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Comparative Assessment of Tree Biomass and Carbon Stocks in ALA and Ogbese Forest Reserve Using Allometric Method

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COMPARATIVE ASSESSMENT OF TREE BIOMASS AND CARBON STOCKS IN ALA AND OGBESE FOREST RESERVE USING ALLOMETRIC METHOD.

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ABSTRACT

Forest ecosystems act as a significant carbon cycle because they constitute large amount of biomass. Increase in industrialization, agriculture, urbanization, and population growth have led to high rate of deforestation and surface temperatures in Nigeria. There is limited information on carbon stock for sustainable management and climate mitigation of Ala and Ogbese Forest Reserve. Thus, this study was designed to assess and compare carbon stocks in Ala Forest Reserve and Ogbese Forest Reserve, Southwest, Nigeria.

A systematic line transect was used for the selection of sampling plots in the forest ecosystems. Two parallel line transects of 500m in length with a distance of 200m apart between the two parallel transects were laid with four plots of 50×50m on each side with a distance of 100m interval distance offset away from each sample plot was observed so as to decrease replication of tree species for collection of tree growth variables: diameter at breast height (dbh, cm), diameter at the base (db, cm), diameter at the top (dt, cm), diameter at the middle (dm, cm) and stem height (m). Wood density was obtained from the global wood density achieve, while Stem Volume (SV, m^3/ha) was estimated using Newton's formular. Biomass (kg/ha) was computed using allometric equations, while carbon stock (kg C/ha) was derived from the biomass using standard method. Biomass and carbon stock ranged from 129.33 kg/ha and 57.74 kg/ha in Ala Forest reserve to 40.20 kg/ha and 20.11 kg/ha in Ogbese Forest Reserve. Implicitly, the Ala forest reserve stores more carbon than Ogbese forest reserve.

However, biomass accumulation is more in Ala forest reserve than in Ogbese forest. Immediate action is required from forestry officials, local communities, and environmental organizations to conserve the remaining forest resources and restore degraded lands.

Keyword: Forest, aboveground tree biomass (AGTB), Below-ground tree biomass (BGTB)

INTRODUCTION

Forest ecosystems play an important role in global carbon cycle because they store carbon in various ways such as vegetation, dead organic matter and soils. Through the uptake of atmospheric carbon dioxide, carbon is stored in the tissues of trees and contribute to the regulation and concentration of atmospheric gases. However, forests can be a source of carbon wen vegetation is removed or degraded. It is important to quantify the amount of carbon stored in forest ecosystems to enable us understand their contribution to climate change mitigation and for supporting decisions on forest conservation and management. A reliable carbon estimation can also provide relevant information for climate initiative and carbon accounting mechanisms (Han *et al*., 2007; Asner *et al*., 2016; Kale *et al*., 2004).

Carbon stock relies majorly on estimates of tree biomass due to the fact that biomass is the basis for calculating the amount of carbon held in vegetation (Powlson *et al*., 2011). However, accurate estimation of biomass is important for tracking changes in the carbon stock through constant assessment of carbon stock. (Cienciala *et al*., 2006; Smith *et al*., 2020). Carbon stock assessment is important for stored carbon and carbon sequestration maps, which is a very important in decision and policy making (Asner *et al*., 2016).

Accurate estimation of forest biomass is essential for understanding variations in carbon storage within forest ecosystems (Ketterings *et al*., 2001; Chave *et al*., 2004). Biomass assessment forms a critical foundation for studies on carbon stocks, the impacts of deforestation, and the role of carbon sequestration in maintaining the global carbon balance. At local, regional, and global scales, reliable biomass measurements are necessary for quantifying carbon storage and for evaluating ecosystem responses to climate change and human-induced disturbances (Ni-Meister *et al*., 2010). However, in many tropical forests, precise biomass estimations remain limited due to the scarcity of robust allometric models suited for species-rich ecosystems. This lack of adequate models hinders accurate predictions of biomass and, consequently, complicates efforts to determine the contribution of tropical species as carbon sinks (Chave *et al*., 2005). In Africa, particularly, significant uncertainties persist regarding both the magnitude and spatial distribution of above-ground biomass, largely because only a few allometric equations are currently available (Fayolle *et al*., 2013).

