



Carbon Stock and Storage Capacity of Tree Species in Strict Nature Reserve of Omo Biosphere Reserve, Ogun State, Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Carbon is the main casual factor for global warming and climate change. Increased industrialization is known to be the chief contributor to increased atmospheric carbon concentration. Forest ecosystem plays significant role as a major terrestrial carbon sinks that reduces atmospheric carbon concentration. This study assessed the amount of carbon sequestered in the Strict Nature Reserve (SNR) of Omo Biosphere Reserve and the contribution of individual tree species to the carbon stocks. A non-destructive approach was deployed in the study. Systematic random sampling technique was used to demarcate 20 sample plots of 30x30 m. In each sample plot, all tree species (DBH \geq 10 cm) were identified and measured for their total heights while diameter were measured at breast height (DBH), base, medium and top. Findings indicated 616 stems/ha in the reserve, *Strombosia pustulata* (63stems/ha) had the highest tree population. Diversity indices showed that the reserve is rich in tree species diversity with potentials for incessant growth due to the existence of young trees in the lower canopy. The high biomass and carbon storage of the tree species revealed the contribution of the reserve to climate change mitigation through CO_2 absorption from the atmosphere. *Ceiba pentandra* (9stems/ha) contributed most (26.14%) to the entire carbon stock in the reserve. However higher stem density of tree species hectare⁻¹ did not translate to higher

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percentage of carbon stock input of the tree species to the entire carbon stock of the reserve. Trees with higher DBH and wood density store more carbon than trees with lesser DBH and wood density. Thus, tree species ability to sequester more carbon is dependent on its DBH and wood density, rather than its population. The need to conserve and increase the tree species diversity is implicated in the study.

Keywords: Carbon sequestration; allometry; biodiversity indices; nature conservation; climate change.

1. INTRODUCTION

Carbon dioxide (CO₂) is one of the most common greenhouse gases having significant consequences in global warming. It is the major causal factor for global warming [1]. Billions of tones of CO₂ are locked as organic matter around the planet, but owing to natural processes, this organic matter is converted into fuels such as diesel, coal, peat, wood and petrol [2]. When the fuel is burnt, the stored carbon dioxide is emitted into the atmosphere, increasing the atmospheric carbon concentration contributing in global warming and climate change. Approximately two-thirds of the total increase in atmospheric CO₂ is as result of the burning of fossil fuels, with the remainder coming from land use change [3]. In other words, high rate of industrialization, urbanization, human population explosion and deforestation have amounted to increased CO₂ in the atmosphere. [4] revealed that urbanization, industrialization and its attendant air pollution, and other human economic activities have, in the last 100 years, contributed to an increase in the concentration of greenhouse gases in the atmosphere leading to intense greenhouse effect, which in turn resulted in climate change that is the most complex environmental issue today.

Atmospheric CO₂ concentrations have risen from approximately 280 parts per million (ppm) prior to 1850, to 381.2 ppm in 2006, with a current annual increase of 0.88 ppm (3.5 GT C/yr) [5]. However, trees absorb carbon through the process of photosynthesis and store them in their leaves, litter, branches, stems, roots and soil in a varying proportion, giving rise to different components of carbon pools in a forest ecosystem [6]. Therefore, forest ecosystem plays significant role in climate change mitigation. According to [7], the amount of carbon stored in vegetation is directly related to their biomass density hence studies on carbon sequestration have been focusing on biomass, since biomass of vegetation consists approximately 50% of

carbon. [8] reported that forest ecosystems contain from 62% to 78% of the total terrestrial carbon, while forest cover which is more than one third of the world's land area constitutes the major terrestrial carbon pool [9]. Thus, forest ecosystems are viable options for achieving reduction of outrageous CO₂ in the atmosphere.

