

## FOREST STRUCTURE AND CARBON HOARD OF A NATURAL FOREST IN A TROPICAL RAINFOREST AREA

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### ABSTRACT

This study aimed to assess the forest structure and carbon storage of a natural forest in Southwestern, Nigeria. All trees with Dbh above 10cm were completely enumerated. Tree growth variables, namely the Diameter at the base (Db), Diameter at breast height (Dbh), Diameter at the middle (Dm), Diameter at the top (Dt) and height, were measured for basal area and volume estimation and their frequency of occurrence was ascertained for tree diversity assessment. The results of the study revealed that a total of 56 trees distributed among 21 species and 11 families were encountered in the study area. Some of these species were *Acacia ataxacantha*, *Blighiasapida*, *Alstonia bonnie*, *Ceibapentandra*, *Celtiszenkeri*, *Khayaivorensis*, etc. *Funtumiaelastica* had the highest frequency of occurrence (11 stems) with a Relative Density of 19.64%. So, it could be regarded as the most abundant species in the natural forest. Shannon Wiener index of 2.62 was recorded for this study with an evenness value of 0.86. Total Above Ground Biomass (ABG) of 53.64 g/m<sup>2</sup>, equivalent to 26.82 tonnes of Carbon was obtained. The results from this study show that the current rate of forest degradation is a threat to biodiversity conservation and climate change mitigation. Therefore, conservative measures must be put in place to protect the forest from further degradation, and this will also go a long way in mitigating climate change by serving as carbon sinks.

Keywords: Rainforest, Forest Structure, Biodiversity, Carbon Storage

### INTRODUCTION

Tropical rainforests support life because of their richness in plant species composition and fauna diversity (Zakaria et al., 2016). They are mostly dominated by a wide variety of broad-leaved trees, which form a dense canopy and make it one of the most complex ecosystems (Lawal and Adekunle, 2013). The tropical rainforest is a vital ecosystem that provides services, such as raw materials, reservoirs for biodiversity, habitat to diverse animal species, soil protection, sources of timber, medicinal plants, carbon sequestration, watershed protection and also forms the livelihood for many different human settlements, including 60 million indigenous people (FAO, 2011c). Besides, it contains up to 82% of the terrestrial plant biomass, interlinked with atmospheric CO<sub>2</sub> levels, through the carbon cycle.

Tree species diversity is one of the important components of the tropical forest and is fundamental to the rainforest ecosystem. Moreover, the favorable environmental conditions and the tropical rainforest's canopy structure are special features that promote species diversity. About 70–90% of living flora and fauna depend on trees for survival in the rainforest ecosystem (Tilman and Lehman, 2001). The high tree species diversity of rainforests is partly responsible for the intense pressure on them and therefore have resulted into species extinction, biodiversity reduction, and primary productivity decrease (Wilcox 1995).

Carbon sequestration is a way to mitigate the accumulation of greenhouse gases in the atmosphere released by burning fossil fuels and other anthropogenic activities. One of the objectives of Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme is to mitigate climate change through climate-smart forestry and conserve biodiversity. More so, the objective of forest management has been focusing on altering deforestation and forest degradation targeting the enormous benefits of REDD+ programme in climate change response. Biomass assessments are very important for many purposes and are used in the measurement of carbon stock of the forest stands.

The tropical forest ecosystem is an important carbon sink source containing most of the aboveground terrestrial organic Carbon. Carbon sequestration is the storage of Carbon to mitigate global warming. The forest ecosystem plays a very important role in the global carbon cycle. Forests are the natural storehouses of biomass and different life form. Thus, the tropical forests sequester and store more carbon

than any other terrestrial ecosystem and are an important natural brake on climate change (Adalarsan et al., 2007). Forests fix, store and emit Carbon by photosynthesis, respiration, decomposition and disturbances through a series of stages in the life cycle from regeneration to harvest (Alves et al., 2010). Human activities are responsible for changing carbon stocks in these pools by changing the land use pattern of the area. Whether and to what degree biodiversity influences carbon stocks in tropical forests is still uncertain. However, experimental work in other ecosystems has shown that biodiversity often promotes stability and primary productivity.

## METHODOLOGY

This study was carried out at Obanla natural forest, a portion of forest left behind during land clearing for the establishment of the Federal University of Technology, Akure, Ondo State, Nigeria, in 1981. As a result, the forest is rich in tree and animal species diversity. It is used presently as a botanical garden and practical field for dendrology courses by students and staff of the Department of Forestry and Wood Technology, FUTA. This forest was formerly part of the Akure forest reserve located between four towns: Akure, Idanre, Ondo and Ilesa. Specifically, Obanla natural forest is located along Akure-Ilesa road in the North Western part of FUTA on Longitude 050 18'E and Latitude 07°17'N. Generally, the vegetation zone is the tropical humid lowland forest ecosystem. FUTA occupies a total land area of 640 ha. As a result of physical development, the original native vegetation has been removed, leaving behind this small portion. The map of the study area is presented in figure 1.

