag{10}$$

Descriptive and Inferential Statistics

Mean, graphs, charts, and tables were used to summarize and present the data. One-way analysis of variance (ANOVA) was used to test the influence of land use on SOC at different depths. The mean was separated using Fisher's least square difference, when the ANOVA test was significant at $\alpha = 0.05$.

Results

A total of 24 tree species spread across 307 individual trees from 13 taxonomic families were identified (Table 1). The highest mean heights were observed for *Cordia millenii* (23.10 m), *Hildegardia barteri* (19.40 m), and *Albizia lebbeck* (18.50 m); while the lowest mean heights were recorded for *Ficus exasperata* (8.32 m), *Ceiba pentandra* (8.50 m), and *Morinda lucida* (8.76 m). The tree species with the highest mean diameter were *Khaya senegalensis* (101.30 cm), *C. millenii* (98.45 cm), and *Bombax bounopozense* (78.43 cm), while *F. exasperata* (19.33 cm), *Sterculia rhinopetala* (19.45 cm), and *Blighia sapida* (27.40 cm) recorded the lowest (Table 1). The highest basal areas were recorded for *T. grandis* (21.50 m^2), *G. arborea* (18.10 m^2), and *T. tetraptera* (5.31 m^2), while *B. sapida* (0.03 m^2), *S. rhinopetala* (0.04 m^2), and *Sterculia africana* (0.06 m^2) had the least. *Tectona grandis* had the highest relative density (29.41%), relative frequency (33.88%), relative dominance (38.41%), and important value index (IVI = 101.69). This was followed by *G. arborea* with a relative density of 25.40%, relative frequency of 28.01%, relative dominance of 32.33%, and IVI of 85.75. *Anogeissus leiocarpa* had a relative density, relative frequency, relative dominance, and IVI of 9.89%, 10.10%, 1.96%, and 21.96, respectively. Five different species (*B. sapida*, *C. pentandra*, *S. africana*, *S. rhinopetala*, and *Terminalia superba*) had the lowest relative density (0.80%) and relative frequency (0.33%), while *B. sapida*, *S. rhinopetala*, and *S. africana* had the lowest relative dominance of 0.05%, 0.07%, and 0.11%, respectively (Table 1).

The Simpson (D) and Shannon–Wiener (H^l) diversity indices were 0.788 and 2.052, respectively. On the other hand, the species evenness (E) was 0.324, while Margalef's index of species richness (d) was 4.016 (Table 2).

There were 13 taxonomic families of tree species in the Osho Forest Reserve (Figure 3). Lamiaceae had the highest tree population (190 trees), followed by Combretaceae (34) and Fabaceae (22). Sterculiaceae and Leguminaceae were both represented by 14 trees each. Moraceae was represented by 12 trees, Bombacaceae by 8 trees, Rubiaceae by 4 trees, and Apocynaceae by 3 trees. Boraginaceae and Meliaceae had two representatives each. Malvaceae and Sapindaceae were the least represented species with one representative each.

Table 1.
Tree Species Composition and Growth Variables in Osho Forest Reserve

Species	Family	Frequency	Mean Height (m)	Mean Dbh (cm)	BA (m^2)	RF (%)	RD (%)	RD_o (%)	IVI
Adansonia digitata	Bombacaceae	5	13.40	43.10	1.42	2.14	1.63	2.54	6.30
Albizia lebbeck	Leguminosae	6	18.50	38.66	1.20	1.07	1.95	2.14	5.17
Alstonia booneii	Apocynaceae	3	14.20	43.56	0.95	1.60	0.98	1.70	4.28
Anogeissus leiocarpa	Combretaceae	31	17.40	28.30	1.10	9.89	10.10	1.96	21.96
Antiaris africana	Moraceae	3	10.40	67.20	0.67	1.07	0.98	1.20	3.24
Blighia sapida	Sapindaceae	1	10.50	27.40	0.03	0.80	0.33	0.05	1.18
Bombax bounopozense	Bombacaceae	3	18.45	78.43	0.61	0.80	0.98	1.09	2.87
Ceiba pentandra	Malvaceae	1	8.50	38.50	0.35	0.80	0.33	0.63	1.75
Cordia millenii	Boraginaceae	2	23.10	98.45	0.44	1.07	0.65	0.79	2.51
Daniellia oliveri	Leguminosae	8	12.10	56.45	0.67	3.21	2.61	1.20	7.01
Ficus exasperata	Moraceae	7	8.32	19.33	0.78	2.67	2.28	1.39	6.35
Gmelina arborea	Lamiaceae	86	9.37	43.40	18.10	25.40	28.01	32.33	85.75
Hildegardia barteri	Sterculiaceae	5	19.40	62.40	0.54	2.14	1.63	0.96	4.73
Khaya senegalensis	Meliaceae	2	21.40	101.30	0.34	1.07	0.65	0.61	2.33
Morinda lucida	Rubiaceae	4	8.76	34.23	0.43	1.87	1.30	0.77	3.94
Pterogota macrocarpa	Sterculiaceae	2	10.32	45.43	0.21	1.07	0.65	0.38	2.10
Sterculia africana	Sterculiaceae	1	12.50	33.30	0.06	0.80	0.33	0.11	1.24
Sterculia oblonga	Sterculiaceae	5	10.33	37.80	0.43	2.14	1.63	0.77	4.54
Sterculia rhinopetala	Sterculiaceae	1	9.50	19.45	0.04	0.80	0.33	0.07	1.20
Tectona grandis	Lamiaceae	104	12.54	43.40	21.50	29.41	33.88	38.41	101.69
Terminalia ivorensis	Combretaceae	2	14.50	28.77	0.07	1.07	0.65	0.13	1.85
Terminalia superba	Combretaceae	1	10.40	31.45	0.39	0.80	0.33	0.70	1.82
Tetrapleura tetraptera	Fabaceae	22	12.55	39.54	5.31	7.22	7.17	9.49	23.87
Treculia africana	Moraceae	2	12.40	27.65	0.34	1.07	0.65	0.61	2.33

