

Original Research Article

CARBON SEQUESTRATION POTENTIALS OF WOODY PLANT SPECIES IN MAKURDI ZOOLOGICAL GARDEN BENUE STATE NIGERIA

ABSTRACT

Aims: The aim of this study is to estimate the total carbon sequestration potentials of some Woody Species in Makurdi zoological garden and its contribution to climate change.

Study Design: Random sample plots of 100 m × 100 m were located in the field using a Garmin GPS and simple allometric procedures using standard carbon inventory principles and techniques that are based on data collection and analysis of carbon accumulating in the above-ground biomass, below-ground biomass, and soil carbon using verifiable modern methods, were adopted.

Place and Duration of Study: Field experiment was carried out at the Makurdi zoological garden, Benue State, Nigeria between September and October 2018.

Methodology: The non-destructive method was used with the view to determine the above ground biomass (AGB), below ground biomass (BGB), Estimate the above ground carbon (AGC), below ground carbon (BGC), Total Carbon Content (TCC) and also to estimate the Above ground CO₂ and below ground CO₂ and the total CO₂ Sequestered in the study area.

Results: A total number of 27 species of trees belonging to 16 different families were found in randomly selected sample plots. The diameter at breast height (DBH) was measured at 1.3m from ground level with a good measuring tape while heights of plants were measured using haga altimeter. The result showed that a total of 3331.05ton/ha of CO₂ was estimated to have been sequestered using the non-destructive field measurement.

Conclusion: This study strategically positions (Guinea savanna) as found in the Zoological garden in Benue State in line for UNFCCC and Kyoto carbon credit trading while substantiating the importance of preserving our indigenous forest reserves.

Keywords: Carbon Sequestration, Above Ground Biomass, Below Ground Biomass, Carbon content, Above Ground Carbon, Below Ground Carbon

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1. INTRODUCTION

Carbon sequestration is a mechanism for the removal of carbon from the atmosphere by storing it in the biosphere [6]. Carbon sequestration in terrestrial ecosystem is referred as the absorption of CO₂ from the atmosphere by photosynthesis. Photosynthesis in plants converts carbon dioxide (CO₂) to biomass, thereby reducing the carbon in the atmosphere and stores it in plant tissues above and below ground [2]. The biomass produced is mainly stored as aboveground biomass (AGB), below ground biomass (BGB), dead wood, and litter, and soil organic matter in the forest ecosystem [8]. Forest ecosystems are very important in the global carbon cycle as they sequester close to 80% and 40% of all above- and below-ground terrestrial organic carbon, respectively [18], and are directly influenced by deforestation and forest degradation [13]. According to the IPCC Special Report on CO₂ Capture and Storage, CO₂ sequestration could provide an emission reduction of CO₂ until 2100 of up to 55% which is known for its potential influence as a greenhouse gas to Climate pattern of the world [36]. Carbon sequestration in growing

43 forests is known to be a cost-effective option for mitigation of global warming and global climatic change.
44 Estimates of carbon stocks and stock changes in tree biomass (above and belowground) are necessary
45 to study climate change under United Nations Framework Convention on Climate Change [15]. The
46 increasing carbon emission is of major concern for the entire world as addressed in Kyoto protocol [6];
47 [33]. Terrestrial vegetation and soil represents important sources and sinks of atmospheric carbon [37].
48 The quantification of CS potential of various ecosystems is a challenge [20]. Forests sequester and store
49 large amounts of atmospheric carbon and thus play a key role in the mitigation of climate change [19].
50 Inventory measurements in both managed and unmanaged forests in temperate and tropical regions
51 indicates that forests accounted for a substantial net sink of 550 Gt CO₂ from 1750 to 2011 [32]; [23]; [22].
52 Hence, estimating and monitoring carbon sequestered in forests is necessary for sustainable
53 management in order to leverage the mitigation potential of forests [19]. Thus, assessing the amount of
54 carbon stored in the forest ecosystem periodically is a means of determining the CO₂ emitted into the
55 atmosphere due to deforestation and degradation [36]. Why carbon cycle drew much attention is because
56 carbon dioxide being the chief among the greenhouse gases has the potentials to influence the global
57 climate pattern [4], and it also has a relatively long residence time in the atmosphere. About 60% of the
58 observed global climate change is attributable to this increasing carbon dioxide concentration in the
59 atmosphere [14].

60 Nature has provided us with natural carbon "sinks" or "sponges" like the terrestrial ecosystem and the
61 oceans. Forest's ecosystem is one of the most important carbon sinks of the terrestrial ecosystem.
62 Forest's vegetation takes up the carbon dioxide in the process of photosynthesis. In this natural process,
63 it removes the carbon dioxide from the atmosphere and stores the carbon in the plant tissues, forest litter
64 and soils [36]. Thus, forest ecosystem plays a very important role in the global carbon cycle by
65 sequestering a substantial amount of carbon dioxide from the atmosphere. This process is more prolific in
66 a relatively new forest where the growths of the trees are still rapid. It is estimated that about 86% of the
67 terrestrial above-ground carbon and 73% of the earth's soil carbon are stored in the forests. The tropical
68 forests are said to play a major role in the global carbon cycle, storing up to about 46% of the world's
69 terrestrial carbon pool and about 11.55% of the world's soil carbon pool, acting as a carbon reservoir and
70 functioning as a constant sink of atmospheric carbon [5]; [27]; [21]; [35]. According to a study conducted
71 by [5], it was suggested that half of the so called "matured forests" could also sequester carbon and the
72 rate of sequestering carbon could be further increased if human pressures are reduced or removed from
73 these forests. In a tropical forest ecosystem, the living biomass of trees, the understory vegetation and
74 the deadwood, which includes the standing deadwood and the fallen deadwood like fallen stems and
75 fallen branches, woody debris and soil organic matters constitute the main carbon pool. Among the above
76 mentioned carbon pools, the above-ground biomass of the tree is mainly the largest carbon pool and it is
77 directly affected by deforestation and forest degradation [13]. The change in the forest areas and the
78 changes in forest biomass due to management and regrowth greatly influence the transfer of carbon
79 between the terrestrial forest ecosystem and the atmosphere [17]. Hence, estimating the forest carbon
80 stocks is mainly important to assess the magnitude of carbon exchange between the forest ecosystem
81 and the atmosphere. Assessment of the amount of carbon sequestered by a forest will give us an
82 estimate of the amount of carbon emitted into the atmosphere when this particular forest area is
83 deforested or degraded. Furthermore, it will help us to quantify the carbon stocks which in turn will enable
84 us to understand the current status of carbon stocks and also derive the near-future changes in the
85 carbon stocks [13]; [17].