Applying generalized allometric equations across diverse ecological regions can bring about bias and error when predicting biomass for specific tree species and sites (Henry *et al*., 2011). There are variations among species in terms of specific wood density, tree dimensions growth stages. Also, some geographic areas lack existing model making it inapplicable with distinct environmental characteristics and similar species (Navar *et al*., 2002). Furthermore, estimation of biomass can be influenced by different factors such as topography, climate, soil fertility, specific wood density, precipitation, tree functional types, distribution of tree species and forest disturbances (Fearnside, 1997; Slik *et al*., 2008). On individual tree level, tree mass is influenced by the size of the tree, its form, and health (Fearnside, 1997).

Allometric equations serve as a fundamental tool for the non-destructive estimation of biomass in woody vegetation. These equations relate tree biomass to easily measurable parameters such as diameter at breast height (DBH), tree height, wood volume, wood density, or a combination of these variables (FAO, 2012; Brown, 2002; Chave *et al*., 2014). Typically, equations derived from a limited sample of trees are applied to estimate biomass at both plot and landscape scales. This approach remains one of the most practical and widely used methods for assessing forest or stand-level biomass. Furthermore, the application of allometric equations in biomass estimation for both forests and agroforestry systems is crucial, as it supports climate change mitigation strategies and promotes the sustainable management of these ecosystems (Wang, 2006).

MATERIALS AND METHODS

Study Area

Ogbese Forest Reserve is located in Ekiti State, southwestern Nigeria. The reserve covers approximately 72.52 km^2 and lies between Latitudes 7˚32'N and 7˚35'N and Longitudes 5˚19'E and 5˚24'E. The reserve has a tropical climate with distinct wet and dry seasons. According to Ok end Olatilu (2011), the rainy season lasts for 9 months annually which is usually between March and November while the dry season occurs from December to February. The mean annual rainfall is 1,367 mm, with an average number of rainy days of 112 per annum. Mean annual temperature is reported to be 27ºC while the mean annual relative humidity varies between 50% and 95% and its heist is in the rainy season months. The reserve is made up of a plantation of mixtures of tree species such as *Terminalia ivorensis* A. Chev., *Tectona grandis Linn*. F. and *Gmelina arborea*, established in 1998 by a manual clearing of the former vegetation (Faboya *et al*., 2005).

Ala Forest Reserve is a protected area situated within the high forest zone of Nigeria, approximately 1 km away from Cocoa Research Institute of Nigeria (CRIN) Owena sub-station. It lies between latitude 7º3'5''N and longitude 5º26'10''E southwestern part of Nigeria populated by the Yoruba race most of whom are farmers. It was formally gazette as a forest reserve on January 9, 1936 through order number 2 of the western region of Nigeria. The reserve, encompassing an area of 65.93 km^2, located within the old Akure Local Government and naturally bounded to the west by Owena River and to the east by the Apomu Rivers. Both the northern and southern boundaries are unrestricted areas (Pelemo *et al*., 2011).