Note: BA = Basal area; Dbh = Diameter at breast height; IVI = Important value index; RD = Relative density; RD_o = Relative dominance; RF = Relative frequency.

Fifteen trees (4.89%) were in the diameter class 10–19.99 cm, 18 trees (5.89%) in diameter class 20–29.99 cm, while 102 trees (33.22%) were in the diameter class 31–49.99 cm (Figure 4). Diameter class 41–50.99 cm had the highest number of trees (115), representing 37.46% of the tree population. Diameter classes 51–60.99 cm, 61–70.99 cm, and ≥81 cm recorded 28 (9.12%), 11 (3.58%), and 10 (3.26%) trees, respectively. The least number of trees (8) was recorded by diameter class 71–80.99 cm.

Eighteen trees or 5.86% were in the <10 m height class, while height classes 20–29.99 m and 30–39.99 m recorded 16 (5.21%) and 10 (3.26%) trees, respectively (Figure 5). Height class 10–19.99 m recorded the highest number of trees (259), which accounts for about 84.36% of the tree population. On the other hand, height class >40 m recorded four trees (1.30%).

In the 0–15 cm soil depth, farmland had the highest bulk density (1.75 ± 0.33 g/cm^3) followed by *T. grandis* plantation (1.54 ± 0.10 g/cm^3), while the secondary forest had the least bulk density (1.32 ± 0.12 g/cm^3). The bulk density did not significantly differ across the land use types (Table 3). The secondary forest had the highest organic carbon content (2.80 ± 0.49%) followed by *G. arborea* plantation (1.85 ± 0.63%), while farmland had the least (0.95 ± 0.33%). Only the organic carbon in the secondary forest significantly differed from other land use types. The soil textural classification in the 0–15 cm depth showed that "loamy sand" was in all the land use types, with sand being the dominant particle size (ranged from 84.45% and 89.17%), while silt ranged from 4.29 to 6.34%.

The 15–30 cm soil depth also followed the pattern of the 0–15 cm depth, farmland (1.79 ± 0.65 g/cm^3), and *T. grandis* plantation (1.56 ± 0.16 g/cm^3) had the highest bulk density. However, *T. tetraptera* plantation had the least (1.41 ± 0.54 g/cm^3). The bulk density in the different land use types did not significantly differ (Table 3). Similar to the 0–15 cm soil depth, the secondary forest had the highest organic carbon content (2.12 ± 0.75%), while farmland had the least (0.65 ± 0.10%).

Table 2.
Diversity Indices of Tree Species in Osho Forest Reserve

Diversity Indices	Value
Simpson index (*D*)	0.788
Shannon–Wiener index (*H'*)	2.052
Evenness index (*E*)	0.324
Margalef's index (*d*)	4.016