Certain strategies are required to boost carbon sequestration potentials in forest ecosystem. FAO [10] recommended three feasible strategies for the management of forest carbon to include: 1) to create more carbon sinks, 2) to reduce carbon release rate, and 3) to cut down the fossil fuel demand. Similarly, the international community in the quest to reduce environmental hazards initiated Reducing Emissions from Deforestation and Degradation plus (REDD+) project, which covers conservation of forest carbon stocks; sustainable forest management and enhancement of forest carbon stocks in developing countries. The Kyoto Protocol, through its Clean Development Mechanism (CDM) concept, introduces carbon credits, afforestation/reforestation activities in developing countries as an effective strategy to improve forest carbon management [11]. Consequently, many international donors and industrialized countries according to [12] have allocated significant funds for provisional cash transfers to tropical countries that commit to limiting deforestation rates, to have healthier forests to clean up the greenhouse gases, especially CO₂, accumulated in the atmosphere. In this way, developing countries, forest owners and other individuals could be motivated to venture into afforestation/reforestation projects to maximize carbon in their forest for gainful carbon trading and other goods and services forest provides rather than conversion of forest land to other land uses.

However, carbon accumulation varies among tree species [13] and forest management, including a change in tree species, has been proposed by [14] as a measure to increase removal of atmospheric CO₂ in national

greenhouse gas budgets. [15,16] also revealed that one of the measures to improve carbon sequestration in forest ecosystem is related to change in the choice of tree species; unfortunately, there is limited knowledge of it. [17,18] reported that the ability to increase C sequestration through forest management has not been properly understood and the uncertainty has adversely affected decision-making in forest carbon management. The lack of in-depth information on carbon storage capacity of different tree species that hinders the knowledge in forest carbon management/establishment justifies the study. Therefore, this research investigated carbon storage capacity of individual tree species in Strict Nature Reserve (SNR) of Omo Biosphere Reserve, Nigeria with the objective of documenting its carbon sequestration potentials and its contribution in reducing atmospheric carbon concentration for climate change mitigations.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Strict Nature Reserve (SNR) of Omo Biosphere Reserve, which is located between Latitudes 6° 35' - 7°

05'N and Longitudes 4° 19' - 4° 40'E (Fig. 1). It covers a total land area of 460 hectares and is located east of Ijebu town, in Ijebu North Local Government Area of Ogun State, Southwestern Nigeria. In 1968, during UNESCO Conference on Rational Use and Conservation of the Resources of the Biosphere, the United Nations Educational, Scientific and Cultural Organization (UNESCO) pioneered the setting up of biosphere reserves when it hosted the 1968 UNESCO Conference on Rational Use and Conservation of the Resources of the Biosphere. This led to the establishment of biosphere reserves in several countries including Nigeria. Thus, Omo Biosphere Reserve which derives its name from river Omo that traverses it was established in the year 1977 [19]. The climatic condition is characterized by heavy rainfall from which commences in March-October. The mean annual rainfall ranges from about 1600 to 2000 mm with two annual peaks in June and September. Temperature ranges from 32.15°C to 21.40°C with a minimum relative humidity of 76.34% [20].

2.2 Data Collection and Analysis

Simple random sampling technique was used to demarcate twenty (20) temporary sample plots of