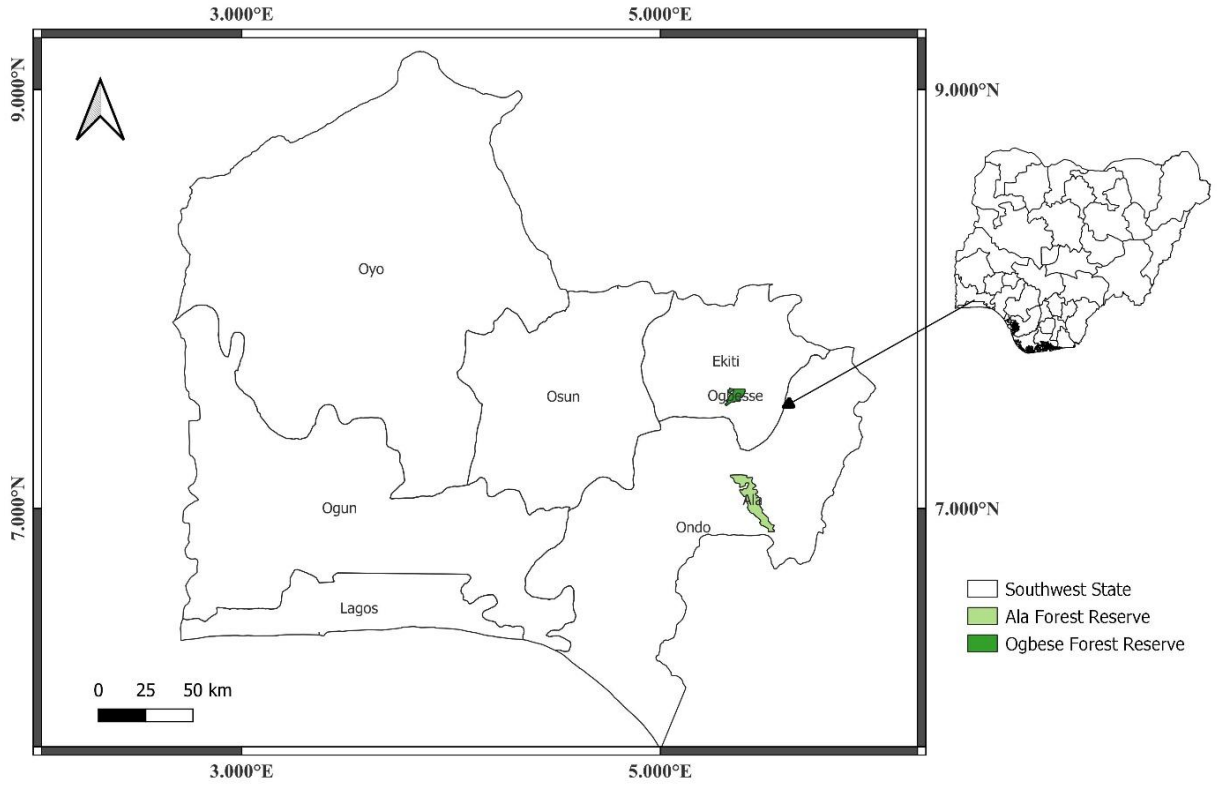

Figure 1: Study Area Map

Sampling Techniques and Data Collection

Systematic line transect was used for the selection of sampling plots in the forest ecosystems guided by existing maps and information from the forest workers. Two parallel line transects of 500m in length with a distance of 200m apart between the two parallel transects were laid with four plots of 50×50m on each side with a distance of 100m interval distance offset away from each sample plot was observed so as to decrease replication of tree species. Enumeration of all the living trees with Dbh ≥ 10 cm was carried out. All the trees were identified and measured in each plot. Tree growth variables such as Diameter at breast height (Dbh) and Diameter at the base (Db) using girth tape, Height (Ht) measurement, Diameter at the middle (Dm), Diameter at the top (Dt) using Spiegel Relaskop.

The following tree parameters was taken during the field exercise for height-diameter relationship;

- Dbh (measured at 1.3m above the base of the tree)
- Rt (measured at the very tip of the tree using Haga altimeter at various distance to the tree) and
- Rb. (measure at the base of the tree using Haga altimeter at various distance to the tree)

Data Analysis

Basal Area Estimation

The basal area for each tree was calculated using equation (6) by Husch *et al*. (2003)

$$BA = \frac{\pi D^2}{4} \quad \text{..... (Eqn. 1)}$$

Where: BA = Basal Area (m^2), D = Diameter at breast height (cm) and π = Pie (3.142).

Volume Estimation

The Volumes of individual tree was estimated using Newton's formula in equation (6) (Husch *et al*., 2003)

$$V = \frac{\pi h}{24} (Db^2 + 4Dm^2 + Dt^2) \quad \text{..... (Eqn. 2)}$$

Where:

V= Volume of tree (m^3), Db= Diameter at the base (cm), Dm= (Diameter at the middle (m), Dt = Diameter ate the top (m), Diameter at the top (m), h = Total height (m).

Wood Density

The wood density was obtained by dividing mass by the volume as given in Equation 8

$$WD = \frac{Mass}{Volume} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn. 3)}$$

Where: *WD = Wood Density*

Estimation of Above-Ground and Below-Ground Biomass

The AGTB was obtained using equation 9 as populated by IPCC (2006)

$$AGTB = V \times \rho \times BEF \ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn. 4)}$$

Where; *AGTB is Above-ground tree biomass (kg)*, *V is Volume (m^3)*, ρ *is wood density (kg/m^3)*

BEF is Biomass expansion Factor

BEF was calculated using equation 10 (when stem volume is less than 215.2m^3/ha) or a constant value of 1.74 (when stem volume is greater than 215.2m^3/ha) as recommended by IPCC (2006).

$$BEF = \exp 3.213 - 0.506 * In\,(BV) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn. 5)}$$