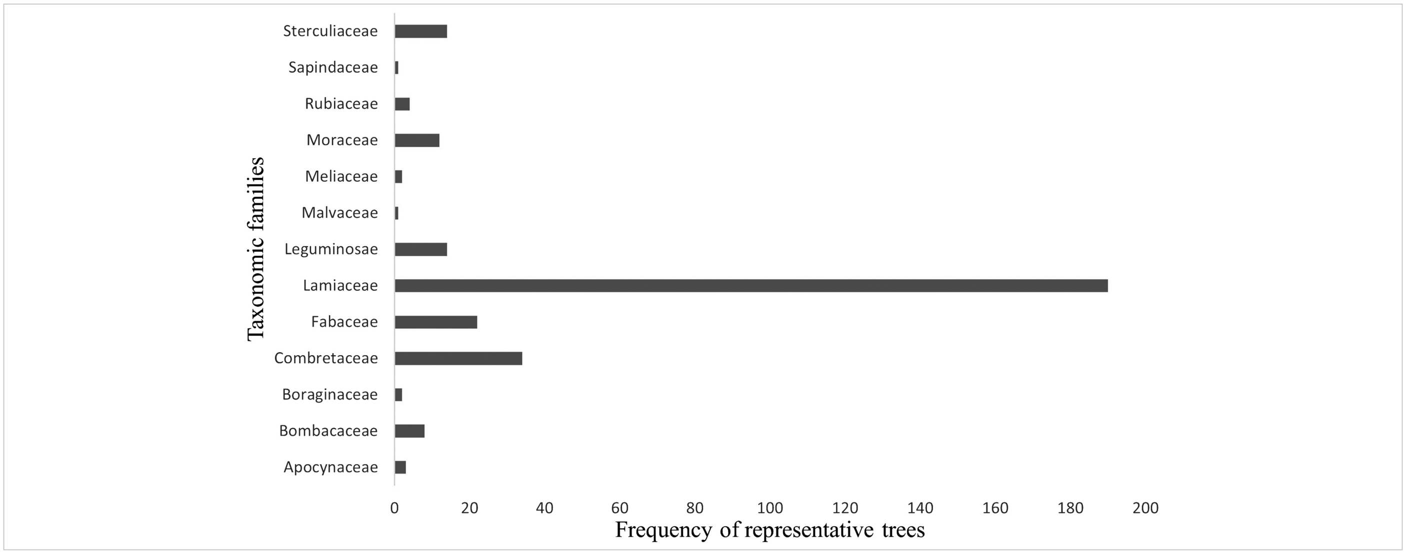

Figure 3.
Taxonomic families of tree species in Osho Forest Reserve

The organic carbon was not significantly different across land use types except for the secondary forest which differed from others. The textural class in all the land use types was "loamy sand." The percentage of clay, silt, and sand ranged between 5.72 and 8.22%, 4.70 and 6.04%, and 84.25 and 89.37%, respectively (Table 3).

Discussion

Species composition and biodiversity in forest ecosystem are indicators of ecological functioning and processes (Moshood et al., 2022; Naidu & Kumar, 2016). The 24 tree species from 13 taxonomic families identified in the Osho Forest Reserve were lower than the 55 species (20 families) in the Shasha Forest Reserve, 54 species (24 families) reported in the Ala Forest Reserve, and 41 species (21 families) in the Omo Forest Reserve (Adekunle, 2006). It was also lower than the 64 tree species (23 families) in the Old Oyo National Park (Adeyemi & Taofeek, 2020), 89 tree species (30 families) in the Ogun River Watershed (Asinwa et al., 2018), 48 tree species in the Arinta Watershed Forest (Olajuyigbe & Akwarandu, 2019), and 60 species (22 families) in the Eda Forest Reserve (Olajuyigbe & Jeminiwa, 2018). It was however higher than the 10 species (8 families) reported by Ibe et al. (2014) in Ohaji/Egbema Watershed in Imo State, Nigeria.

The sparsity of trees in the forest reserve reveals the level of disturbance and degradation that had been previously reported by earlier researchers for forest reserves in Oyo State (Haastrup et al., 2020; Salami & Akinyele, 2017). Osho Forest has about eight neighboring communities that depend on it for active farming activities and fuel wood extraction. This has impacted the species composition since trees are removed for agricultural expansion. Four species (*A. leiocarpa*, *G. arborea*, *T. grandis*, and *T. tetraptera*) were relatively abundant in the reserve, because they were planted by the state government. However, none of the species