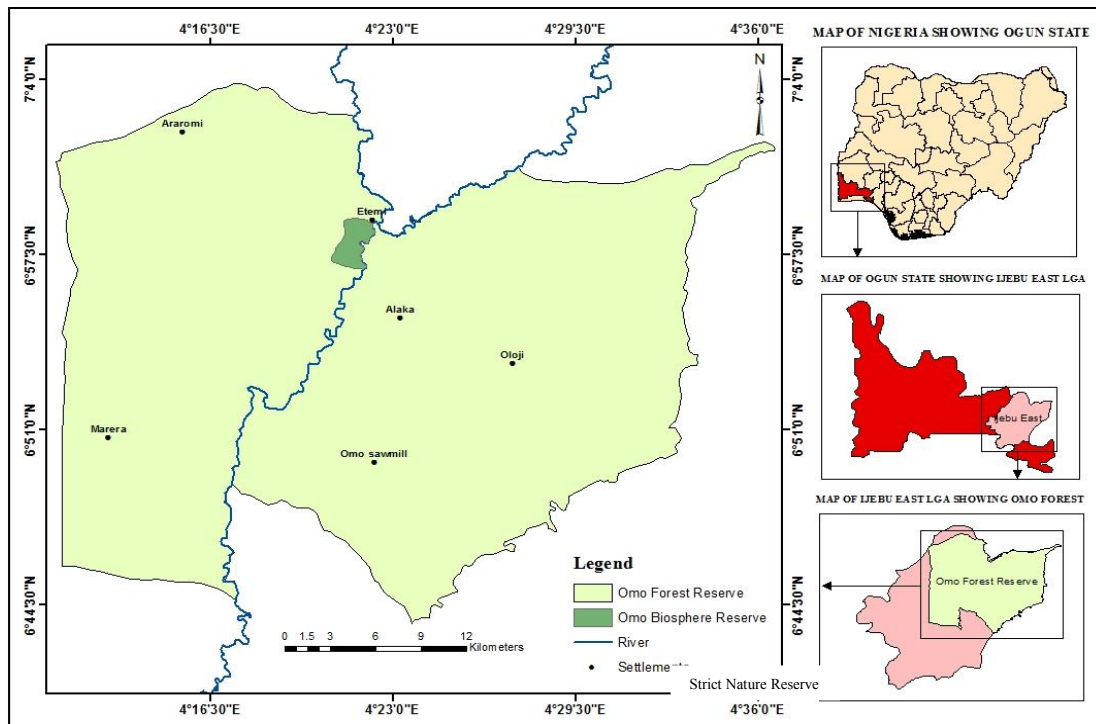


Fig. 1. Omo Forest Reserve showing the Strict Nature Reserve

Source: Chenge, 2017. Unpublished PhD thesis

30 mx30 m. In each sample plot, tree species with diameter at breast height (DBH) ≥ 10 cm were identified to species level. All unidentified tree species in each plot were properly collected and sent to Forest Herbarium Ibadan, of Forestry Research Institute of Nigeria (FRIN) Ibadan. Total Tree height and dbh were measured using Haga altimeter and Spiegel Relaskop respectively. Shannon-Weiner index, Simpson's index and Margalef's index were used to assess the tree species richness and diversity [21].

- **Shannon-Weiner diversity index (H)**

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

Where: H' = Shannon-Weiner diversity index, S = Total number of species in the community, P_i = Proportion of S made up of the ith species, ln = natural logarithm

- **Shannon's equitability (E_H)**

$$E_H = \frac{H}{\ln S} \dots\dots\dots (2)$$

- **Simpson's index of diversity (1-D)**

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right) \dots\dots\dots (3)$$

Where n = is the total number of organisms of a particular species and N is the total number of individual species.

- **Margalef's index of species richness (M)**

$$M = \frac{(S-1)}{\ln N} \dots\dots\dots (4)$$

Where: S = total number of species in the community, N = total number of all individual trees.
ln = natural logarithm.

2.3 Aboveground Biomass Estimation

The tree growth variables (height and diameters) obtained in the sample plots were used to estimate the aboveground biomass of tree stems of each species portion [22,23].

Tree stem biomass = Tree stem volume x Wood density ---- (5)

2.4 Tree Volume Estimation

The volume of each tree encountered in the sampled plot was calculated using Newton's formula [24]

$$V = \left(\frac{h}{6} \right) (A_b + 4A_m + A_t) \dots\dots\dots (6)$$

Where V =tree volume (m³); A_b, A_m and A_t = tree cross-sectional area (m²) at the base, middle and top of merchantable height, respectively, while h = total height (meters). Plot volumes were also obtained by adding the volumes of all the trees in the plot.

2.5 Basal Area of Tree Stem

The basal area (BA) of each tree species in the sampled plots was computed using the following formula;

$$BA = \frac{\pi d^2}{4} \dots\dots\dots (7)$$

Where BA = basal area (m²), π = 3.143, d = diameter (m)

2.6 Wood Density

Woody densities of forest tree species were obtained from the Wood Density Database [25]. This database has been widely used by researchers [26,27] in forest biomass and carbon studies.

2.7 Above Ground Carbon Stock of Tree Stems

Tree stem biomass was estimated to quantify the carbon stock in the study area. [28,7] explained that carbon is about 50% of biomass estimate. The stem biomass of individual tree species was estimated per plots, and sum of total biomass per species in all the plots were calculated and converted to species biomass per hectare.

$$\text{Carbon stock (kg/ha)} = \text{tree stem biomass(kg/ha)} \times 0.5 \dots\dots\dots (9)$$

The carbon was converted to CO₂ equivalent to estimate the amount of carbon sequestered by the forest. The relationship is given as: 1C = 3.67 CO₂ [29].