86 There are a few existing estimations of forest biomass carbon stocks in Nigeria, from that in Effan Forest
87 Reserve, north-western Nigeria [1] to the study in Ile-Ife, south-western Nigeria [31], and also the study in
88 Oluwa forest, south-western Nigeria [24] to the study in Benue state, north central Nigeria [12] and a
89 general overview of carbon fluxes in five forest zones in Nigeria from 1990 to year 2000 [28]. [28] carried
90 out an estimation of the carbon fluxes in the forest zones of Nigeria from 1990 to 1995, with extrapolation
91 up to year 2000. The report established that of the five categories of forest life zones, lowland rainforest
92 occupies close to 80% of the land area and contributes about 84% to the total carbon stock in the forest
93 zones of Nigeria in year 2000. Total carbon stored was estimated to be 2.55 TgC in 2000, the estimated
94 value of 2.84 TgC in 1990. [17] Estimated that 90% of the world's terrestrial carbon is sequestered in
95 forests, which makes about 3.6 billion hectares (28%) of the land area. The influence of forests
96 ecosystem on climate change is not well quantified and is often disregarded. Human influences on forests

(inefficient management) can further affect CO₂ sequestered [30]. Thus, adequate information should be available to better understand the consequences of anthropogenic activities in our forest ecosystem.

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2 MATERIALS AND METHODS

2.1 STUDY AREA

Makurdi Zoological garden is located in Makurdi Local Government Area of Benue State. Makurdi is the state capital of Benue State and lies on the south bank of the Benue River. It Coordinates is 7° 43'50"N 8°32'10E. (- The study area is shown in Figure 1).



Figure 1: Map of Makurdi showing the study area

Source: Google Map

2.2 FIELD DATA

2.2.1 Sampling design

Random sample plots of 100 m × 100 m were located in the field using a Garmin GPS. The use of GPS receivers enables efficient and accurate placement of the plots. In each of the plots, all trees with DBH (i.e. diameter at 1.3m) exceeding 5 cm were measured with a 50 m girth measuring tape and their heights measured with Hhaga altimeter.

Comment [Office4]: We need more details of these plots. How many, age of the forest, health, etc.

2.2.2 Soil sampling

Soil samples were randomly collected at the center of each plot at depths of 0–15 and 15–30 cm, respectively, since the highest proportion of the total root is within first 30 cm of the soil surface. About two- thirds of the carbon in terrestrial ecosystems comes from soil organic carbon. As a result, the soil samples were carefully collected since it forms the major component of the result, thereby preventing the top-layer soil from falling to the lower samples according to best practices.

2.3 DATA PREPARATION

2.3.1 Estimation of Biomass

2.3.1.1 Above ground biomass.

130 The pan tropical biomass allometric equation proposed by [7] for tropical moist forest was used for the
131 estimation of tree aboveground biomass:

132
$$\text{TAGB} = \exp(-2.977 + \ln(\rho D^2 H)) = 0.0509 \times \rho D^2 H \quad (1)$$

Comment [Office5]: Describe characteristics of this equation

133 Where TAGB is tree aboveground biomass, D is diameter at breast height, H is total height and ρ is
134 wood density (wood specific gravity) and estimated as 0.88.

135 2.3.1.2 Below ground biomass.

136 Below Ground Biomass is estimated from Above Ground Biomass. A non-destructive approach depends
137 on belowground biomass values for vegetation as 20% of the aboveground biomass.

Comment [Office6]: Authors?

138 Below ground biomass = 20% × above ground biomass

139 That is:

140
$$\text{BGB} = 20\% \times \text{Agb} \quad (2)$$

141

142 2.3.2 Estimation of Carbon Stock

143 2.3.2.1 Aboveground carbon stock

144 To estimate the Above Ground Carbon (AGC), the aboveground biomass (AGB) was multiplied by 50%

Comment [Office7]: Authors

145
$$\text{AGC} = \text{total AGB} \times 0.50$$

146 2.3.2.2 Below ground carbon stock

147 To estimate Below Ground Carbon (BGC), the Below Ground Biomass (BGB) was multiplied by 50%

148
$$\text{BGC} = \text{total AGB} \times 0.50$$

149 2.3.2.3 Soil carbon stock.

150 The Total Organic Carbon (TOC) of soil matter was determined by collecting soil samples from the sub-
151 plot within the main sample plots using the Walkley–Black method. A total of 20 samples at 0–15 and 15–
152 30 cm were collected for TOC (%Carbon). Soil carbon stock was computed by multiplying the
153 concentration of total carbon (C) by bulk density and the corresponding depth at which the sampling was
154 done:

155
$$\text{Soil carbon (Mg/ha)} = \frac{\text{bulk density (g/cm}^3\text{)} \times \text{soil depth interval (cm)} \times \text{C (\%)}}{100}$$

156
$$100 \quad (3)$$

Comment [Office8]: To improve equation presentation with word equation tools

157 Soil carbon at 0-15 cm = TOC × Depth × Bulk Density,

158 Soil carbon at 15-30 cm = TOC × Depth × Bulk Density:

159

160 2.3.3 Estimation of Carbon dioxide

161 2.3.3.1 Above Ground Biomass Carbon dioxide

162 To estimate the amount of Carbon dioxide (CO₂) sequestered in the above ground biomass, the
163 aboveground carbon was multiplied by 3.67 which is the ratio of the molecular weights between CO₂ and
164 carbon.

165
$$\text{CO}_2 = \text{aboveground carbon stock} \times 3.67$$

166 **2.3.3.2 Below Ground Biomass Carbon dioxide**

167 To estimate the amount of Carbon dioxide (CO₂) sequestered in the belowground biomass, the
168 belowground carbon was multiplied by 3.67 which is the ratio of the molecular weights between CO₂ and
169 carbon.