Where: BV is Biomass of inventoried volume in m^3/ha, calculated as the product of VOB/ha (m^3/ha and wood density (t/m^3), VOB is Volume over bark (Newton Formula)

Below-Ground Biomass

Below-ground biomass is an important carbon pool for many vegetation types and land use systems and accounts for above 20% (Santantonio *et al*., 1997) to 26% (Cairns *et al*., 1997) of the total biomass. BGB was calculated as adopted by Hangarge *et al*. (2012) which include multiplying AGB by factor of 0.26.

$$BGTB = AGTB \times 0.26 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn. 6)}$$

Where:

BGTB = Below Ground Tree Biomass, AGTB = Above Ground Tree Biomass

Estimation of Total Biomass (TB) of Trees

The trees total biomass was calculated using equation adopted by Sheikh *et al*. (2011) and FAO (2011).

TB = AGTB (excluding litter) + BGTB…… (Eqn. 7)

Where:

TB = Total Biomass of Tree

AGTB = Above Ground Tree Biomass

BGTB = Below Ground Tree Biomass

RESULTS

Above and Below-ground Biomass of Ala and Ogbese Forest Reserve

Table 1 shows the results of the above ground, below ground and total biomass for Ala Forest reserve. Five hundred and seventy-one (571) individual trees were encountered within the sample plots. On the average, there were 33 stems per hectare. The Dbh ranged from 230 cm to 18 cm, with an average of 44.2 cm for the entire sample plots. However, the average number of species per hectare was 2. The highest and lowest mean Dbh, for the species were 79.33 cm (*Pycnanthus angolense*) and 20.00 cm (*Scottellia coriacea*). More so, the highest and lowest mean tree height recorded base on species are 27 m (*Khaya angolensis*) and 10 m (*Pierreodendron africanum*).
The overall average volume per hectare base on sample plot and species are 5.49 m^3 and 2.58 m^3. In addition, mean basal area per hectare was 1.08 m^2**.** Aboveground biomass was within the range of 0.19kg/ha and 15.91 kg/ha with an average of 2.23 kg/ha while the range for BGB was 0.01 kg/ha and 4.14kg/ha with an average of 0.57 kg/ha. The total AGTB and BGTB estimated for the reserve were 102.64 kg/ha and 26.69 kg/ha which result to a total biomass of 129.33 kg/ha.

Table 2 shows the results of the above ground, below ground and total biomass for Ogbese Forest reserve. Forty-Nine (49) individual trees were encountered within the sample plots. On the average, there were 22 stems per hectare. The Dbh ranged from 64.6 cm to 10 cm, with an average of 32.8 cm for the entire sample plots. However, the average number of species per hectare was 3. The highest and lowest mean Dbh, for the species were 64.6 cm (*Cola gigantea*) and 10.00 cm (*Albizia ferruginea*). More so, the highest and lowest mean tree height recorded base on species are 24.8 m (*Canarium schweinfurthii*) and 6 m (*Spathodea companulata*).
The overall average volume per hectare base on sample plot and species are 13.24 m^3 and 1.70 m^3. In addition, mean basal area per hectare was 3.22 m^2**.** Aboveground biomass was within the range of 0.01kg/ha and 14.52 kg/ha with an average of 1.39 kg/ha while the range for BGB was 0.002 kg/ha and 3.78 kg/ha with an average of 0.36 kg/ha. The total AGTB and BGTB estimated for the reserve were 31.90 kg/ha and 8.30 kg/ha which result to a total biomass of 40.20 kg/ha