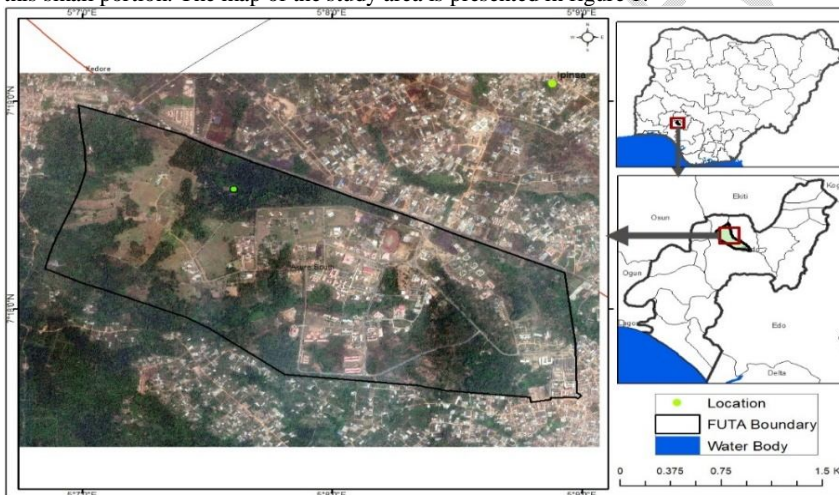


Figure 1: Map of the study area

## METHOD OF DATA COLLECTION

### Sampling Technique

A complete enumeration method was adopted in this study. GPS Coordinates points were taken on the boundaries of forest land to generate the digitized forest map (figure 1).

### Tree enumeration

All trees with Dbh above 10 cm were tagged for enumeration. Tree growth variables such as the Diameter at the base (Db), Diameter at breast height (Dbh), Diameter at the middle (Dm), Diameter at the top (Dt) and Height were measured for basal area and volume estimation.

### Tree Diversity Assessment

Frequencies of occurrence of each of the tree species encountered was obtained. The scientific names of all trees tagged and enumerated were recorded. Where a tree's botanical name was not known, such tree was identified by its commercial or local name and later translated to botanical name using Gbile (1984) and Keay (1989).

## METHOD OF DATA ANALYSIS

### Basal Area Estimation

Tree basal area was estimated using equation 1.

$$BA = \frac{\pi D^2}{4} \dots \dots \dots \text{eqn 1}$$

Where BA = Basal Area (m<sup>2</sup>), D = Dbh (m) and  $\pi=3.142$

### Tree Volume Estimation

The volume of all trees was calculated using the Newton formula in eqn 2 (Husch et. al., 2003)

$$V = \frac{\pi H}{24} (D_b^3 + 4 D_m^3 + D_t^3) \dots \dots \dots \text{eqn 2}$$

Where, V= Volume of tree (m<sup>3</sup>); Db= Diameter at the base (m); Dm= Diameter at the middle (m); Dt= Diameter at the top (m); H= height (m).

### Tree Species Diversity Indices

(1) Relative density (%) of each species was computed using eqn 3.

$$RD = \frac{n_i}{N} \times 100 \dots \dots \dots \text{eqn 3}$$

Where RD is the relative density of the species; ni is the number of individuals of species i, and N is the total number of all individual trees.

(2) Species Relative Dominance (%) of each species was estimated using eqn 4

$$RD_o = \frac{\sum Ba_i \times 100}{\sum Ba_n} \dots \dots \dots \text{eqn 4}$$

Where: Bai = basal area of individual tree belonging to species I and Ban = stand basal area.

(3) The Species evenness (E): Species evenness in each plot was determined using Shannon's equitability (EH), which was obtained using eqn 5

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^S P_i \ln(P_i)}{\ln(S)} \dots \dots \dots \text{eqn 5}$$

(4) Important Value Index (IVI%) was computed using eqn 6

$$IVI = \frac{(RD + RD_o)}{2} \dots \dots \dots \text{eqn 6}$$

Where RD is the Relative Density of the species; RD<sub>o</sub> is the Relative Dominance of the species.

(5) Shannon-Wiener Diversity Index: Species diversity index was calculated using eqn 7

$$H' = -\sum_{i=1}^S p_i \ln(p_i) \dots \dots \dots \text{eqn 7}$$

Where  $H_1$  = Shannon diversity index,  $S$  = the total number of species in the community,  $P_i$  = proportion  $S$  (species in the family) made up of the  $i$ th species and  $\ln$  = natural logarithm.