170
$$\text{CO}_2 = \text{belowground carbon stock} \times 3.67$$

171 **2.3.3.3 Total Carbon stock estimation**

172 The total carbon stock was estimated as the total stock of carbon in the ecosystem, including above
173 ground and below ground stock. The constituents of the below ground stock are the carbon content in
174 roots and all Below Ground Biomass and the carbon in the soil. The total below ground carbon stock is
175 the addition total below ground carbon stock Below Ground Biomass and soil carbon. The sum total of all
176 the biomass obtained from the three pools considered which Above Ground Biomass, Below Ground
177 Biomass is and Soil Organic Carbon was calculated and the carbon stock was obtained using Equation
178 (4).

179
$$\text{Total Carbon Stock} = \text{Total biomass} \times \% \text{ Carbon}, \quad (4)$$

180 Total carbon stock can be calculated from Carbon stock in standing tree as follows:

181
$$\text{Total carbon stock} = \text{AG carbon stock} + \text{BG carbon stock} = \text{AG carbon stock} + \text{carbon belowground}$$

182
$$\text{biomass} + \text{carbon stock in soil}$$

183 **2.3.3.4 Total Carbon dioxide (CO₂) sequestered**

184 The total carbon stock can be converted to CO₂ by multiplying carbon stock by 3.67 which is the ratio of
185 the molecular weights between CO₂ and carbon.

186
$$\text{CO}_2 = \text{Total carbon stock} \times 3.67.$$

187

188 **3 RESULTS AND DISCUSSION**

189 **3.1 THE FOREST STRUCTURE**

190 A total of 27 plant species from 16 families were identified (Table 1). A total of 689 trees were sampled in
191 the study area. Among the species sampled, *Daniella oliveri* was the dominant species (339) followed by
192 *Azadirachta indica* (95), *Elaeis guineensis* (39) and *Vitex doniana* (34). Other species recorded are
193 *Acacia seyal* (1) and *Parkia biglobosa* (1). This information is also represented in figure 2.

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Comment [Office9]: In this part the authors describe the potential of these forest to store carbon not only the stock of carbon because these is the aim of this research.

Comment [Office10]: In this case some biodiversity indexes give the reader more and better information

197 **Table 1: species collected from Makurdi Zoological Garden with their mean DBH, mean height,**
198 **number of plots in which they occur and number of trees.**

S/N	Species scientific name	Family	No. of plots species occur	Total no. of trees	Mean DBH (cm)	Mean height (m)
1	<i>Anacardum ocindentel</i>	Anacardiaceae	1	2	37	10
2	<i>Ficus sur</i>	Moraceae	6	17	38.7	10.7
3	<i>Daniella oliveri</i>	Caesalpinoideae	10	339	62.3	17.6
4	<i>Gmelina aborea</i>	Verbanaceae	4	21	32.8	13.8
5	<i>Azadirachta indica</i>	Meliaceae	8	95	50.5	15.6
6	<i>Ficus exasperate</i>	Moraceae	5	20	37.2	11
7	<i>Acacia seyal</i>	Fabaceae	1	1	57	10
8	<i>Pterocarpus erinaceus</i>	Fabaceae	3	26	74	12.7
9	<i>Vattelleria paradoxa</i>	Sapotaceae	4	10	31.8	10
10	<i>prosopis Africana</i>	Mimosoideae	2	7	35.6	11
11	<i>Vitex doniana</i>	Verbanaceae	4	34	32	10.5
12	<i>Lannea shimperi</i>	Anacardiaceae	1	2	43	19.5
13	<i>Elaeis guineensis</i>	Arecaceae	6	39	42.4	10.2
14	<i>Bridelia ferruginea</i>	Euphorbiaceae	1	3	21	7
15	<i>Psedocedrella kotschyi</i>	Meliaceae	2	6	37.2	10
16	<i>Lannea acida</i>	Anacardiaceae	5	23	47.2	14.4
17	<i>Acacia nilotica</i>	Mimosoideae	5	15	45.2	13.2
18	<i>Mytragyna inermis</i>	Rubiaceae	1	3	40	10
19	<i>Terminalia avicenniodes</i>	Combretaceae	2	7	34.6	8
20	<i>Magnifera indica</i>	Anacardiaceae	3	29	45.3	16
21	<i>Hannoa undulate</i>	Simaroubaceae	3	6	16.3	6
22	<i>Sterculia setigera</i>	Sterculiaceae	1	2	40	12
23	<i>Albizia zygia</i>	Mimosoideae	2	6	47.2	10.5
24	<i>Delonix rigia</i>	Fabaceae	1	2	58	8
25	<i>Schefflera actinophylla</i>	Araliaceae	1	12	28	9

26	<i>Parkia biglobosa</i>	Mimosoideae	1	1	88	12
27	<i>Lophira lanceolata</i>	Onchnaceae	1	3	15	6