Table 1*: Above and Below Ground Biomass of Ala Forest Reserve*

Above and Below ground Biomass of Okoo-Iro Natural Forest base on species								
Species	**Number of Species/ha**	**Mean Dbh (cm)**	**Avg Ht (m)**	**TV/ha (m^3)**	**BA/ha (m^2)**	**AGB/ha (kg/ha**	**BGB/ha (Kg/ha)**	**TB**
Afzelia africana	5	72.64	20.38	13.65	2.97	15.91	4.14	20.04
Albizia feruginea	2	34.33	14.83	0.75	0.20	0.62	0.16	0.78
Albizia lebbeck	1	48.73	12.73	0.57	0.17	0.51	0.13	0.65
Albizia zygia	1	31.37	18.17	0.49	0.12	0.39	0.10	0.50
Alstonia boneii	5	32.51	16.90	2.33	0.45	1.38	0.36	1.74
Antiaris africana	3	38.76	18.09	2.76	0.45	1.77	0.46	2.24
Antiaris toxicaria	2	31.10	13.99	0.84	0.19	0.55	0.14	0.70
Berlinia coriacea	0	21.00	16.00	0.08	0.01	0.08	0.02	0.11
Bombax bounopozense	2	36.38	17.81	1.74	0.30	0.97	0.25	1.22
Brachystegia nigerica	2	52.13	20.13	3.34	0.47	3.03	0.79	3.81
Bridelia ferruginea	0	34.95	14.50	0.17	0.04	0.18	0.05	0.22
Canarium schweinfurthii	1	50.70	23.77	0.95	0.13	0.66	0.17	0.83
Ceiba pentandra	1	74.24	14.44	1.36	0.51	0.62	0.16	0.77
Celtis zenkeri	1	42.16	15.01	1.10	0.23	1.13	0.29	1.42
Chrysophyllum albidum	0	29.00	18.30	0.06	0.01	0.06	0.01	0.07
Cola gigantea	2	39.08	19.16	0.96	0.22	0.77	0.20	0.97
Cordia millenii	8	50.82	15.84	9.68	2.07	5.73	1.49	7.21
Cordia platythrsa	1	50.20	16.93	1.24	0.30	0.78	0.20	0.98
Dracryodes edulis	0	37.80	24.60	0.13	0.02	0.11	0.03	0.14

Entandrophragma angolensis	0	51.00	19.75	0.44	0.10	0.34	0.09	0.43
Ficus exasperata	2	47.85	14.83	1.79	0.53	1.00	0.26	1.26
Futumia elastica	1	25.58	13.88	0.19	0.04	0.14	0.04	0.18
Gossweileirodendro balsamiferum	2	39.75	20.17	1.25	0.25	0.87	0.23	1.09
Havea brasiliensis	3	33.38	14.73	1.03	0.33	0.88	0.23	1.11
Irvingia gabonensis	2	33.19	19.01	0.93	0.17	1.15	0.30	1.45
Khaya angolensis	0	70.00	27.00	2.11	0.07	2.02	0.53	2.55
Khaya ivorensis	2	47.91	18.63	1.96	0.32	1.50	0.39	1.89
Lophira alata	1	41.88	15.98	0.56	0.13	0.85	0.22	1.08
Lovoa trichiliodes	4	44.48	15.97	3.69	0.80	2.89	0.75	3.64
Mansonia altisima	9	36.47	16.23	6.16	1.12	6.22	1.62	7.83
Milicia excelsa	1	42.07	21.04	1.79	0.24	2.02	0.52	2.54
Mitragyna ciliata	2	46.16	19.31	2.46	0.34	1.93	0.50	2.43
Pierreodendron africanum	0	42.00	10.00	0.07	0.03	0.07	0.02	0.09
Pterygota macrocapa	4	55.78	16.70	3.81	1.24	3.58	0.93	4.51
Pycnanthus angolense	1	79.33	22.83	2.92	0.41	2.03	0.53	2.56
Ricinodendron hendelotii	0	34.75	20.10	0.19	0.04	0.06	0.02	0.08
Scottellia coriacea	0	20.00	10.50	0.03	0.01	0.03	0.01	0.04
Sterculia oblonga	1	32.00	18.94	0.53	0.08	0.56	0.15	0.71
Sterculia rhinopetala	13	36.58	15.05	6.80	1.54	7.57	1.97	9.54
Sterculia triagacantha	1	31.05	18.55	0.26	0.06	0.20	0.05	0.25
Stombosia pustulata	8	31.07	16.53	3.42	0.71	4.76	1.24	6.00

Terminalia ivorensis	2	59.01	19.58	5.62	0.99	5.67	1.47	7.14
Terminalia superba	5	69.83	18.01	16.07	2.94	12.58	3.27	15.85
Treculia africana	1	21.967	12.267	0.07	0.02	0.04	0.01	0.05
Trichilia prieuereana	0	31.50	13.00	0.11	0.03	0.12	0.03	0.15
Triplochiton scleroxylon	6	57.07	22.38	14.57	2.14	8.14	2.12	10.25
Zanthozxylum xanthozanloides	0	38.00	14.50	0.15	0.04	0.19	0.05	0.24
Average	2			2.58	0.50	2.18	0.57	2.75
Total	**108.76**			**121.16**	**23.60**	**102.64**	**26.69**	**129.33**