2.8 Below Ground Biomass and Carbon

Below-ground biomass was estimated from aboveground biomass. [30,31] explained that in non-destructive approach of biomass estimation, 20% of the above ground stem biomass is equivalent to below ground biomass.

Below ground biomass (kg/ha) = Aboveground biomass (kg/ha) x 0.2 (10)

Below ground carbon (kg/ha) = Below ground biomass (kg/ha) X 0.5 (11)

2.9 Litter Biomass and Carbon

Litter biomass was estimated from above-ground biomass. [31] reported that 15% of aboveground biomass was considered for litter biomass estimation.

Litter Biomass (kg/ha) = Aboveground biomass (kg/ha) x 0.15 (12)

Litter carbon (kg/ha) = Litter Biomass (kg/ha) x 0.5 (13)

3. RESULTS

3.1 Tree Species Diversity

The result of the diversity indices of the reserve is presented in Table 1 below. The species richness recorded was 81 tree species while average stem density per hectare was 616 stem ha⁻¹. The value of Shannon-Wiener Index (H), Simpson's Index (D) and Margalef index obtained were 3.58, 0.95, and 11 respectively. All the diversity indices indicated that the reserve is rich in tree species diversity. The Shannon's equitability (E_H) value was 0.81 an indication of uniformity in the distribution of individuals across the species in the forest stand.

Table 1. Diversity indices of Strict Nature Reserve (SNR)

Indices	Value
Species richness	81.0
Mean Stem density(stem/ha)	616
Simpson_1-D	0.95
Shannon_H	3.58
Shannon's equitability (E _H)	0.81
Margalef	11.56

3.2 Tree Species Abundance and Carbon Stocks

The seven most abundant tree species recorded in the reserve as shown in Table 2 below were *Strombosia pustulata* (63stems ha⁻¹), *Milletia thonningii* (56stems/ha), *Xilopia villosa* (53stems/ha), *Diospyros dendo* (42stems/ha), *Khaya grandifoliola* (29stems/ha), *Funtumia*

elastic (25 stems/ha), *Sterculia rhinopetala* (23 stems/ha) while 42 tree species occurred 1stem/ha among which were *Mallotus subulatus* (1stems/ha), *Piptadeniastrum africanum* (1stems/ha), *Spondias mombin* (1stems/ha), *Uapaca togoensis* (1stems/ha), *Lecaniodiscus cupanioides* (1stems/ha), *Cola afzelii* (1stems/ha), *Berlinia grandiflora* (1stems/ha⁻¹). The amount of carbon sequestered in the aboveground, belowground and litter biomass were 1713.63 kg/ha, 342.73 kg/ha, and 257.04 kg/ha respectively, totaling 2313.40 kg/ha of carbon concentration in the reserve, and a corresponding value of 8490.18 kg/ha CO₂ equivalent.

It was observed that higher tree species population per hectare did not translate to the higher carbon contribution of the species to the entire carbon in the reserve. *Ceiba pentandra* (9stems/ha) had the highest total carbon accumulation of 604.79 kg/ha, and 2219.59 kg/ha CO₂eq., thus contributed 26.14% of the entire carbon concentration in the reserve, followed by *Terminalia superba* (14stems/ha), 407.21 kg/ha carbon, 1494.48 kg/ha CO₂ eq., and 17.60% carbon input, *Khaya grandifolia* (29stems/ha), 202.63 kg/ha carbon, 743.65 kg/ha CO₂ eq., and 8.76% carbon input, *Diospyros dendo* (42stems/ha), 117.34 kg/ha carbon, 430.62 kg/ha CO₂eq., and 5.07% carbon input, *Strombosia pustulata* (63stems/ha), 30.56 kg/ha carbon, 112.17 kg/ha CO₂ eq., and 1.32% carbon input, *Xylopi villosa* (53stems/ha), 7.57 kg/ha of total carbon, 27.79 kg/ha CO₂ eq., and 0.33% carbon input. While, *Cola milleni* (1stem/ha) had the least total carbon concentration, CO₂ eq. and percentage carbon input of 0.26 kg/ha, 0.94 kg/ha and 0.0001% respectively, followed by *Trichilia monadelpha* (1stem/ha), 0.05 kg/ha carbon, 0.20 kg/ha CO₂ eq., and 0.002% carbon input, *Enantia chloranta* (1stem/ha), 0.04 kg/ha carbon, 0.15 kg/ha CO₂ eq., and 0.002% carbon input, and *Erythrina suaveolens* (1stem/ha), 0.05 kg/ha carbon, 0.17 kg/ha CO₂ eq., and 0.002% carbon input.