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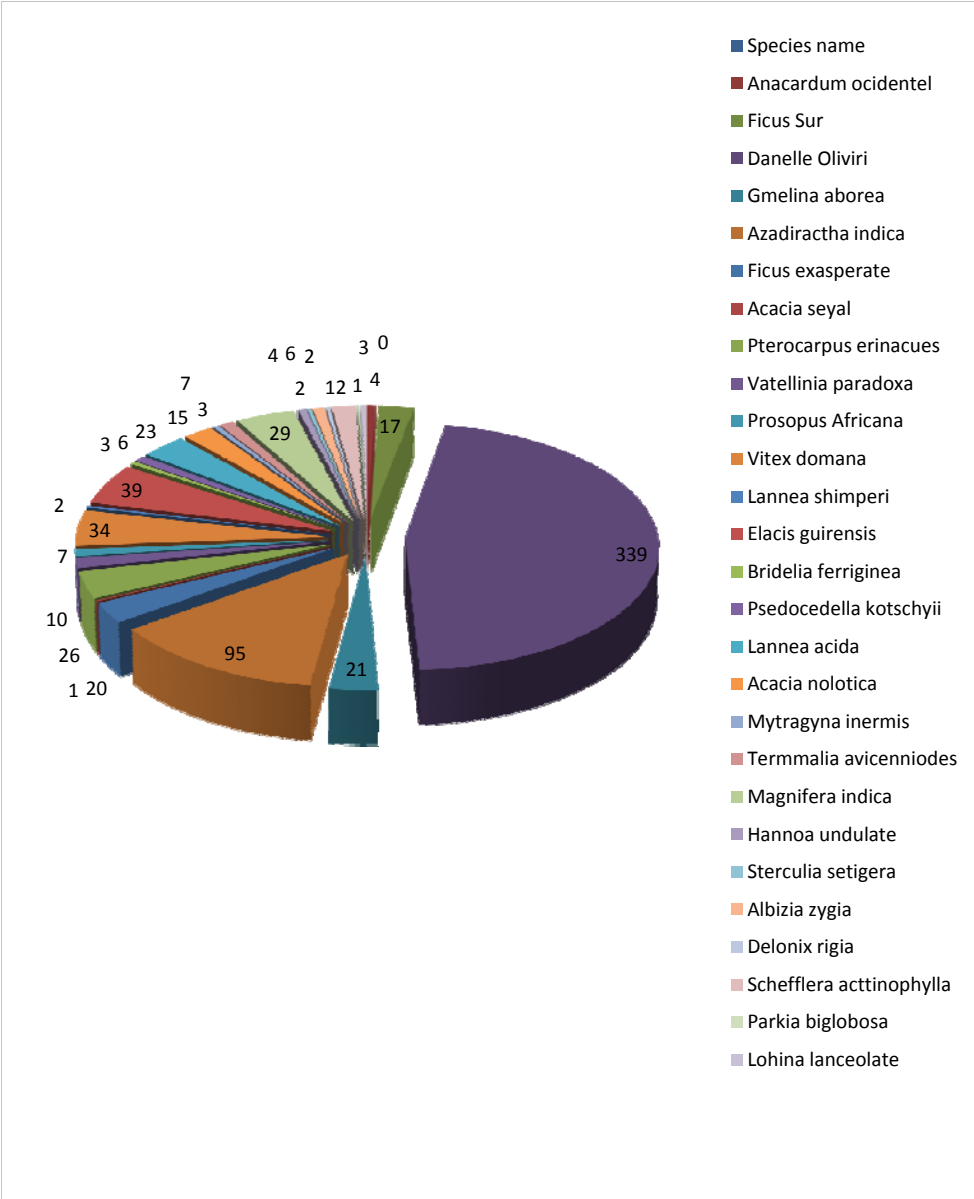


Figure 2: ~~Pie chart showing~~ trees species distributions in the studied area

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UNDER PEER REVIEW

3.2 DBH DISTRIBUTION OF MAKURDI ZOOLOGICAL GARDEN

The DBH class 51-70 was dominant, followed by 31-50cm, 71-90cm and 10-30cm respectively. As mentioned in table 1, the mean maximum DBH value in the studied area was recorded for *Parkia biglobosa* with the mean DBH value of 88cm followed by *Pterocarpus erinaceus* and *Daniella oliveri* with the mean DBH value of 74cm and 62.3cm respectively. The least mean DBH was recorded for *Lophira lanceolata* with the mean value of 15cm followed by *Hannoa undulate* with the mean value of 16.3 (figure 3)

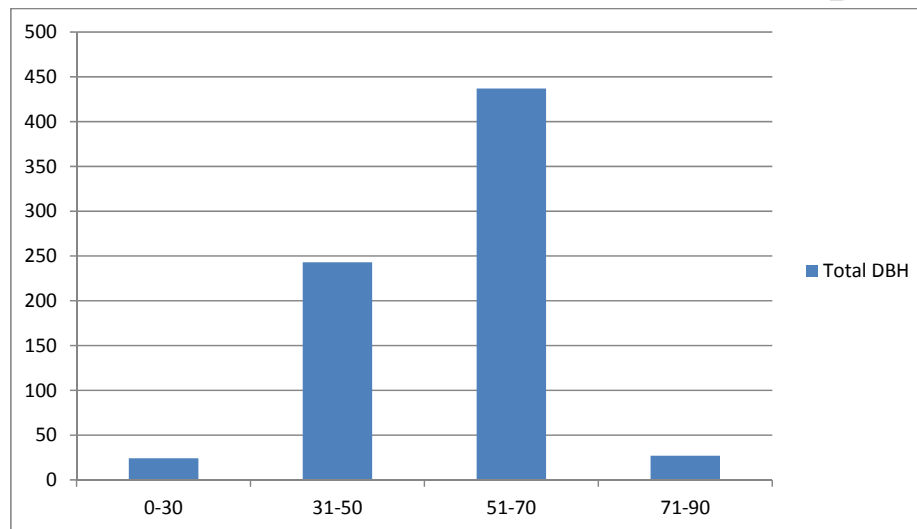


Figure 3: Bar chart showing DBH class distribution of trees in the studied area.

3.2 HEIGHT DISTRIBUTION OF MAKURDI ZOOLOGICAL GARDEN

Height distribution was based on class rang. Class range of 0 – 10 has an approximate height distribution of 90, while class rang of 11 – 15 has an approximate value of 170 and class range of 16 -20 has an approximate value of 470 (Table 2). The numbers of trees between 16-20m height have the highest number of individual tree species followed by 11-15m, and 5-10 respectively (Figure 4). As a result, the higher class with the height range of 16-20m consists of the greatest number of individual tree species. About 63.6% of the total trees found in the studied area fall between the height ranges of 16-20cm. 23.5% of trees were found between the height ranges of 11-15m while 12.9% of trees were found between the ranges of 5-10m (Figure 4).