#### Tree Density, Biomass and Carbon stock

Density of each tree species was obtained from literature and the internet. The density was multiplied by the volume to obtain the biomass (eqn 8). The biomass estimated was used to determine the amount of carbon stock in each of the tree since it is known that 50% of biomass estimate contains the Carbon (eqn 9) (Samaka et al., 2007). The total tree biomass and Carbon for the entire forest were obtained by adding the biomass and Carbon of all the trees.

$$\text{Biomass} = \text{Density} \times \text{Volume (kg)} \dots\dots\dots (\text{eqn 8})$$

$$\text{Carbon estimation} = \frac{\text{Biomass}}{2} \dots\dots\dots (\text{eqn 9})$$

#### RESULTS

The results of tree species composition in the study area are presented in Table 1. A total of 56 trees distributed among 21 tree species were encountered in this study. *Funtumia elastica* was the dominant tree species represented by 11 stems. This was followed by *Musangacecropiodes* with 10 stems. Tree species represented by a single stem were *Acacia ataxacantha*, *Blighiasapida*, *Celtiszenkeri*, *Cola milenii*, *Newbouldialaavis*, *Pterygotasp*, *Symphonioglobulifera*, *Trichilimonadelpha* and *Triplochitonscleroxylon*. *Funtumia elastica* had the highest Shannon Wiener index value of 0.32 while *Acacia ataxacantha*, *Blighiasapida*, *Celtiszenkeri*, *Cola milenii*, *Newbouldialaavis*, *Pterygotasp*, *Symphonioglobulifera*, *Trichilimonadelpha* and *Triplochitonscleroxylon* all had Shannon Wiener index value of 0.07. Species evenness of 0.86 was recorded for the study area.

**Table 1: Tree Species Composition of the study area**

S/n	Species	Family	Frequency	H <sup>1</sup>	E
1	<i>Acacia ataxacantha</i> (DC.) Kyal&Boatwr.	Fabaceae	1	-0.07	-0.02
2	<i>Albizialebeck</i> (L.) Benth	Fabaceae	6	-0.24	-0.08
3	<i>Alstonia bonnie</i> De Wild	Apocynaceae	2	-0.12	-0.04
4	<i>Blighiasapida</i> K.D. Koenig	Sapindaceae	1	-0.07	-0.02
5	<i>Brachystegia eurycoma</i> Harms	Fabaceae	2	-0.12	-0.04
6	<i>Ceibapentandra</i> (L.) Gaertn	Malvaceae	3	-0.16	-0.05
7	<i>Celtiszenkeri</i> L.	Cannabaceae	1	-0.07	-0.02
8	<i>Cola millenii</i> K.Schum.	Malvaceae	1	-0.07	-0.02
9	<i>Ficusexasperata</i> Vahl	Moraceae	3	-0.16	-0.05
10	<i>Funtumia elastica</i> Stapf	Apocynaceae	11	-0.32	-0.11
11	<i>Khayaivorensis</i> A. Chev.	Meliaceae	1	-0.07	-0.02
12	<i>Khayasengalensis</i> (Desr.) A. Juss	Meliaceae	1	-0.07	-0.02
13	<i>Lecaniodiscus cupanioides</i> Planch. ex Benth	Sapindaceae	1	-0.07	-0.02
14	<i>Musangacecropioides</i> R.Br. & Tedile	Urticaceae	10	-0.31	-0.10
15	<i>Myrianthus arboreus</i> P. Beauv. 1804	Urticaceae	5	-0.22	-0.07
16	<i>Newbouldialaavis</i> (P.Beauv.) Seem. ex Bureau	Bignoniaceae	1	-0.07	-0.02

17	<i>Pterygotasp Schott &amp; Endl.</i>	<i>Malvaceae</i>	1	-0.07	-0.02
18	<i>Ricinodendron heudelotii (Baill.) Heckel</i>	<i>Euphorbiaceae</i>	2	-0.12	-0.04
19	<i>Symphonia globulifera L.f.</i>	<i>Clusiaceae</i>	1	-0.07	-0.02
20	<i>Trichilimon adelpha (Thonn.) JJ de Wilde</i>	<i>Meliaceae</i>	1	-0.07	-0.02
21	<i>Triplochiton scleroxylon K. Schum.</i>	<i>Malvaceae</i>	1	-0.07	-0.02
<b>Total</b>			<b>56</b>	<b>2.62</b>	<b>-0.86</b>

\*Key:  $H^1$  = Shannon Wiener index,  $E$  = Species Evenness

Table 2 is on the summary of tree growth variables. Total tree Dbh ranged from 15.5-333.6cm. It was found to be highest for *Funtumia elastica* with a dbh of 333.6cm and *Lecaniodiscus cupanioides* had the lowest value of 11.60cm. It was recorded that *Lecaniodiscus cupanioides* had the lowest basal area of 0.01m<sup>2</sup> and the highest was recorded for *Ceibapentandra* with 1.02m<sup>2</sup>. The total volume of all the tree species also ranged from 0.06-17.84m<sup>3</sup>. It was found to be lowest for *Lecaniodiscus cupanioides* with a value of 0.06m<sup>3</sup> and highest for *Ceibapentandra* with a value of 17.84m<sup>3</sup>. Some of the species with low tree volume were *Acacia ataxacantha* (0.34m<sup>3</sup>), *Cola milenii* (0.78m<sup>3</sup>), *Newbouldialaavis* (0.16m<sup>3</sup>) etc. Generally, the forest had a total Dbh of 2032cm, total basal area of 8.12m<sup>2</sup> and total tree volume of 113.13m<sup>3</sup>.