MDbh =Mean Diameter at Breast Height, Avg Ht = Average Height, TV/ha = Total Volume per hectare, BA/ha = Basal Area per hectare, AGB/ha =Above-ground Biomass per hectare, BGB/ha = Below-ground Biomass per hectare

Table 2:Above and Below Ground Biomass of Ogbese Forest Reserve

Above and Below ground Biomass of Okoo-Iro Natural Forest base on species								
Species	**Number of Species/ha**	**Mean Dbh (cm)**	**Avg Ht (m)**	**TV/ha (m^3)**	**BA/ha (m^2)**	**AGB/ha (kg/ha**	**BGB/ha (Kg/ha)**	**TB**
Albizia ferruginea	1	10.0	6.0	0.01	0.01	0.01	0.003	0.01
Antiaris africana	3	21.2	12.5	0.20	0.09	0.13	0.034	0.16
Bliphia sapida	1	11.0	6.8	0.03	0.01	0.03	0.009	0.04
Bombax buonopozense	4	41.6	13.8	2.90	0.56	1.62	0.420	2.04
Brachystegia cynometroides	3	45.0	17.8	5.31	0.46	5.17	1.345	6.52
Bridelia micrantha	4	45.2	15.7	1.94	0.65	1.59	0.413	2.00

Canarium schweinfurthii	1	40.5	24.8	1.46	0.17	1.02	0.265	1.28
Ceiba pentandra	4	21.9	7.7	0.25	0.16	0.11	0.029	0.14
Celtis zenkeri	1	45.0	21.0	1.28	0.21	1.31	0.342	1.66
Cola gigantea	13	64.6	19.1	18.14	4.65	14.52	3.776	18.30
Cola milleni	7	25.5	9.4	0.72	0.36	0.87	0.227	1.10
Discoglypremna caloneura	1	41.0	15.0	0.54	0.18	0.30	0.078	0.38
Ficus exapsirata	1	39.5	11.0	0.33	0.16	0.18	0.048	0.23
Funtumia elastica	1	14.7	10.5	0.06	0.02	0.04	0.011	0.05
Lecaniodiscuss cupanioides	5	26.2	11.3	1.00	0.32	1.34	0.347	1.68
Myrianthus arboreus	1	18.0	7.5	0.07	0.03	0.06	0.016	0.08
Pterocarpus angolensis	1	36.9	18.8	0.81	0.14	0.83	0.216	1.05
Ricinodendron heudelotii	4	49.3	14.7	2.47	0.77	0.86	0.224	1.08
Spathodea companulata	1	11.0	6.0	0.02	0.01	0.01	0.002	0.01
Sterculia rhinopetala	1	31.0	14.5	0.54	0.10	0.60	0.156	0.76
Sterculia trigacantha	1	34.5	11.8	0.44	0.12	0.34	0.088	0.42
Terminalia superba	1	64.0	18.8	1.15	0.43	0.90	0.234	1.13
Triplochiton scleroxylon	1	16.2	8.5	0.06	0.03	0.04	0.009	0.05
Average	**2**	**32.8**	**13.2**	**1.7**	**0.4**	**1.4**	**0.4**	**1.7**
Total	**49**	**753.8**	**302.9**	**39.7**	**9.7**	**31.9**	**8.3**	**40.2**

MDbh =Mean Diameter at Breast Height, Avg Ht = Average Height, TV/ha = Total Volume per hectare, BA/ha = Basal Area per hectare, AGB/ha =Above-ground Biomass per hectare, BGB/ha = Below-ground Biomass per hectare

Carbon in Above and Below-ground Biomass of Okoo-Iro Forest Reserve

Table 3 shows the AGC and BGC of Ala Forest Reserve. The AGC was within the range of 0.06 kg/ha and 7.03 kg/ha with an average of 2.18 kg/ha while the range for the BGC was 0.02 kg/ha and 1.83kg/ha with an average of 0.57kg/ha. The total AGC and BGC estimated are 45.83 kg/ha and 11.91 kg/ha respectively which result to a total carbon of 57.74 kg/ha.