Table 2: Class range and approximate height distribution

Class range	Height distribution
0 - 10	90
11 - 15	170
16 - 20	470

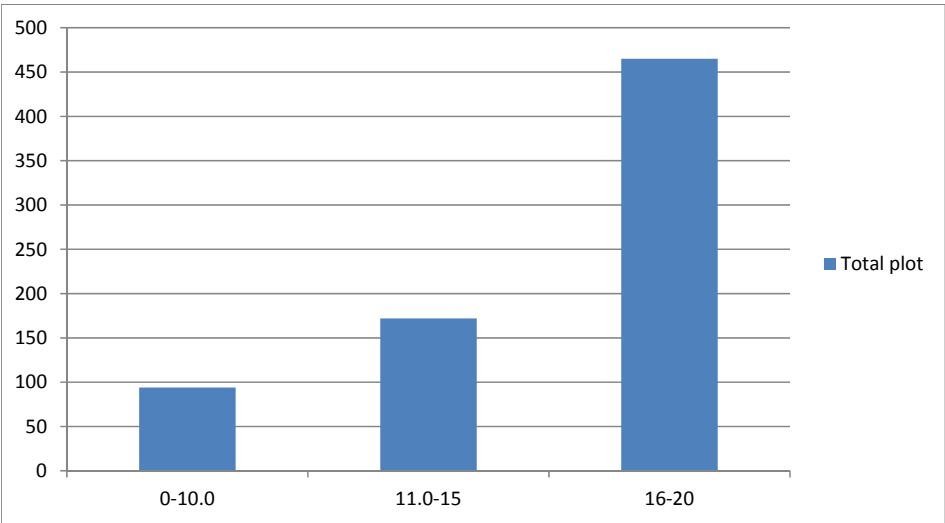


Figure 4: Bar chart showing height class distribution of trees in the studied

3.3 ESTIMATION OF BIOMASS

3.3.1 Above Ground Biomass (AGB)

The result shows that the maximum above ground biomass sequestered by the plant species was 1037.3 ton/ha, the minimum above ground biomass sequestered by plant species was 0.181ton/ha and the total above ground biomass (TAGB) for the studied area was 1512.7ton (Table 3). The graphical representation of the biomass of each plant species is shown in figure 5.

3.3.2 Below Ground Biomass (BGB)

The maximum below ground biomass sequestered by plant species was 207.5ton/ha, the minimum below ground biomass sequestered by plant species was 0.036ton/ha while the total below ground biomass

(TBGB) for the studied area was 302.579ton (Table 3). The graphical representation of the above information is shown in figure 6.

286

287 **Table 3: Estimated above and below ground biomass of species**

S/N.	SCIENTIFIC NAME	TOTAL AGB Ton/ha	TOTAL BGB Ton/ha
1	<i>Anacardum ocindentel</i>	1.2264	0.2453
2	<i>Ficus sur</i>	12.203	2.441
3	<i>Daniella oliveri</i>	1037.3	207.5
4	<i>Gmelina aborea</i>	13.965	2.793
5	<i>Azadirachta indica</i>	169.29	33.858
6	<i>Ficus exasperate</i>	13.636	2.727
7	<i>Acacia seyal</i>	1.4553	0.2911
8	<i>Pterocarpus erinaceus</i>	80.99	16.198
9	<i>Vattelleria paradoxa</i>	4.529	0.906
10	<i>prosopis Africana</i>	4.37	0.874
11	<i>Vitex doniana</i>	16.375	3.275
12	<i>Lannea shimperi</i>	3.229	0.6459
13	<i>Elaeis guineensis</i>	32.033	6.4066
14	<i>Bridelia ferruginea</i>	0.4148	0.0829
15	<i>Psedocedrella kotschyi</i>	3.719	0.744
16	<i>Lannea acida</i>	33.05	6.6101

17	<i>Acacia nilotica</i>	18.12	3.624
18	<i>Mytragyna inermis</i>	2.15	0.43
19	<i>Terminalia avicenniodes</i>	3.003	0.601
20	<i>Magnifera indica</i>	42.65	8.53
21	<i>Hannoa undulate</i>	0.428	0.0857
22	<i>Sterculia setigera</i>	1.72	0.344
23	<i>Albizia zygia</i>	6.287	1.257
24	<i>Delonix rigia</i>	2.411	0.4822
25	<i>Schefflera actinophylla</i>	3.793	0.759
26	<i>Parkia biglobosa</i>	4.162	0.832
27	<i>Lophira lanceolata</i>	0.181	0.0363
Total		1,512.7	302.579

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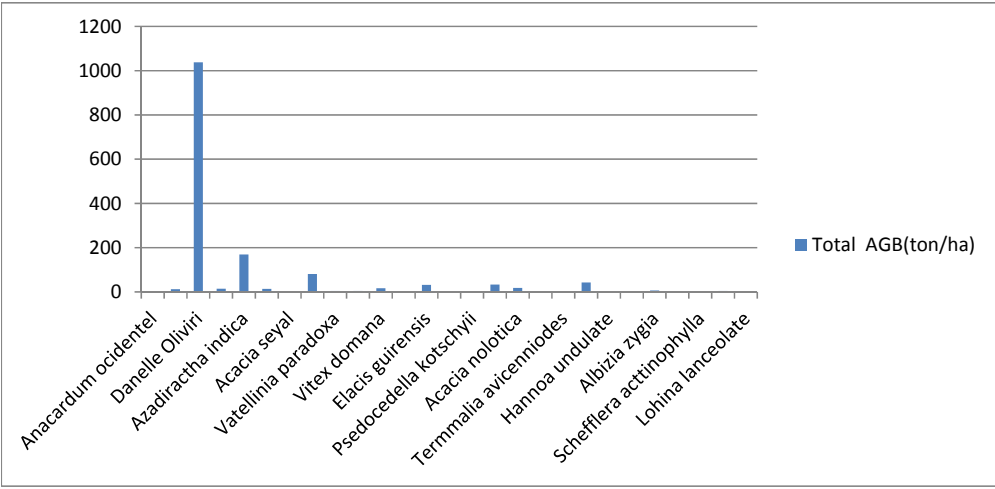


Figure 5: A Bar chart showing above ground biomass of species

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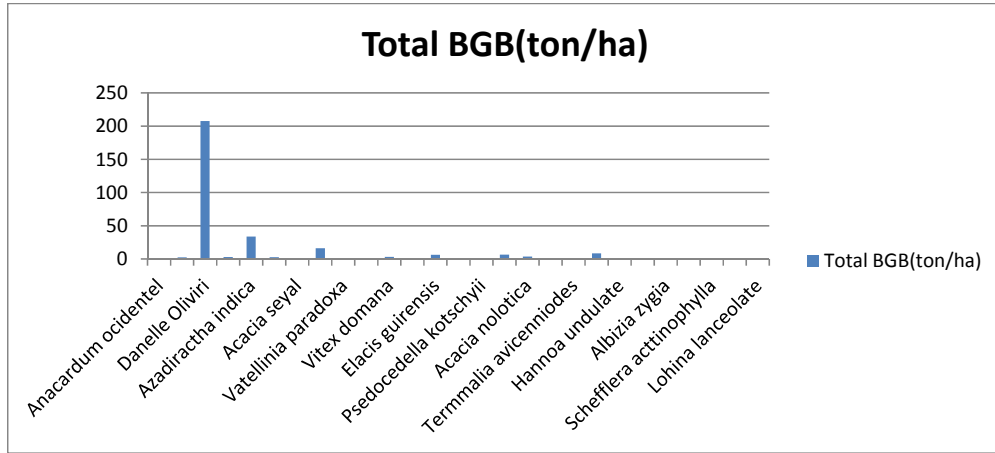


Figure 6: Bar chart showing Below Ground Biomass

Comment [Office13]: Improve this caption

327 **3.4 ESTIMATION OF CARBON STOCKS**

328 **3.4.1 Above Ground Carbon Stock**

329 The maximum and the minimum above ground carbon stock potentials of each plant species sampled in
330 Makurdi zoological garden was 518.65ton/ha and 0.0905ton/ha while the total above ground carbon
331 (TAGC) in the studied area was 756.4ton (Table 4). The above information is also represented by figure
332 7.