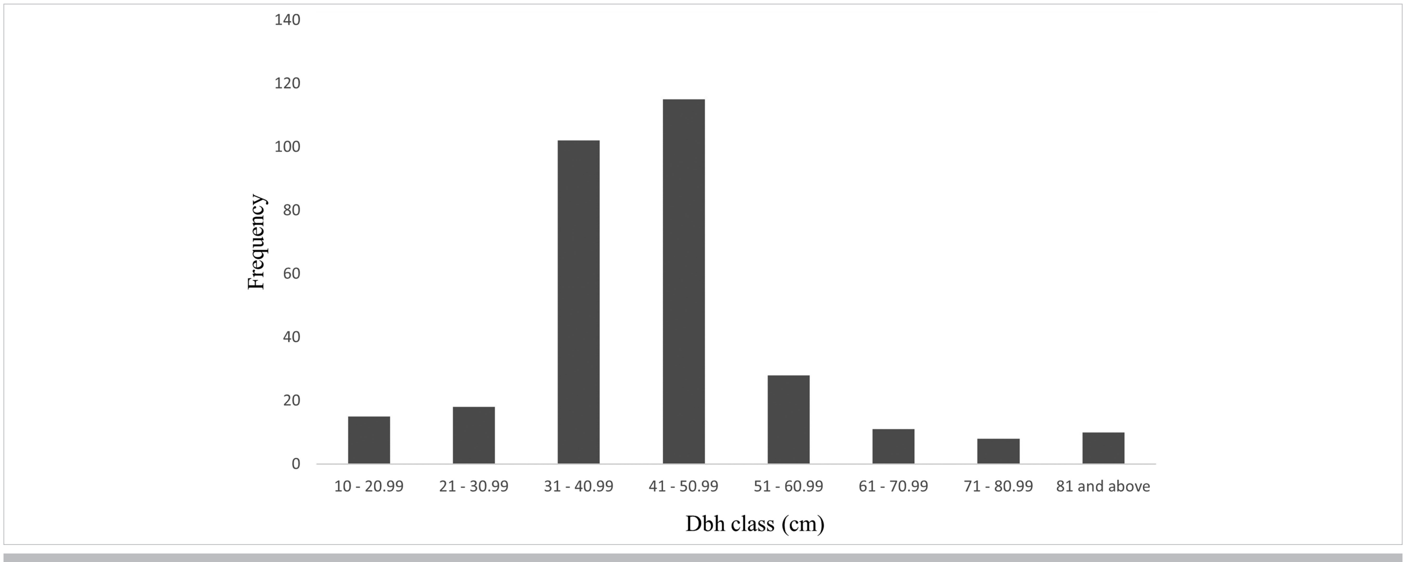

Figure 4.
Diameter at breast height (Dbh) distribution of trees in Osho Forest Reserve

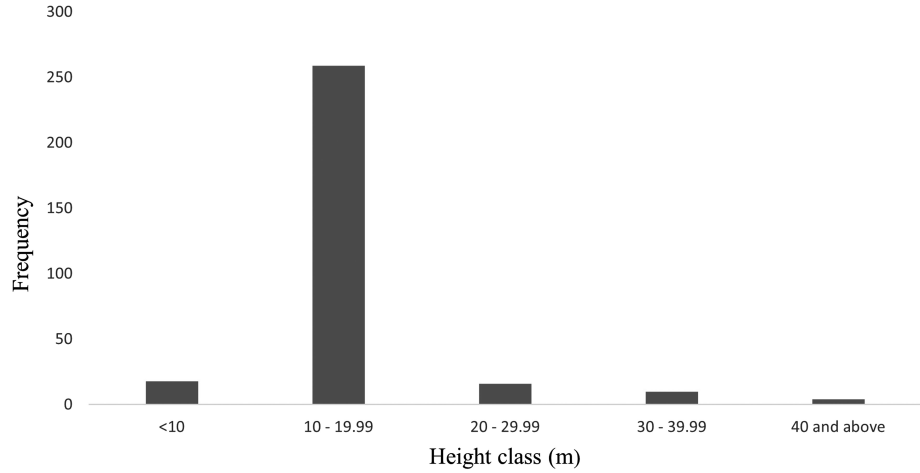

Figure 5.
Height distribution of trees in Osho Forest Reserve

in the secondary forest appeared up to ten times in the sampling plots, indicating high level of disturbance.

The Shannon–Weinner index ($H^I = 2.052$) reported was lower than the 3.74 reported by Adekunle et al. (2013) in the Akure Strict Nature Reserve, 3.65 reported by Olajuyigbe and Adaja (2014) in the Akure-Ofosu Forest Reserve, 3.56 reported by Salami and Akinyele (2017) in the Gambari Forest Reserve, and 3.14 reported for the secondary forest in the Eda Forest Reserve (Olajuyigbe & Jeminiwa, 2018). It was however higher than the 1.94 reported in the Kurba Forest Reserve (Salami et al., 2022) and 1.45 in the Dabagi Forest Reserve (Shamaki et al., 2015). The H^I in the study area is a further indication of the level of disturbances. These disturbances include illegal felling, deforestation, and agricultural expansion. According to Magurran (2004), the value for H^I might range from 0 to 7, with 0–2 as low diversity, 2–3 as moderate diversity, and above 3 as high diversity. Based on this, the study area is moderately diverse. The IVI which combines the attributes of relative density, relative frequency, and relative dominance (Olajuyigbe & Adaja, 2014) indicates the importance of a species in the ecosystem. *Tectona grandis* followed by *G. arborea* and *T. tetraptera* recorded the highest IVI. The *T. grandis* and *G. arborea* are exotic species, while *T. tetraptera* is a native plant. These plantation species have become part of the forest ecosystem as their high IVI indicates their ecological success (Bello et al., 2022).

On tree population basis, the Osho Forest Reserve is dominated by Lamiaceae, given that the two most abundant species (*T. grandis* and *G. arborea*) belong to this family. On tree species basis, Sterculiaceae was the dominant species, followed by Moraceae and Combretaceae. This agrees with Haastrup et al. (2020) and Nurudeen et al. (2017) who reported that the Gambari Forest Reserve was dominated by Sterculiaceae family. However, it disagrees with Ihenyen et al. (2009) and Adeyemi and Taofeek (2020) who reported Fabaceae as the dominant

Table 3.
Physical Properties of Soil in Different Land Use and at Different Soil Depths (0–15 cm and 15–30 cm) in Osho Forest Reserve