4. DISCUSSION

The diversity indices obtained in the reserve indicated that the reserve is rich in tree species diversity. The value of Shannon-Wiener Index (3.58) obtained was higher than Kodayar Forest Reserve (2.20–2.65) in the West of Ghats, Southern India [32], and Kalakad Reserved Forests (3.31) in Western Ghats [33], but less

Table 2. Biomass and carbon stocks according to species in Strict Nature Reserve, Omo Biosphere Reserve

Sl No	Species	Stems/ha	AGB kg/ha	AGC kg/ha	BGC kg/ha	LC kg/ha	Total Carbon kg/ha	CO ₂ equiv. kg/ha	%C/ha
1	<i>Azelia africana</i>	1	0.19	0.10	0.02	0.01	0.13	0.47	0.01
2	<i>Azelia bella</i>	1	2.78	1.39	0.28	0.21	1.88	6.89	0.08
3	<i>Albizia ferruginea</i>	1	0.85	0.43	0.09	0.06	0.57	2.11	0.02
4	<i>Albizia zigia</i>	1	0.27	0.14	0.03	0.02	0.18	0.67	0.01
5	<i>Allanblackia floribunda</i>	1	0.35	0.18	0.04	0.03	0.24	0.87	0.01
6	<i>Alstonia bonnei</i>	8	80.62	40.31	8.06	6.05	54.42	199.72	2.35
7	<i>Aningeria robusta</i>	8	7.14	3.57	0.71	0.54	4.82	17.69	0.21
8	<i>Antiaris africana</i>	1	0.13	0.07	0.01	0.01	0.09	0.32	0.01
9	<i>Baphia nitida</i>	13	17.43	8.72	1.74	1.31	11.77	43.18	0.51
10	<i>Berlinia grandiflora</i>	1	1.15	0.58	0.12	0.09	0.78	2.85	0.03
11	<i>Blighia sapida</i>	8	11.95	5.98	1.20	0.90	8.07	29.60	0.35
12	<i>Bombax buonopozense</i>	1	11.89	5.95	1.19	0.89	8.03	29.45	0.35
13	<i>Bosqueia angolensis</i>	12	20.02	10.01	2.00	1.50	13.51	49.59	0.58
14	<i>Brachystegia eurycoma</i>	5	63.93	31.97	6.39	4.79	43.15	158.37	1.87
15	<i>Brachystegia nigerica</i>	1	0.76	0.38	0.08	0.06	0.51	1.88	0.02
16	<i>Bridelia micrantha</i>	1	0.24	0.12	0.02	0.02	0.16	0.59	0.01
17	<i>Carapa procera</i>	1	2.99	1.50	0.30	0.22	2.02	7.41	0.09
18	<i>Ceiba pentandra</i>	9	895.99	448.00	89.60	67.20	604.79	2219.59	26.14
19	<i>Celtis mildbraedii</i>	1	2.55	1.28	0.26	0.19	1.72	6.32	0.07
20	<i>Celtis zenkeri</i>	10	67.56	33.78	6.76	5.07	45.60	167.36	1.97
21	<i>Chrysophyllum prunifolium</i>	1	0.38	0.19	0.04	0.03	0.26	0.94	0.01
22	<i>Cleistiopholis patens</i>	4	3.96	1.98	0.40	0.30	2.67	9.81	0.12
23	<i>Cola acumunata</i>	1	0.80	0.40	0.08	0.06	0.54	1.98	0.02
24	<i>Cola afzelii</i>	1	0.21	0.11	0.02	0.02	0.14	0.52	0.01
25	<i>Cola gigantea</i>	20	97.16	48.58	9.72	7.29	65.58	240.69	2.84