333 **3.4.2 Below Ground Carbon stock**

334 The maximum and the minimum value of the below ground carbon sequestered in the area was 103.73
335 tons/ha and 0.0181tons/ha respectively while the total below ground carbon (TBGC) for the studied area
336 was 151.294ton (Table 4). The above information is shown in figure 8.

337 **Table 4: Estimated above and below ground carbon Stock of species**

S/N	SCIENTIFIC NAME	TOTAL AGC Ton/ha	TOTAL BGC Ton/ha
1	<i>Anacardum ocindentel</i>	0.6132	0.1227
2	<i>Ficus sur</i>	6.1015	1.2203
3	<i>Daniella oliveri</i>	518.65	103.73
4	<i>Gmelina aborea</i>	6.9825	1.3965
5	<i>Azadirachta indica</i>	84.645	16.3965
6	<i>Ficus exasperate</i>	6.818	1.3636
7	<i>Acacia seyal</i>	0.7277	0.1455
8	<i>Pterocarpus erinaceus</i>	40.495	8.099
9	<i>Vattelleria paradoxa</i>	2.265	0.453
10	<i>Prosopis Africana</i>	2.185	0.437
11	<i>Vitex doniana</i>	8.188	1.6375
12	<i>Lannea shimperi</i>	1.6145	0.3229

13	<i>Elaeis guineensis</i>	16.017	3.2033
14	<i>Bridelia ferruginea</i>	0.207	0.0415
15	<i>Psedocedrella kotschy</i>	1.8595	0.372
16	<i>Lannea acida</i>	16.53	3.305
17	<i>Acacia nilotica</i>	9.06	1.812
18	<i>Mytragyna inermis</i>	1.075	0.215
19	<i>Terminalia avicenniodes</i>	1.502	0.3003
20	<i>Magnifera indica</i>	21.33	4.265
21	<i>Hannoa undulate</i>	0.214	0.043
22	<i>Sterculia setigera</i>	0.86	0.172
23	<i>Albizia zygia</i>	3.144	0.629
24	<i>Delonix rigia</i>	1.2055	0.2411
25	<i>Schefflera actinophylla</i>	1.897	0.379
26	<i>Parkia biglobosa</i>	2.081	0.416
27	<i>Lophira lanceolata</i>	0.0905	0.0181
TOTAL		756.4	151.29

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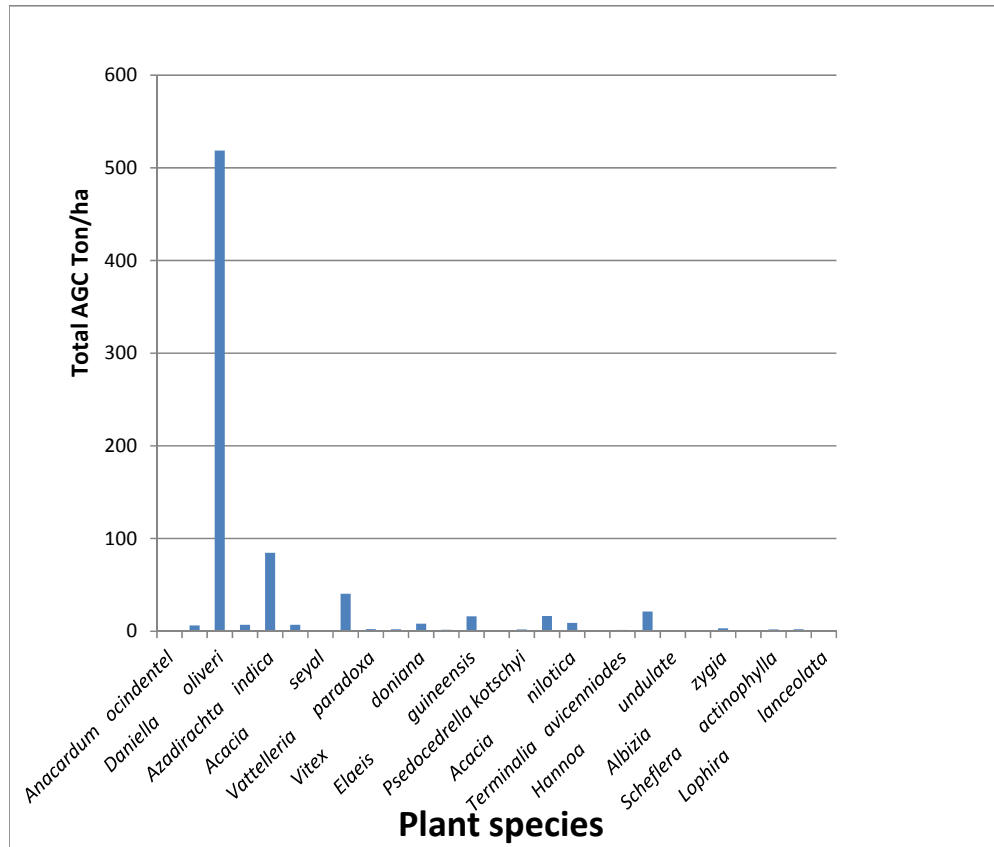