**Table 2: Total Dbh, Basal Area and Volume of each of the trees species encountered at the study site**

S/n	Tree Sp	Frequency	Total Dbh (cm)	Total BA(m <sup>2</sup> )	Total Volume (m <sup>3</sup> )
1	<i>Acacia ataxacantha</i>	1	23	0.04	0.34
2	<i>Ficus exasperate</i>	3	54.2	0.09	1.04
3	<i>Albizia spp.</i>	6	250.7	0.96	8.54
4	<i>Alstonia bonnie</i>	2	64	0.18	3.03
5	<i>Blighiasapida</i>	1	58.5	0.27	2.2
6	<i>Brachystegia eurycoma</i>	2	101.5	0.52	8.9
7	<i>Ceibapentandra</i>	3	179.9	1.02	17.84
8	<i>Celtis zenkeri</i>	1	94	0.69	15.12
9	<i>Cola milenii</i>	1	22.7	0.04	0.78
10	<i>Funtumia elastica</i>	11	333.6	0.98	10.12
11	<i>Khaya ivorensis</i>	1	33	0.09	3.71
12	<i>Khaya sengalensis</i>	1	100.5	0.79	16.19
13	<i>Lecaniodiscus cupanioides</i>	1	11.6	0.01	0.06
14	<i>Musangacecropioides</i>	10	301.1	0.75	4.83
15	<i>Myrianthus arboreus</i>	5	79.3	0.11	2.43
16	<i>Newbouldialaavis</i>	1	18.4	0.03	0.16
17	<i>Pterygotasp</i>	1	85.3	0.57	6.41

18	<i>Ricinodendronheudelotii</i>	2	104.5	0.44	3.18
19	<i>Symphoniaglobulifera</i>	1	15.5	0.02	0.2
20	<i>Trichiliamonadelpha</i>	1	24	0.05	2.29
21	<i>Triplochitonscleroxylon</i>	1	77	0.47	5.77
<b>Grand Total</b>		<b>56</b>	<b>2032.3</b>	<b>8.12</b>	<b>113.13</b>

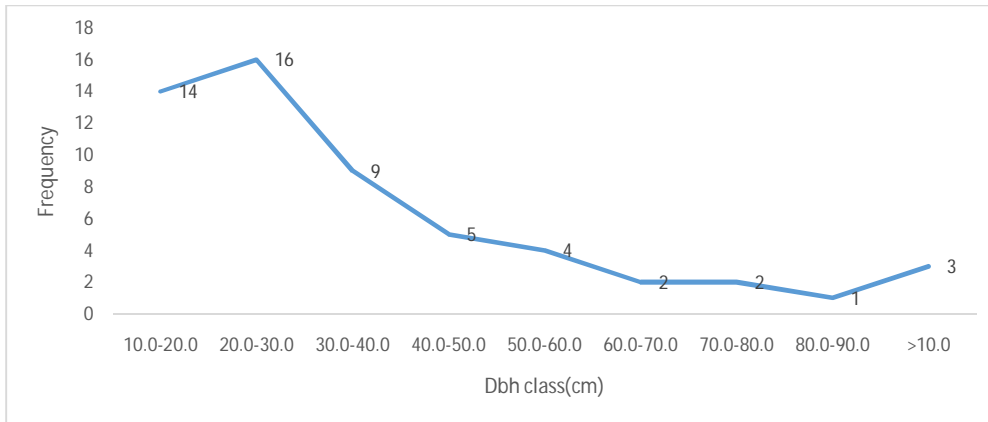
Importance Value Index (IVI%) of tree species is presented in table 3. It was found that *Funtumiaelastica* was the most important tree species in the study area with IVI of 15.96%, and *Lecaniodiscuscupanioides* had the lowest IVI of 0.96%. IVI of 1.15%, 3.22%, 11.25%, 2.89%, 2.55%, 5.00%, 8.98%, 5.17% and 1.14% were obtained for *Acacia ataxacantha*, *Ficusexasperata*, *Albizialebek*, *Alstonia bonnie*, *Blighiasapida*, *Brachystegiaeurycoma*, *Ceibapentandra*, *Celtiszenkeri* and *Cola milenii* respectively.

**Table 3: Species Importance Value Index (IVI)**

s/n	Species	Freq	RD(%)	RDo (%)	IVI(%)
1	<i>Acacia ataxacantha</i>	1	1.79	0.51	1.15
2	<i>Ficusexasperata</i>	3	5.36	1.09	3.22
3	<i>Albizialebek</i>	6	10.71	11.79	11.25
4	<i>Alstonia bonnie</i>	2	3.57	2.22	2.89
5	<i>Blighiasapida</i>	1	1.79	3.31	2.55
6	<i>Brachystegiaeurycoma</i>	2	3.57	6.42	5.00
7	<i>Ceibapentandra</i>	3	5.36	12.60	8.98
8	<i>Celtiszenkeri</i>	1	1.79	8.55	5.17
9	<i>Cola milenii</i>	1	1.79	0.50	1.14
10	<i>Funtumiaelastica</i>	11	19.64	12.28	15.96
11	<i>Khayaivorensis</i>	1	1.79	1.05	1.42
12	<i>Khaya senegalensis</i>	1	1.79	9.77	5.78
13	<i>Lecaniodiscuscupanioides</i>	1	1.79	0.13	0.96
14	<i>Musangacecropioides</i>	10	17.86	9.27	13.56
15	<i>Myrianthusarbores</i>	5	8.93	1.29	5.11
16	<i>Newbouldialaavis</i>	1	1.79	0.33	1.06
17	<i>Pterygotaspp</i>	1	1.79	7.04	4.41
18	<i>Ricinodendronheudelotii</i>	2	3.57	5.35	4.46
19	<i>Symphoniaglobulifera</i>	1	1.79	0.23	1.01
20	<i>Trichiliamonadelpha</i>	1	1.79	0.56	1.17
21	<i>Triplochitonscleroxylon</i>	1	1.79	5.74	3.76
<b>Total</b>		<b>56</b>	<b>100</b>	<b>100.00</b>	<b>100.00</b>