Land Use	Bulk Density (g/cm³)	Organic Carbon (%)	Clay (%)	Silt (%)	Sand (%)	Textural Class
			0–15 cm			
Secondary forest	1.32 ± 0.12ᵃ	2.80 ± 0.49ᵃ	8.43 ± 0.65	5.32 ± 0.32	86.25 ± 0.34	Loamy sand
Tectona grandis plantation	1.54 ± 0.10ᵃ	1.69 ± 0.50ᵇ	9.21 ± 0.45	6.34 ± 0.12	84.45 ± 0.55	Loamy sand
Gmelina arborea plantation	1.42 ± 0.23ᵃ	1.85 ± 0.63ᵇ	5.48 ± 0.35	4.92 ± 0.44	89.60 ± 0.74	Loamy sand
Anogeissus leiocarpus plantation	1.40 ± 0.29ᵃ	1.46 ± 0.94ᵇ	6.48 ± 0.52	4.29 ± 0.56	89.23 ± 0.93	Loamy sand
Tetrapleura tetraptera plantation	1.40 ± 0.63ᵃ	1.53 ± 0.82ᵇ	5.98 ± 0.74	4.85 ± 0.54	89.17 ± 1.43	Loamy sand
Farmland	1.75 ± 0.33ᵃ	0.95 ± 0.33ᵇ	7.54 ± 0.23	4.93 ± 0.11	87.54 ± 2.10	Loamy sand
			15–30 cm			
Secondary forest	1.42 ± 0.18ᵃ	2.12 ± 0.75ᵃ	8.22 ± 0.59	5.99 ± 0.22	85.79 ± 0.21	Loamy sand
Tectona grandis plantation	1.56 ± 0.16ᵃ	1.11 ± 0.86ᵇ	9.71 ± 0.37	6.04 ± 0.19	84.25 ± 0.60	Loamy sand
Gmelina arborea plantation	1.51 ± 0.55ᵃ	1.04 ± 0.32ᵇ	6.84 ± 0.27	4.92 ± 0.51	88.24 ± 0.84	Loamy sand
Anogeissus leiocarpus plantation	1.45 ± 0.67ᵃ	1.23 ± 0.86ᵇ	6.23 ± 0.81	4.84 ± 0.96	88.93 ± 0.61	Loamy sand
Tetrapleura tetraptera plantation	1.41 ± 0.54ᵃ	1.53 ± 0.52ᵇ	5.72 ± 0.52	4.91 ± 0.82	89.37 ± 1.22	Loamy sand
Farmland	1.79 ± 0.65ᵃ	0.65 ± 0.10ᵇ	7.40 ± 0.91	4.70 ± 0.19	87.90 ± 0.36	Loamy sand

Note: Means with the same letter(s) in the same column are not significantly different from each other.

family in the Ehor Forest Reserve and the Old Oyo National Park, respectively. The poor representation of some families may be attributed to anthropogenic activities which may have prevented natural regeneration from seeds of mother trees, which had been felled and removed from the forest (Adeyemi & Taofeek, 2020).

The diameter distribution of trees formed an upside-down "U" curve, which indicates that the diameter classes 31–40.99 cm and 41–50.99 cm were the most represented. This disagrees with the upside-down "J" curve that was observed by Olajuyigbe and Akwarandu (2018). The abundance of trees in the middle and upper diameter classes more than in the lower diameter classes indicates that the natural regeneration of trees will be difficult. Conversely, the low frequency of trees in the 51–60.99 cm diameter class and above is a clear indication of the high level of disturbance (Olajuyigbe & Adaja, 2014). The overall mean basal area of 55.98 m^2 reported in the study was higher than the 28.89 m^2 reported by Adeyemi and Taofeek (2020), 31.06 m^2 reported by Olajuyigbe and Akwarandu (2018) but similar to 54.2 m^2 reported by Addo-Fordjour et al. (2009). This implies a better structural diversity and indicates the presence of grounded root architecture for nutrient absorption (Adeyemi & Taofeek, 2020).

Soil bulk density reflects the soil's ability to provide structural support, water and solute movement, and soil aeration. The study observed no significant difference in the bulk density across land use types, with farmland having the highest bulk density. According to Brady and Weil (2016), bulk density is changed by crop and land management practices, which affect soil cover, organic matter, soil structure, and porosity. High bulk density has been observed in cultivated lands (Celik, 2005; Onwuka & Adesemuyi, 2019). This is probably due to the mechanical disturbance of pore arrangements by tillage. Cultivation destroys soil organic matter and weakens the natural stability of soil aggregates, making them susceptible to damage by water and wind (Brady & Weil, 2016). In general, soils that are porous, loose, and rich in organic matter usually have lower bulk density. It, therefore, follows that the secondary forest was the richest in organic matter with the lowest bulk density (Olujobi et al., 2022; Onwuka & Adesemuyi, 2019). The study also shows that bulk density increased as soil depth increased in all the land use types. This agrees with the findings of Khresat et al. (2007) in the native forests of the Mediterranean region of northwestern Jordan; Mhawish (2015) within an agricultural ecosystem in Jordan, and Olujobi et al. (2022) in the Akure Forest Reserve.