Figure 7: Bar chart showing the Above-ground Carbon sequestered by plant species

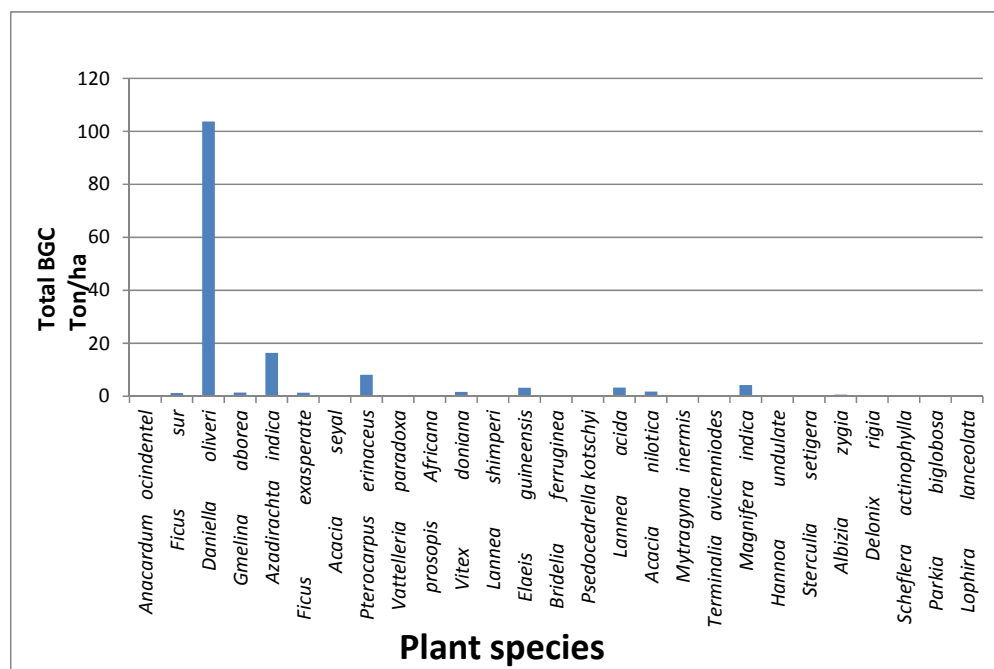


Figure 8: Bar chart showing the below ground carbon sequestered by plant species

3.5 CARBON DIOXIDE (CO₂) ESTINATION

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3.5.1 Above-ground CO₂

The maximum and minimum above ground carbon dioxide sequestered in the study area was 1903.45tons/ha and 0.332tons/ha respectively while the total above ground CO₂ sequestered was 2775.8tons/ha (Table 5).This information is graphically represented in figure 9

3.5.2 Below-ground CO₂

The maximum and minimum below ground carbon dioxide sequestered in the study area was 380.7tons/ha and 0.0666tons/ha respectively while the total below ground CO₂ sequestered was 555.25ton/ha (Table 5). This information is represented in figure 10. Also, the total CO₂ sequestered in the study area = total above ground CO₂ + total below ground CO₂. Total CO₂ = 2775.8 +555.25 = 3331.05ton/ha

401

402 **Table 5: Estimated carbon dioxide sequestered by plant species**

S/N	SCIENTIFIC NAME	TOTAL AG CO ₂ Ton/ha	TOTAL BG CO ₂ Ton/ha
1	<i>Anacardum ocindentel</i>	2.25	0.45
2	<i>Ficus sur</i>	22.4	4.48
3	<i>Daniella oliveri</i>	1903.45	380.7
4	<i>Gmelina aborea</i>	25.6257	5.125
5	<i>Azadirachta indica</i>	310.65	62.129
6	<i>Ficus exasperate</i>	25.022	5.005
7	<i>Acacia seyal</i>	2.6705	0.534
8	<i>Pterocarpus erinaceus</i>	148.62	29.723
9	<i>Vattelleria paradoxa</i>	8.3107	1.662
10	<i>prosopis Africana</i>	8.0189	1.604
11	<i>Vitex doniana</i>	30.05	6.009
12	<i>Lannea shimperi</i>	5.925	1.185
13	<i>Elaeis guineensis</i>	58.78	11.76
14	<i>Bridelia ferruginea</i>	0.7612	0.1522
15	<i>Psedocedrella kotschyi</i>	6.824	1.365
16	<i>Lannea acida</i>	60.65	12.13
17	<i>Acacia nilotica</i>	33.25	6.65
18	<i>Mytragyna inermis</i>	3.95	0.789
19	<i>Terminalia avicenniodes</i>	5.511	1.102
20	<i>Magnifera indica</i>	78.3	15.652
21	<i>Hannoa undulate</i>	0.785	0.157
22	<i>Sterculia setigera</i>	3.156	0.6312
23	<i>Albizia zygia</i>	11.5366	2.307
24	<i>Delonix rigia</i>	4.424	0.885
25	<i>Schefflera actinophylla</i>	6.96	1.392

Comment [Office15]: Be consistent ton or tons

26	<i>Parkia biglobosa</i>	7.64	1.528
27	<i>Lophira lanceolata</i>	0.332	0.0666
Total		2775.8	555.23

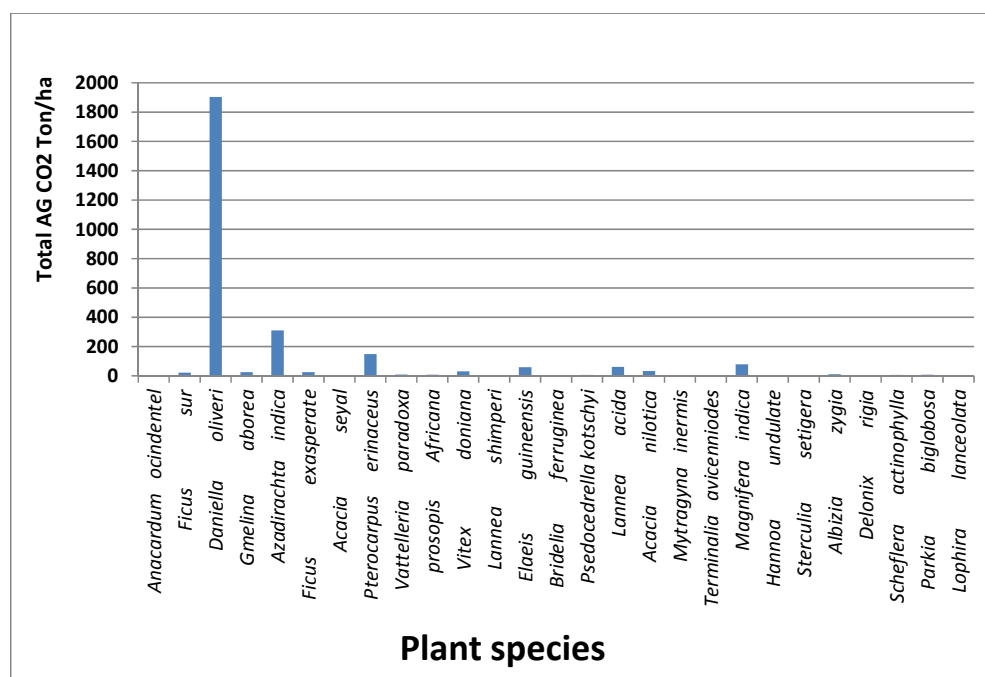


Figure 9: Bar chart showing Above ground carbon dioxide sequestered by plant species