26	<i>Cola milleni</i>	1	0.01	0.01	0.00	0.00	0.01	0.02	0.00
27	<i>Cola mucoso</i>	1	0.43	0.22	0.04	0.03	0.29	1.07	0.01
28	<i>Cordia millenii</i>	8	15.95	7.98	1.60	1.20	10.77	39.51	0.47
29	<i>Dallium guinensis</i>	1	2.38	1.19	0.24	0.18	1.61	5.90	0.07
30	<i>Daniella ogea</i>	6	7.50	3.75	0.75	0.56	5.06	18.59	0.22
31	<i>Diospyros dendo</i>	42	173.83	86.92	17.38	13.04	117.34	430.62	5.07
32	<i>Diospyros iturensis</i>	20	23.60	11.80	2.36	1.77	15.93	58.46	0.69
33	<i>Diospyros mespiliformis</i>	6	9.80	4.90	0.98	0.74	6.62	24.28	0.29
34	<i>Enantia chloranta</i>	1	0.06	0.03	0.01	0.00	0.04	0.15	0.00
35	<i>Entandrophragma cylindricum</i>	2	3.94	1.97	0.39	0.30	2.66	9.76	0.11
36	<i>Entandrophragma utile</i>	8	55.82	27.91	5.58	4.19	37.68	138.28	1.62
37	<i>Entandrophragma angolense</i>	1	0.28	0.14	0.03	0.02	0.19	0.69	0.01
38	<i>Erythrina suaveolens</i>	1	0.07	0.04	0.01	0.01	0.05	0.17	0.00
39	<i>Fagara lepreuri</i>	1	0.49	0.25	0.05	0.04	0.33	1.21	0.01
40	<i>Ficus capensis</i>	2	5.63	2.82	0.56	0.42	3.80	13.95	0.16
41	<i>Ficus exasperate</i>	1	9.79	4.90	0.98	0.73	6.61	24.25	0.29
42	<i>Ficus mucoso</i>	1	5.71	2.86	0.57	0.43	3.85	14.15	0.17
43	<i>Ficus thonningii</i>	3	53.77	26.89	5.38	4.03	36.29	133.20	1.57
44	<i>Funtumia africana</i>	1	0.13	0.07	0.01	0.01	0.09	0.32	0.00
45	<i>Funtumia elastica</i>	25	23.62	11.81	2.36	1.77	15.94	58.51	0.69
46	<i>Hexalobus crispiflorus</i>	1	0.80	0.40	0.08	0.06	0.54	1.98	0.02
47	<i>Hildegardia barteri</i>	1	0.20	0.10	0.02	0.02	0.14	0.50	0.01
48	<i>Hunteria umbellata</i>	14	54.53	27.27	5.45	4.09	36.81	135.08	1.59
49	<i>Irvingia gabonensis</i>	1	7.82	3.91	0.78	0.59	5.28	19.37	0.23
50	<i>Khaya grandifoliola</i>	29	300.19	150.10	30.02	22.51	202.63	743.65	8.76
51	<i>Khaya senegalensis</i>	1	7.23	3.62	0.72	0.54	4.88	17.91	0.21
52	<i>Lecaniodiscus cupanioides</i>	1	1.49	0.75	0.15	0.11	1.01	3.69	0.04
53	<i>Mallotus subulatus</i>	1	0.12	0.06	0.01	0.01	0.08	0.30	0.00
54	<i>Milicia excelsa</i>	1	0.85	0.43	0.09	0.06	0.57	2.11	0.02
55	<i>Milletia thonningii</i>	56	50.84	25.42	5.08	3.81	34.32	125.94	1.48
56	<i>Mitragyna stipulosa</i>	1	0.64	0.32	0.06	0.05	0.43	1.59	0.02
57	<i>Morusmeso zygia</i>	2	2.02	1.01	0.20	0.15	1.36	5.00	0.06