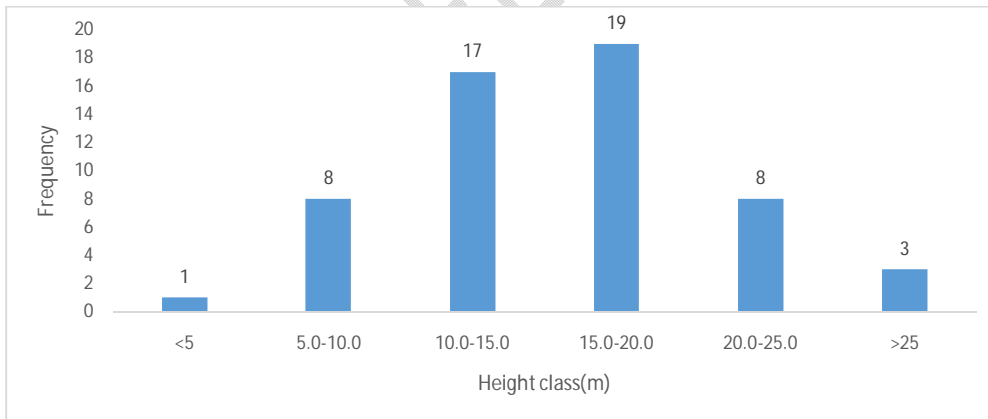
Figure 2 shows the distribution of tree species according to Dbh class. It was observed that most of the trees (16 stems) fell in the Dbh class of 20-30cm. Also, 14 stems fell in the dbh class of 10-20cm, and 9

stems fell in the Dbh class of 30-40cm. Only a few trees fell in the dbh class of 40-50cm (5stems),50-60cm (4 stems) ,60-70cm (2 stems) and 70-80cm (2 stems). Only one and three treeswere in theDbh class of 80-90cm and above 100cm



**Figure 2: Tree species distribution curve according to DBH class**

Figure 3 is on tree species distribution according to height class. It was observed that most of the trees (19 stems) fell in the height class of 15-20m, and about 17 trees were in the height class of 10-15m. Only one tree fell in the height class below 5m.



**Figure 3: Tree species distribution according to height class**

As shown in table 4, all the tree species encountered were distributed among 11 families. *Urticaceae* family had the highest relative density of 26.79%. This was followed by the family of Apocynaceae with RD of 23.21%, and the lowest of 1.79% was recorded for the families of Cannabaceae, Bignoniaceae and

Clusiaceae. Family Relative Dominance ranged from 0.23-25.88%. It was lowest for *Clusiaceae* and highest for *Malvaceae*. It was also observed that the family of *Malvaceae* had the highest FIV of 18.55% and *Clusiaceae* had the lowest of 2.26%. Family Important Value (FIV) of 16.36%, 3.74%, 15.75%, 5.47%, 5.03%, 10.34%, 15.62%, 2.29% and 4.56% were obtained for the families of *Fabaceae*, *Moraceae*, *Apocynaceae*, *Sapindaceae*, *Cannabaceae*, *Meliaceae*, *Urticaceae*, *Bignoniaceae* and *Euphorbiaceae* respectively.

**Table 4: Family Important Value (FIV) of tree species in the study area,**

S/N	Family	RD%	RF%	RDo%	FIV%
1	Fabaceae	16.07	14.29	18.72	16.36
2	Moraceae	5.36	4.76	1.09	3.74
3	Apocynaceae	23.21	9.52	14.5	15.75
4	Sapindaceae	3.57	9.52	3.31	5.47
5	Malvaceae	10.71	19.05	25.88	18.55
6	Cannabaceae	1.79	4.76	8.55	5.03
7	Meliaceae	5.36	14.29	11.38	10.34
8	Urticaceae	26.79	9.52	10.56	15.62
9	Bignoniaceae	1.79	4.76	0.33	2.29
10	Euphorbiaceae	3.57	4.76	5.35	4.56
11	Clusiaceae	1.79	4.76	0.23	2.26
<b>Total</b>		<b>100.00</b>	<b>100.00</b>	<b>100</b>	<b>100</b>