According to Brady and Weil (2016), the bulk density of soil generally increases as its depth increases due to less pore space, less organic material, clumping, and root penetration in the lower layers. In addition, the subsurface levels are pressed down by the weight of the layers of soil that are above them. The soil texture observed in all the land use types was loamy sandy and the proportion of sand was high in all the land use types. This agrees with the findings of Falade and Taiwo (2020) in Osun Osogbo sacred grove and Olujobi et al. (2022) in the Akure Forest Reserve. This may also have influenced the relatively high bulk density of the soils since the total pore space in the sand is less than that of silt and clay. Soils with fine textures such as silt and clay have good structure and lower bulk density compared to sandy soils.

The highest SOC was recorded in the secondary forest, while farmland had the least at both depths. The SOC recorded for the secondary forest (2.80%) in the 0–15 cm was similar to the 2.97% recorded for forestland in Umuahia South Local Government (Onwuka & Adesemuyi, 2019). Anikwe (2010) also observed the highest SOC in forest land use and the lowest SOC in conventionally tilled and continuously cropped plots in southeastern Nigeria. This result also agrees with the findings of Lal (2002), Ufot et al. (2016), and Wasige et al. (2014). This may be attributed to the high aboveground biomass and the continuous input and decomposition of litter and roots in the secondary forest (Kleber et al., 2011). The SOC pool decreased with soil depth in all the land use types. The high carbon input, biomass activity at the soil surface, and fast carbon turnover in tropical soils could be responsible for this.

Conclusion and Recommendations

Anthropogenic factors are the major sources of forest degradation in the tropics. Agricultural expansion and illegal harvesting of trees remain arguably the two major factors ravaging the forest reserves in developing countries including Nigeria. This study examined the tree species composition and SOC in the Osho Forest Reserve, Oyo State, Nigeria. The study identified a total of 24 tree species belonging to 13 taxonomic families. Combretaceae, Fabaceae, Sterculiaceae, Leguminaceae, Moraceae, Bombacaceae, Rubiaceae and Apocynaceae were the most represented taxonomic families in the study area. It was established that *T. grandis*, *G. arborea, T. tetraptera*, and *A. leiocarpa* were the most abundant in the forest reserve. Farmland and secondary forest had the highest bulk density and SOC. Loamy sand was the textural class in all the land use types. The study established that land use types have significant effects on soil properties at different soil depths; hence, a comprehensive study on the influence of land use types on soil properties should be conducted in other forest reserves in the rainforest ecosystems. The study, therefore, recommends that urgent steps be taken by stakeholders to control degradation in the Osho Forest Reserve.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.J.M.; Design – F.J.M., S.O.O.; Supervision – S.O.O.; Resources – F.J.M.; Materials – F.J.M.; Data Collection and/or Processing – F.J.M.; Analysis and/or Interpretation – F.J.M.; Literature Search – F.J.M.; Writing Manuscript – F.J.M., S.O.O.; Critical Review – F.J.M., S.O.O.; Other – F.J.M., S.O.O.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

- Addo-Fordjour, P., Obeng, S., Anning, A., & Addo, M. (2009). Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. *International Journal of Biodiversity and Conservation*, *1*(2), 21–37.
- Adekunle, V. A. J. (2006). Conservation of tree species diversity in tropical rainforest ecosystem of South-West Nigeria. *Journal of Tropical Forest Science*, *18*(2), 91–101.
- Adekunle, V. A. J., Olagoke, A. O., & Akindele, S. O. (2013). Tree species diversity and structure of a Nigerian strict nature Reserve. *Tropical Ecology*, *54*(3), 275–289.
- Adeyemi, A. A., Jimoh, S. O., & Adesoye, P. O. (2013). Assessment of tree diversities in Oban division of the Cross River national park (CRNP). *Nigeria Journal of Agriculture, Forestry and Social Sciences*, *11*(1), 216–230.
- Adeyemi, A. A., & Taiwo Taofeek, H. (2020). Tree structural diversity and yield prediction models for tree species in old Oyo national park, Nigeria. *American Journal of Plant Biology*, *5*(2), 11–20. [CrossRef]
- Al-Bakri, J. T., Salahat, M., Suleiman, A., Suifan, M., Hamdan, M. R., Khresat, S., & Kandakji, T. (2013). Impact of climate change and land use changes on water and food security in Jordan: Implications for transcending "the tragedy of the commons". *Sustainability*, *5*(2), 724–748. [CrossRef]
- Anikwe, M. A. N. (2010). Carbon storage in soils of Southeastern Nigeria under different management practices. *Carbon Balance and Management*, *5*(5), 5. [CrossRef]