S/ No	Species	Ste ms/ ha	AGB kg/ha	AGC kg/ha	BGC kg/ha	LC kg/ha	Total Carbon kg/ha	CO ₂ equiv. kg/ha	%C/ha
58	<i>Musanga cecropioides</i>	1	0.41	0.21	0.04	0.03	0.28	1.02	0.01
59	<i>Nauclea diderrichii</i>	10	90.15	45.08	9.02	6.76	60.85	223.32	2.63
60	<i>Nesogordonia papaverifera</i>	18	28.54	14.27	2.85	2.14	19.26	70.70	0.83
61	<i>Parinari excelsa</i>	3	8.33	4.17	0.83	0.62	5.62	20.64	0.24
62	<i>Phyllanthus angolensis</i>	1	21.68	10.84	2.17	1.63	14.63	53.71	0.63
63	<i>Phyllanthus discoideus</i>	8	32.86	16.43	3.29	2.46	22.18	81.40	0.96
64	<i>Phyllanthus mullerianus</i>	1	0.53	0.27	0.05	0.04	0.36	1.31	0.02
65	<i>Piptadeniastrum africanum</i>	1	82.02	41.01	8.20	6.15	55.36	203.18	2.39
66	<i>Pterygota macrocarpa</i>	4	107.20	53.60	10.72	8.04	72.36	265.56	3.13
67	<i>Pycnanthus angolensis</i>	15	45.39	22.70	4.54	3.40	30.64	112.44	1.32
68	<i>Ricinodendron heudelotii</i>	19	35.25	17.63	3.53	2.64	23.79	87.32	1.03
69	<i>Spondias mombin</i>	1	0.55	0.28	0.06	0.04	0.37	1.36	0.02
70	<i>Sterculia rhinopetala</i>	23	93.89	46.95	9.39	7.04	63.38	232.59	2.74
71	<i>Sterculia tragacantha</i>	18	71.68	35.84	7.17	5.38	48.38	177.57	2.09
72	<i>Strombosia pustulata</i>	63	45.28	22.64	4.53	3.40	30.56	112.17	1.32
73	<i>Terminalia superba</i>	14	603.28	301.64	60.33	45.25	407.21	1494.48	17.60
74	<i>Treculia africana</i>	1	0.37	0.19	0.04	0.03	0.25	0.92	0.01
75	<i>Trichilia heudelotii</i>	2	4.54	2.27	0.45	0.34	3.06	11.25	0.13
76	<i>Trichilia monadelpha</i>	1	0.08	0.04	0.01	0.01	0.05	0.20	0.00
77	<i>Trichilia prieureana</i>	2	27.02	13.51	2.70	2.03	18.24	66.94	0.79
78	<i>Uapaca togoensis</i>	1	3.57	1.79	0.36	0.27	2.41	8.84	0.10
79	<i>Xylopi aethiopica</i>	2	1.75	0.88	0.18	0.13	1.18	4.34	0.05
80	<i>Xylopi villosa</i>	53	11.22	5.61	1.12	0.84	7.57	27.79	0.33
81	<i>Zanthoxylum zanthoxynoides</i>	1	0.79	0.40	0.08	0.06	0.53	1.96	0.02
TOTAL		616	3427.26	1713.63	342.73	257.04	2313.40	8490.18	100.00

Where AGB = Above Ground Biomass, AGC = Above Ground Carbon, BGC = Below Ground Carbon, LC = Litter Carbon, %C = percentage Carbon stock

than Oban Forest Reserve (3.79) in Southeastern of Nigeria [34]. In a similar study by [35] in same site, 80 tree species with 3.46 Shannon Wiener index value were recorded in 2014, whereas this study recorded 81 tree species with higher Shannon Wiener index value of 3.58 in same site. This is an indication that the reserve is stable and has remained undisturbed over the years. Also, the richness in tree species diversity recorded in the reserve makes it a live gene bank for most tree species, and thus showed that the reserve fulfilled the mandate of a biodiversity conservation strategy [36].