The results of density, volume, biomass and Carbon of each of the tree species in the study area are presented in Table 5. The highest density of 0.75g/cm<sup>3</sup> was obtained for *Acacia ataxacantha*, and the lowest of 0.23g/cm<sup>3</sup> was recorded for both *Ceibapentandra* and *Musangacecropioides*. The tree volume ranged from 0.06-16.19m<sup>3</sup>, and the biomass also ranged from 0.02g/m<sup>2</sup>- 9.71g/m<sup>2</sup>. Similarly, Carbon obtained for the tree species ranged from 0.01-4.86 tonnes. *Khayasengalensis* (Desr.) A. Juss had the highest biomass (9.71 g/m<sup>2</sup>) and carbon storage potential (4.86 tonnes) at this site, and *Ficusexasperata* Vahl had the lowest biomass and carbon storage potential of 0.02m<sup>2</sup> and 0.01tonnes.

**Table 1: Density, Volume, Biomass and Carbon of trees in the study area.**

S/N	Species name	Volume(m <sup>3</sup> )	Density (g/cm <sup>3</sup> )	Biomass (g/m <sup>2</sup> )	Carbon (tonnes)
1	<i>Ceibapentandra</i> (L.) Gaertn	2.90	0.23	0.67	0.33

2	<i>Albizialebbeck (L.) Benth</i>	1.01	0.55	0.56	0.28
3	<i>FuntumiaelasticaStapf</i>	0.58	0.51	0.30	0.15
4	<i>Brachystegiaeurycoma Harms</i>	8.23	0.52	4.28	2.14
5	<i>Triplochitonscleroxylon K. Schum.</i>	5.77	0.32	1.84	0.92
6	<i>Trichiliamonadelpha (Thonn.) JJ de Wilde</i>	2.29	0.50	1.15	0.57
7	<i>Acacia ataxacantha (DC.) Kyal&amp;Boatwr.</i>	0.34	0.75	0.26	0.13
8	<i>Albizialebbeck (L.) Benth</i>	2.02	0.55	1.11	0.55
9	<i>Albizialebbeck (L.) Benth</i>	3.44	0.55	1.89	0.95
10	<i>Albizialebbeck (L.) Benth</i>	1.35	0.55	0.74	0.37
11	<i>Ceibapentandra (L.) Gaertn</i>	1.31	0.23	0.30	0.15
12	<i>Brachystegiaeurycoma Harms</i>	0.67	0.52	0.35	0.17
13	<i>Myrianthusarboreus P. Beauv 1804</i>	0.51	0.54	0.27	0.14
14	<i>Myrianthusarboreus P. Beauv 1804</i>	0.57	0.54	0.31	0.15
15	<i>Myrianthusarboreus P. Beauv 1804</i>	0.22	0.54	0.12	0.06
16	<i>Myrianthusarboreus P. Beauv 1804</i>	0.57	0.54	0.31	0.15
17	<i>Myrianthusarboreus P. Beauv 1804</i>	0.56	0.54	0.30	0.15
18	<i>Albizialebbeck (L.) Benth</i>	0.26	0.55	0.14	0.07
19	<i>Albizialebbeck (L.) Benth</i>	0.46	0.55	0.25	0.13
20	<i>Lecaniodiscuscupanioides Planch. ex Benth</i>	0.06	0.57	0.03	0.02
21	<i>Newbouldialaervis (P.Beauv.) Seem. ex Bureau</i>	0.16	0.31	0.05	0.03
22	<i>FicusexasperataVahl</i>	0.89	0.40	0.36	0.18
23	<i>SymphoniaglobuliferaL.f.</i>	0.20	0.58	0.11	0.06
24	<i>FicusexasperataVahl</i>	0.11	0.40	0.04	0.02
25	<i>Ricinodendronheudelotii (Baill). Heckel</i>	1.82	0.36	0.65	0.33
26	<i>FuntumiaelasticaStapf</i>	0.29	0.51	0.15	0.08
27	<i>FicusexasperataVahl</i>	0.04	0.40	0.02	0.01
28	<i>Celtiszenkeri L.</i>	15.12	0.59	8.92	4.46
29	<i>Alstonia bonnie De Wild</i>	2.00	0.70	1.40	0.70
30	<i>Alstonia bonnie De Wild</i>	1.03	0.40	0.41	0.21
31	<i>Cola milleniiK.Schum.</i>	0.78	0.40	0.31	0.16
32	<i>FuntumiaelasticaStapf</i>	1.34	0.51	0.68	0.34
33	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.31	0.23	0.07	0.04
34	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.65	0.23	0.15	0.07
35	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.41	0.23	0.09	0.05
36	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.51	0.23	0.12	0.06
37	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.65	0.23	0.15	0.08
38	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.30	0.23	0.07	0.03
39	<i>Musangacecropioides R.Br. &amp;Tedile</i>	0.23	0.23	0.05	0.03
40	<i>FuntumiaelasticaStapf</i>	0.24	0.51	0.12	0.06
41	<i>FuntumiaelasticaStapf</i>	0.28	0.51	0.14	0.07