Table 4 also shows the AGC and BGC of Ogbese Forest Reserve. The AGC was within 4.38 kg/ha and 6.79 kg/ha with an average of 5.32kg/ha while BGC ranged from 1.14 kg/ha 1.77 kg/ha with an average of 1.38 kg/ha. The total AGC and BGC estimated are 15.96 kg/ha and 4.15 kg/ha respectively which resulted to a total carbon of 20.11 kg/ha

Table 3: Carbon Stock in Ala Forest Reserve

Plot Number	AGC (kg/ha)	BGC (Kg/ha)	TC (Kg/ha)
1	2.67	0.70	3.37
2	0.06	0.02	0.08
3	3.52	0.91	4.43
4	2.98	0.77	3.75
5	1.72	0.45	2.17
6	1.45	0.38	1.82
7	1.81	0.47	2.28
8	1.59	0.41	2.01
9	2.47	0.64	3.11
10	2.40	0.62	3.02
11	0.91	0.24	1.15
12	1.28	0.33	1.61
13	5.32	1.38	6.70
14	0.86	0.22	1.08
15	2.04	0.53	2.57
16	1.76	0.46	2.21
17	7.03	1.83	8.85
18	1.36	0.35	1.72
19	1.77	0.46	2.23
20	1.43	0.37	1.80
21	1.41	0.37	1.78
Average	**2.18**	**0.57**	
Total	**45.83**	**11.91**	**57.74**

Table 4: Carbon Stock in Ogbese Forest Reserve

Plot Number	AGC (kg/ha)	BGC (Kg/ha)	TC (Kg/ha)
1	4.38	1.14	5.52
2	6.79	1.77	8.56
3	4.78	1.24	6.02
Average	**5.32**	**1.38**	
Total	**15.96**	**4.15**	**20.11**

DISCUSSION

Carbon in Above and Below-Ground Biomass of Ala and Ogbese Forest reserve

Dbh and height measurements are important in estimating carbon pools. Beyond their utility in calculating volume and basal area, these metrics are instrumental in developing allometric equations, which are valuable for future carbon studies **(**Pearson *et al*. 2007; Goslee *et al*. 2015; Phalla *et al*. 2018). In this study, the estimated basal area and volume were lower than those reported by Adekunle *et al*. (2013), Etigale *et al*. (2014), and Aigbe *et al*. (2017). This difference may be due to the focus on larger tree classes (dbh = 79.33 cm) for Ala Forest Reserve and 64.6 cm for Ogbese Forest Reserve in the present research, compared to the smaller classes (dbh = 10 cm) targeted in the other studies. McElhinny (2002) highlighted basal area to be an important indicator of stand volume and biomass, with significant implications for carbon assessment. Aboveground biomass (AGTB) in this study ranged from 0.19 kg/ha to 15.91 kg/ha, with an average of 2.23 kg/ha for Ala Forest Reserves and 0.01 kg/ha to 14.52 kg/ha, with an average of 1.39 kg/ha for Ogbese Forest Reserve, while belowground biomass (BGTB) ranged from 0.01 kg/ha to 4.14 kg/ha, averaging 0.57 kg/ha for Ala Forest Reserve and 0.002 kg/ha to 3.78 kg/ha with an average of 0.36 kg/ha for Ogbese Forest Reserve. The study shows that Ala Forest Reserve has higher Biomass compare to Ogbese Forest Reserve this might be due to high rate of deforestation and urbanization within Ogbese Forest Reserve

CONCLUSION

Globally, forest ecosystems represent the largest carbon pools, functioning as major sources and sinks that drive carbon in nature. Thus, their management is therefore a vital factor of climate change mitigation and adaptation strategies. Estimating forest carbon stocks is important in assessing carbon emissions during deforestation and quantifying carbon storage potential of forest ecosystems.

This research review has highlighted the importance of estimating carbon stocks in forest reserve in south west, Nigeria for effective forest management and climate change mitigation. The research has presented results on carbon stock estimation in Ala and Ogbese forest Reserve of Nigeria. Additionally, the study established that anthropogenic disturbances are negatively affecting the floristic composition of the reserve. Logging activities, in particular, have altered the forest

structure by removing large, tall trees. Therefore, controlling human activities is essential for protecting plant species and promoting effective management and utilization.

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DECLARATIONS

Author Contribution

Olagoke Felix Ogunrinu: Conceptualization, Methodology, Data Collection and Data Analysis, writing of the original draft and Correction based on review.

Daniel Akintunde-Alo: Supervision, Validation, Review and Editing of the manuscript.

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Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.