- Asinwa, I. O., Olajuyigbe, S. O., & Adegeye, A. O. (2018). Tree species diversity, composition and structure in Ogun River watershed, Southwestern Nigeria. *Journal of Forestry Research and Management*, *15*(1), 114–134.
- Azeez, I. O., Popoola, L., & Shulamite, I. O. (2017). An assessment of the forest regeneration potential of the taungya system of farming in Oyo State, South-Western Nigeria. *Southern Forests*, *79*(2), 143–151. [CrossRef]
- Bello, A., Salami, K. D., Odewale, M. A., Kareem, A. A., & Gidado, H. A. (2022). Woody plant species composition, structure, and diversity in Rabadi Forest Reserve, Jigawa State, Nigeria. *Journal of Forest Science and Environment*, *7*, 23–31.
- Boboye, O., & Jimoh, S. O. (2016). Pattern of plant species diversity in a dry forest ecosystem of Nigeria. *Journal of Forestry Research and Management*, *13*, 31–47.
- Brady, N. C., & Weil, R. R. (2016). *The nature and properties of soils* (15th ed). Pearson Prentice Hall.
- Celik, I. (2005). Land use effect on physical properties and organic matter of soil in a Southern Mediterranean Highland of turkey. *Soil and Tillage Research*, *83*(2), 270–277. [CrossRef]
- Etuk, I. M., Akpan, M. P., & Etuk, A. I. (2013). Biodiversity conservation: A critical component of green economy. Proceeding of the 36th Annual Conference of the Forestry Association of Nigeria (pp. 162–168). The Green Economy: Balancing Environment Sustainability and Livelihoods in an Emerging Economy.
- Falade, O. F., & Taiwo, A. J. (2020). Forest structure and carbon stocks of Osun-Osogbo sacred Grove, Nigeria. *International Journal of Biodiversity and Conservation*, *12*(1), 23–30.
- Fasona, M. J., Akintuyi, A. O., Udofia, S. K., Akoso, T. M., Ariori, A., Adeonipekun, P. A., et al. (2018). Deforestation and land-cover changes in the forest reserves of Southwest Nigeria. *Lagos Journal of Geoinformation Science*, *5*, 67–87.
- Food and Agriculture Organization (2018). *The state of the World's forests, 2018 - Forest Pathways to Sustainable Development*; 2022. www.fao.org/forestry/site/1223/.
- Gerke, J. (2022). The central role of soil organic matter in soil fertility and carbon storage. *Soil Systems*, *6*(2), 1–14. [CrossRef]
- Grossman, R. B., & Reinsch, T. G. (2002). Bulk density and linear extensibility. In J. H. Dane & G. C. Top (Eds.), *Methods of soil analysis part 4. Physical methods. Soil Science Society of America Book Series* (vol. *5*). ASA and SSA Madison.
- Haastrup, N. O., Agboje, I., Lawal, M. O., Fadimu, B. O., Sangotoyinbo, O. A., Mangodo, C., Oripelaye, O. S., Ganiyu, O. A., & Fadoyin, A. S. (2020). Composition of tree species in Onigambari Forest Reserve, Oyo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *24*(10), 1815–1819. [CrossRef]
- Ibe, A. E., Onuoha, G. N., Adeyemi, A. A., Ogueri, C. U., Ibe, M. A., & Okafor, D. C. (2014). Assessment of ecological status and tree diversity in Ohaji/Egbema watershed, SouthEastern, Nigeria. *International Journal of Natural and Applied Sciences*, *10*(1), 21–33.
- Ihenyen, J., Okoegwale, E. E., & Menshak, J. (2009). Timber resource status of Ehor Forest Reserve Uhunmwode Local Government area of Edo State, Nigeria. *Natural Science Journal*, *7*(8), 19–25.
- Khresat, S., Al-Bakri, J., & Al-Tahhan, R. (2007). Impacts of land use/cover change on soil properties in the Mediterranean region of Northwestern Jordan. *Land Degradation and Development*, *18*, 1–15.
- Kleber, M., Nico, P. S., Plante, A. F., Filley, T., Kramer, M., Swanston, C., & Sollins, P. (2011). Old and stable soil organic matter is not necessarily chemically recalcitrant. Implications for modelling concepts and temperature sensitivity. *Global Change Biology*, *17*(2), 1097–1107. [CrossRef]
- Lal, R. (2002). Soil carbon dynamic in cropland and rangeland. *Environmental Pollution*, *116*(3), 353–362. [CrossRef]
- Lal, R. (2013). Soil carbon management and climate change. *Carbon Management*, *4*(4), 439–462. [CrossRef]
- Magurran, A. E. (2004). *Ecological diversity and its measurement*. Princeton University Press.
- Margalef, D. R. (1958). Information theory in ecology. *General System Bulletin*, *3*, 36–71.
- Mhawish, Y. M. (2015). Effect of land-use/cover change in physical and chemical soil properties within an agricultural ecosystem of Ajloun Area-Jordan. *International Journal of Geology, Earth and Environmental Sciences*, *5*(2), 1–17.
- Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being: Synthesis*. Island Press.
- Mittermeier, R. A., Robles-Gil, P., Hoffman, M., Pilgrim, J. D., Brooks, T., Mittermeier, C. G., & Da Fonseca, G. A. (2004). *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. Conservation International in Association with CEMEX.