42	<i>Funtumiaelastica</i> Stapf	0.55	0.51	0.28	0.14
43	<i>Funtumiaelastica</i> Stapf	1.19	0.51	0.61	0.30
44	<i>Musangacecropioides</i> R.Br. &Tedile	0.54	0.23	0.13	0.06
45	<i>Musangacecropioides</i> R.Br. &Tedile	0.61	0.23	0.14	0.07
46	<i>Musangacecropioides</i> R.Br. &Tedile	0.62	0.23	0.14	0.07
47	<i>Blighiasapida</i> K.D. Koenig	2.20	0.72	1.59	0.79
48	<i>Funtumiaelastica</i> Stapf	0.24	0.51	0.12	0.06
49	<i>Ricinodendronheudelotii</i> (Baill). Heckel	1.36	0.36	0.49	0.25
50	<i>Ceibapentandra</i> (L.) Gaertn	13.63	0.23	3.14	1.57
51	<i>Funtumiaelastica</i> Stapf	2.13	0.51	1.08	0.54
52	<i>Funtumiaelastica</i> Stapf	0.60	0.51	0.31	0.15
53	<i>Khayasengalensis</i> (Desr.) A. Juss	16.19	0.60	9.71	4.86
54	<i>Khayaivorensis</i> A. Chev.	3.71	0.44	1.63	0.82
55	<i>Funtumiaelastica</i> Stapf	2.68	0.51	1.37	0.68
56	<i>Pterogota</i> spp. Schott &Endl.	6.41	0.57	3.65	1.83
<b>Total</b>		<b>113.13</b>	<b>25.01</b>	<b>53.64</b>	<b>26.82</b>

Table 6 shows the summary of the tree basal area, volume, biomass, Carbon and tree diversity indices obtained in the study area. A total of 56 trees were encountered in the study area with a Shannon Weiner index of 2.62 and spp. evenness of 0.86. Mean basal area and Total basal area had the value of 0.15 and 8.12, Mean volume and Total Volume had a value of  $2.02m^3$  and  $113.13m^3$  respectively. Similarly, mean biomass and total biomass were  $0.96 g/m^2$  and  $53.64 g/m^2$  respectively. The mean and Total Carbon that was recorded are 0.48 and 26.82tonnes

**Table 2: Summary of Tree Basal Area, Volume, Biomass, Carbon and Tree Diversity Indices**

Diversity indices & tree growth variables	Values
No of trees	56
Shannon Weiner index	2.62
Species Evenness	0.86
Mean Basal Area ( $m^2$ )	0.15
Total Basal Area ( $m^2$ )	8.12
Mean Volume ( $m^3$ )	2.02
Total Volume ( $m^3$ )	113.13
Mean Biomass ( $g/m^2$ )	0.96
Total Biomass ( $g/m^2$ )	53.64
Mean Carbon (tonnes)	0.48
Total Carbon (tonnes)	26.82

The relationship between tree growth variables is shown in table 7. There is a strong positive correlation value of 0.66 between Dbh and height. Also, a positive relationship of 0.85 occurred between Dbh and volume, 0.97 between Dbh and basal area, 0.88 between Dbh and Ln Volume, 0.95 between Dbh and Ln

BA, 0.61 between Dbh and Ln Height. Other relationship such as the height and basal area(0.60), volume and basal area (0.93) also showed a high level of relationship.

**Table 3: Correlation matrix of Dbh, Height, Basal Area and Volume**

	Dbh(cm)	Ht (m)	BA(m <sup>2</sup> )	Volume(m <sup>3</sup> )	Ln Vol. (m <sup>3</sup> )	Ln BA(m <sup>2</sup> )	Ln Ht
Dbh(cm)	1						
Ht (m)	0.66	1					
BA (m <sup>2</sup> )	0.97	0.60	1				
Volume (m <sup>3</sup> )	0.85	0.60	0.93	1			
Ln Volume (m <sup>3</sup> )	0.88	0.76	0.83	0.79	1		
Ln BA (m <sup>2</sup> )	0.95	0.69	0.86	0.71	0.89	1	
Ln Ht (m)	0.61	0.97	0.54	0.50	0.71	0.69	1

## DISCUSSION

### Forest Structure and Tree Species Diversity and Abundance of the study area.

Tree species diversity and abundance is vital to rainforest biodiversity (Olawoyin et al. 2020; Daramola et al. 2020). Forest ecosystem plays vital roles in water cycles, climate change mitigation and carbon sequestration. According to Akindele & LeMay (2006), the tropical ecosystem has been adjudged to be the richest single ecosystem in the world due to its species richness and diversity. The results of the study showed that all the encountered plants in the forest were mostly indigenous tropical hardwood species. A total of 56 trees distributed among 21 tree species were found in the study area. *Funtumia elastica* had the highest number of occurrences (11 stems) and a relative density of 19.64 %. So, it could be regarded as the most abundant species in the forest. The small number of trees in this area could be attributed to deforestation activities that have occurred in the forest in the past years and have reduced the quality of the forest. Most of the hardwood species with quality aesthetic values have been over-exploited in the forest to the extent that they are no longer available. Hence, timber contractors now resulted in harvesting low quality softwood species that have been abandoned over the years. This affirms what was reported by the study of Akinbowale et al., (2020) that despite the increase in global awareness and education on the importance of trees to humans and their environments, the rainforests continue to disappear at a very high rate.