Comment [Office16]: The graph or the figure choose one

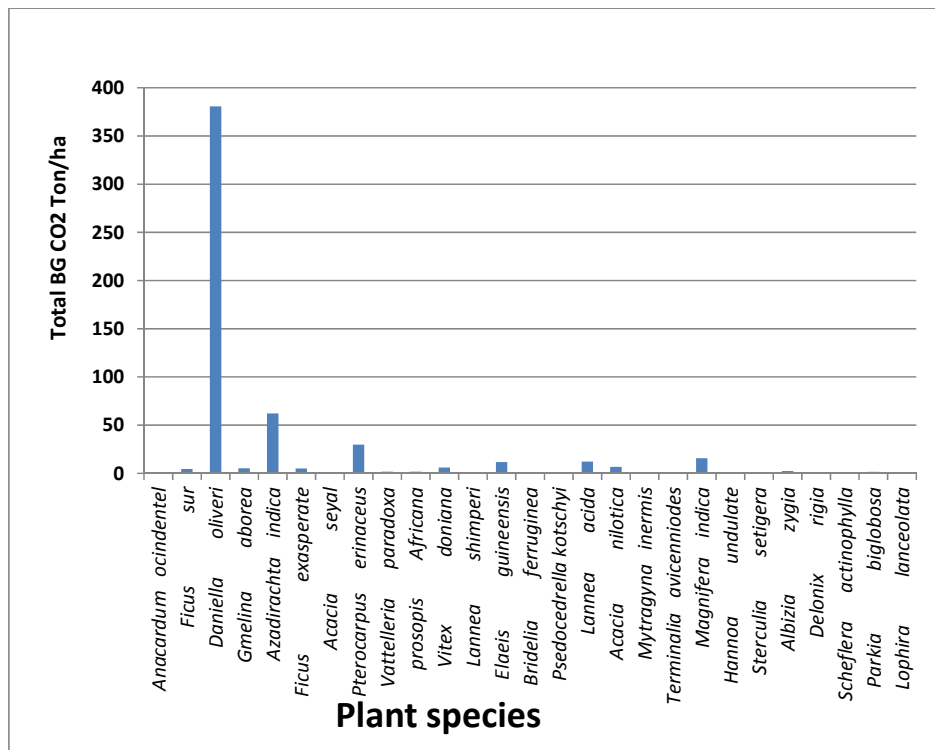


Figure 10: Bar chart showing Below-ground carbon dioxide sequestered by plant species

To estimate the AGB and BGB in the study area, determine the total carbon stock and evaluate the total carbon dioxide sequestered, a total of 731 tree species from sixteen different families were measured on field. The average DBH of all tree species measured ranged from 15cm to 88cm. *Daniellia oliveri* has the highest number of trees of 331 having an average DBH of 62.3cm while *Parkia biglobosa* has the least number of trees of one with DBH of 88cm. The pantropical biomass allometric equation proposed by [7] for tropical moist forests was used for the estimation of tree aboveground biomass which has been tested and shown to accurately predict TAGB in several sites. Tree aboveground biomass per plot was estimated by the summation of the TAGB of all individual trees in the plot. The total AGB for the studied area ($1512.7 \text{ tonha}^{-1}$) was higher when compared with [29] assertion that the global AGB in tropical dry and wet forest range between $30\text{-}275 \text{ tonha}^{-1}$ and $213\text{-}1173 \text{ tonha}^{-1}$ respectively and that recorded in Ile-Ife (54.52 tonha^{-1}) and reported by [31] but was smaller when compared with other studies. [4] estimated above ground biomass to be an average $215 \text{ mg tonha}^{-1}$ and $192 \text{ mg tonha}^{-1}$ for undisturbed tropical forest of Asia and the world respectively and also with study carried out by [24] that the total AGB of Oluwa forest of Ondo state was $162,826.343 \text{ tonha}^{-1}$ that is, $162 \text{ mg tonha}^{-1}$. The total above ground carbon stock estimated was 756.4 tonha^{-1} of carbon while the total below ground carbon stock was $151.294 \text{ tonha}^{-1}$ of carbon are lower when compared with the value found in other system in Africa. E.g. 152 mg t c/ha for cocoa agroforestry in South Cameroon [9]; $66\text{-}88 \text{ mg t c/ha}$ for rubber plantation in

463 Cameroon [11] but however higher than the value of carbon stock recorded in Ile- lfe (28.18) reported by
464 [31]. A total of 3331.04 ton ha⁻¹ of CO₂ was estimated to have been sequestered in the area.

465 Generally one must exercise caution in comparing the study results because of differences in the forest
466 types, site types, management systems, monitoring, the methodology and model equation used in
467 different studies [26]; [7]; [25]. [34] Reported that fast growing species accumulate more carbon in the first
468 stages of their life span, while the high specific gravity of slower-growing species accumulates more
469 carbon in the long term. Above ground biomass and consequently carbon stock has been reported to be
470 influenced in any particular region by factors such as climate, solar radiation, and disturbance, age of
471 forest, species composition, and soil characteristics [3]. [10] Has also pointed out that the rate of carbon
472 storage in forest biomass depends on tree growth rate: the more biomass is added through
473 photosynthesis the more carbon is stored. It is clear from this study that species composition, disturbance
474 and age of the vegetation are the main factors influencing carbon stock especially in the above ground
475 biomass.

476 4 CONCLUSIONS

477 This preliminary evaluation strategically positions (guinea savanna) as found in Benue State in line for
478 UNFCCC and Kyoto carbon credit trading while substantiating the importance of preserving our
479 indigenous forest reserves.

Comment [Office17]: This is not a conclusion

480 COMPETING INTERESTS

481 The authors have declared that no competing interest exists.

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