- Moses, F., & Anthony, K. (2015). Assessment of trees species diversity in Taia riverine Forest along Njala community, Moyamba District, Sierra Leone. *Journal of Sustainable Environmental Management*, *7*, 11–20.
- Moshood, F. J., Muhali, M. O., & Ngwuli, C. P. (2022). Species diversity and public perceptions of urban trees in Ilorin metropolis, Kwara State. In A. O. Oluwadare, O. F. Akinyemi, O. Idumah, D. A. Akintunde-Alo & A. Lawal (Eds.) *Forestry and the challenge of insecurity, climate change and covid-19 pandemic in Nigeria*. Proceedings of the 8th Biennial National Conference of the Forests and Forest Products Society, Nigeria (pp. 24–32).
- Naidu, M. T., & Kumar, O. A. (2016). Tree diversity, stand structure and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *Journal of Asia-Pacific Biodiversity*, *9*(3), 328–334. [CrossRef]
- Nurudeen, T. A., Aina-oduntan, O. A., Awotedu, B. F., & Salami, K. D. (2017). Structure and tree species diversity pattern of Gambari Forest reserve Southwestern Nigeria. *International Journal of Applied Research and Technology*, *6*(6), 21–29.
- Olajuyigbe, S. (2018). Green gold of Africa: Nigeria's Forest, a depleted but resilient renewable resource. *Irish Forestry*, *75*, 92–112.
- Olajuyigbe, S. O., & Adaja, A. A. (2014). Floristic composition, tree canopy structure and regeneration in a degraded tropical humid rainforest in Southwest Nigeria. *Tanzania Journal of Forestry and Nature Conservation*, *84*(1), 5–23.
- Olajuyigbe, S. O., & Akwarandu, K. E. (2019). Floristic composition and stand structure in a tropical watershed Forest: Implications for biodiversity conservation. *Environtropica*, *15*, 79–94.
- Olajuyigbe, S. O., & Jeminiwa, M. S. (2018). Tree species diversity and structure of Eda Forest Reserve, Ekiti State, Nigeria. *Asian Journal of Research in Agriculture and Forestry*, *2*(1), 1–12. [CrossRef]
- Olayode, O. O., Bada, S. O., & Popoola, L. (2015). Carbon stock in teak stands of selected forest reserves in Southwestern Nigeria. *Environmental and Natural Resources*, *5*(3), 109–115.
- Olujobi, O. J., Adeyinka, M. A., & Bashiru, W. A. (2022). Soil carbon storage as influenced by land use types in Akure forest Reserve, Ondo State, Nigeria. *International Journal of Scientific Advances*, *3*(3), 408–411. [CrossRef]
- Oluwajuwon, T. V., Alo, A. A., Ogana, F. N., & Adekugbe, O. A. (2021). Forest cover dynamics of a lowland rainforest in Southwestern Nigeria using GIS and remote sensing techniques. *Journal of Geographic Information System*, *13*(2), 83–97. [CrossRef]
- Onwuka, B. M., & Adesemuyi, E. A. (2019). Spatial distribution of soil bulk density, organic carbon and pH under different land use systems along Umuahia south Local Government area of Abia State in Southeastern Nigeria. *Notulae Scientia Biologicae*, *11*(2), 298–303. [CrossRef]
- Price, P. W. (1997). *Insect ecology* (3rd ed). Wiley.
- Salami, K. D., & Akinyele, A. O. (2017). Tree species diversity and abundance in degraded Gambari Forest Reserve, SouthWest Nigeria. In O. Ojurongbe (Ed.). *Translating research findings into policy in developing countries. Contributions from Humboldt Kolleg* (pp. 276–287). LAP Lambert Academic Publishing.
- Salami, K. D., Kareem, A. A., Folohunsho, W. O., Ogunwande, O. A., & Akinyemi, G. O. (2022). Plant species biodiversity, composition and regeneration potential in Kurba Forest Reserve, Bauchi State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *15*(5), 676–687.
- Shamaki, S. B., Bello, A. G., & Dikko, A. A. (2015). Tree species Density and Distribution in Dabagi Forest Reserve in Semi-Arid Region of Nigeria. In Proceedings of the 4th Biennial National Conference of the Forest and Forest Products Society, Nigeria (pp. 144–149).
- Smaling, E. M. A., Nandwa, S. M., & Janssen, B. H. (1997). Soil fertility in Africa is at stake. In R. J. Buresh, P. A. Sanchez & F. Calhoun (Eds.). *Replenishing soil fertility in Africa* (ss. 47–61). Soil Science Society of America Special Publication. [CrossRef].
- Ufot, U. O., Iren, O. B., & Chikere-Njoku, C. U. (2016). Effects of land use on soil physical and chemical properties in Akokwa area of Imo State, Nigeria. *International Journal of Life Sciences Scientific Research*, *2*(3), 273–278.
- Wajim, J. (2020). Impact of deforestation on socio-economic development and environment in Nigeria. *International Journal of Social Sciences and Humanities Invention*, *7*(3), 5852–5863. [CrossRef]
- Walkley, A., & Black (1934). An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and inorganic soil constituents. *Soil Science*, *63*, 251–263.
- Wasige, J. E., Groen, T. A., Rwamukwaya, B. M., Tumwesigye, W., Smaling, E. M. A., & Jetten, V. (2014). Contemporary land use/land cover types determine soil organic carbon stocks in Southwest Rwanda. *Nutrient Cycling in Agroecosystems*, *100*(1), 19–33. [CrossRef]