The high species richness of the tropical rainforests is responsible for the high pressure from human anthropogenic activities (Akinbowale et al.,2020). The high number of keystone species are being threatened while some are becoming extinct. These threats have resulted majorly from land use and climate change. As one of the important components of the tropical forest, tree species diversity is fundamental to rainforest biodiversity (Olawoyin et al., 2020). Biodiversity assessment is important for the tropical forest because it enables us to understand the interrelationship between the forest and its components. Tree diversity indices were used to put the tree species composition of the forest on a scale of comparison. The higher the value of an ecological index, the higher the species richness (IIRS, 2002). The floristic composition and diversity( $H^1=2.62$ ) of this study site is still within the range of value that can be recorded for tropical rainforest, and it compares favorably with some selected forest reserves in southwest Nigeria (Adekunle et al., 2006, 2013), The high species evenness recorded showed a forest with an evenly distributed number of tree species and stems.

The distribution of tree species according to their diameter class indicates how well the forest is regenerating (Adekunle *et al.*, 2013). The diameter distribution of trees is used to represent the population structure of forests ranging from small to large diameter (Rao *et al.*, 1990). Our results revealed that as tree diameter increases, the number of trees decreases and the basal area increases as the Dbh increases. This shows that there is a high level of correlation between the Dbh and the basal area and this has resulted to a better forest growth which is expected of a rainforest. The natural forest is dominated by trees with small Diameters, which is common to tropical rainforests. Similar results have been reported by previous workers in other tropical rainforests of Nigeria (Adekunle *et al.*, 2004). The reason for few numbers of trees having Dbh greater than 50cm could be as a result of degradation activities which might have removed large trees, as well as the fact that some trees with large diameters would have been removed through selective logging. This implied that the natural forest had experienced exogenous or endogenous disturbances. Similarity, height distribution shows a forest whose population structure is expanding, ensuring its stability. The floristic composition of this site was dominated by a suite of understory species because of the dominance of small-stem trees.

Tonolli *et al.*, (2011) reported that tree stem volume is vital in forest management and sustainability. However, it requires data collection from the field. Many researchers have adopted different formulas to calculate tree volume, and these have resulted in obtaining different results because some formulas overestimate while some underestimate. However, the analytical formula, popularly known as “Newton’s formula” (Husch *et al.*, 2003), was used to calculate trees volume in this study. To use this formula, tree growth variables were measured for all trees during forest inventory. The total volume obtained for this study was below what was obtained by other researchers who have worked in the similar tropical forest ecosystems. The reason for this might be attributed to the volume estimation method and that trees with large diameter have been removed from this site in time past.

#### **Biomass and Carbon hoard of tree species encountered in the study area**

The aboveground wood biomass (AWB) of tropical forests plays important role in the global carbon cycle, and local AWB estimates provide essential data that enable the extrapolation of biomass stocks of an ecosystem (Wittmann *et al.*, 2008). Ramachandran *et al.*, (2007) reported that the absorbing of carbon dioxide from the atmosphere and moving it into the physiological system and biomass of the plants, and finally into the soil, is the only practical way of removing large volumes of this major greenhouse gas from the atmosphere into the biological system. To understand the roles of trees in climate change mitigation, it is therefore important to assess biomass because it provides information on the structure and functional attributes of the forest to mitigate climate change and sequester Carbon from the atmosphere (Bijalwanet *al.*, 2010). The total Above Ground Biomass of 53.64 g/m<sup>2</sup>, which is equivalent to 26.82 tonnes of Carbon was stored in all trees encountered at this study site. This low value of AGB and Carbon stored by this forest could be that valuable economic tree species with high carbon storage potential have been harvested from this forest. Generally, the big trees, which are always the target of tree fellers in Nigeria, contributed immensely to the carbon sink. The AGB of this forest is less than the worldwide tropical average of 278 Mg/ha (Clark *et al.*, 2001) and 206–382 Mg/ha of flood plain forests in the Peruvian Amazon (Nebelet *et al.*, 2001). The variation in these values could be attributed to factors like the methods of biomass estimation, sampling intensity, inter-location variations, soil properties and the different climatic conditions. And the degree of forest degradation that has occurred in the study area.

## CONCLUSION AND RECOMMENDATIONS

The present rate of forest degradation is a threat to biodiversity conservation and climate change mitigation in Nigeria. The biodiversity indices were high, and the forest structure shows that the forests will continue to grow until they become mature and stable forests. The results of this study have provided baseline data for the sustainable management of the natural forest. Forest trees are important carbon reservoirs and have the potential to form the chief components in the mitigation of global warming and adaptation to climate change. Estimating the carbon stocks will enable the assessment of the amount of carbon loss during deforestation. This study recommends that conservative measures should be put in place to protect forests from deforestation and that more protected areas should be established. The forests that have been degraded should also be protected from further degradation.

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