The above-ground biomass (AGB) of tropical forest plays vital role in the global carbon cycle. It provides essential data needed for the extrapolation of biomass stocks of an ecosystem [37]. According to [38], forest ecosystem is one of the major practical ways of reducing large concentration of atmospheric carbon that result in global warming. However, the amount of total carbon per hectare (2313.40 kg/ha) and the CO₂ equivalent (8490.18CO₂eq/ha) estimated in this study reveals the contribution of the reserve in cleaning the atmosphere from CO₂ dirt, thus supports the above claims by Ramachandran. The amount of carbon sequestered in the

reserve is less than the amount of carbon recorded in Eda SNR (4897.82 kg/ha) Nigeria and (5360.84 kg/ha) in Katarnia-Ghat Wildlife Sanctuary (KGWS) India by [39]. The aboveground Biomass (AGB) estimated in the reserve is not up to the 278 Mg/ha worldwide tropical average by [40] and the 206–382 Mg/ha recorded by [41] for Andaman giant evergreen forests, India, but greater than 864.88kg/ha carbon stock recorded by [42] in Teak plantation, Gambari forest reserve Nigeria.

According to [39], the discrepancies in the carbon values observed could be linked to many factors such as methods of biomass calculation, sampling intensity, inter-location variations, soil properties and different climatic conditions. More so, age of the reserve/individual tree species, type of tree species composition and the management techniques adopted could be among the factors for the discrepancies. There is also variation in storage capacity of individual tree species, in other words, the higher the stem density of tree species in the reserve did not translate to the higher percentage of carbon stock input of the individual tree species to the carbon stock of the entire reserve. One would expect the tree species of highest population in the reserve to be the chief contributor of carbon

stocks in the entire reserve, but the expectations did not hold. This supports the finding of [15] that carbon sequestration varies among tree species. Also, the previous studies [43,44,45] revealed that the amount of carbon in tree biomass depended on the tree size. Diameter and tree height are the most important predictor variables of aboveground carbon. The individual tree species that contributed most to the total carbon stock of the reserve in this study were the ones with higher DBH, wood density and height, but not those that have higher population of tree species densities. According to [46], DBH accounted for over 90% of the variation in the aboveground tropical forest carbon stock. However, the high carbon concentration in the reserve could be as a result of the presence of big trees in the reserve since aboveground carbon depended on tree size.

This study further disagrees with the report by [47], that there is significant correlation between tree species diversity and high carbon sequestration potentials in tropical forests. In other words, the higher the tree species diversity the higher the carbon stocks. [39] in their study estimated 4897.82 kg/ha of carbon stock in Eda SNR Nigeria (200 km²) with Shannon–Wiener Index 2.12, Margalef’s index of species richness 7.25, and 500trees/ha. Also, in Katarnia Ghat Wildlife Sanctuary (KGWS) India (400 km²), they recorded 5360.84 kg/ha of carbon stock, Shannon–Wiener Index 2.09, Margalef’s index of species richness 4.33, and 539trees/ha. While this study recorded higher tree species diversity indices, but less carbon stocks when compared. More carbon was also sequestered in tree stems (Aboveground biomass) than in the root and leaf biomass, this was in line with the findings of [42], they recorded 73.1% in Aboveground biomass and 26.89% in belowground biomass.

5. CONCLUSION AND RECOMMENDATIONS

Omo SNR holds significant amount of carbon that helps to reduce atmospheric carbon concentration and therefore contribute in global warming and climate change mitigations. *Strombosia pustulata* had the highest population of tree species in the reserve while *Ceiba pentandra* and *Terminalia superba* were the chief contributor of the carbon in the reserve. Carbon storage capacity varies among the tree species, and the ability of tree species to sequester more carbon is dependent on its size, rather than its population. Trees with higher DBH, height, and

wood density store more carbon than trees with lesser DBH, height and wood density. Therefore, the high carbon sequestration potentials of tree species with high DBH and Wood density, afforestation or reforestation project that gears towards maximizing carbon should consider tree species with such qualities. The diversity indices showed that Omo SNR is rich in tree species diversity. Evidently, SNRs are veritable tools for biodiversity conservation and climate change mitigation. It is therefore recommended that more forest lands should be delineated as SNR specifically in Nigeria where the number of SNRs are limited. More robust study that will consider other aspect of carbon pools such as the soil is therefore recommended in order to have a clearer view of the total carbon in the reserves.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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