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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 ≥ 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, S*trombosia 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 (CO_2) 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2, 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 CO_2 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

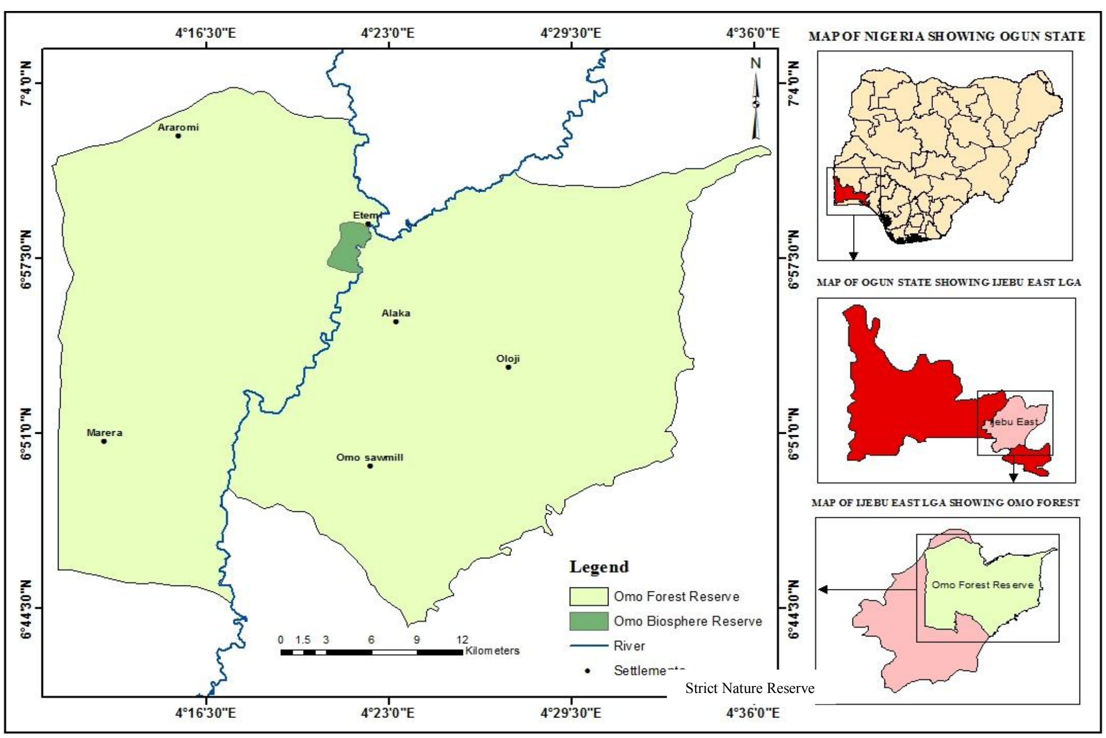

Fig. 1. Omo Forest Reserve showing the Strict Nature Reserve
Source: Chenge, 2017. Unpublished PhD thesis

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)**

$$H = -\sum_{i=1}^{s} p_i \ln p_i \text{ ……………..} \quad (1)$$

Where: H' = Shannon-Weiner diversity index, S = Total number of species in the community, P_i = Proportion of S made up of the i^{th} species, In = natural logarithm

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

$$E_H = \frac{H}{\ln S} \text{ ………………..} \quad (2)$$

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

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right) \text{ ………..} \quad (3)$$

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)**

$$M = \frac{(S-1)}{\text{InN}} \text{ ………………………….} \quad (4)$$

Where: S = total number of species in the community, N = total number of all individual trees.
In = 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]

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

Where V =tree volume (m^3); A_b, A_m and A_t = tree cross-sectional area (m^2) 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;

$$BA = \frac{\pi d^2}{4} \text{ -----------------------------} \quad (7)$$

Where BA = basal area (m^2), 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.

Carbon stock (kg/ha) = tree stem biomass(kg/ha) x 0.5……………………………………………… (9)

The carbon was converted to CO_2 equivalent to estimate the amount of carbon sequestrated by the forest. The relationship is given as: 1C = 3.67 CO_2 [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), *Xillopia 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 CO_2 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 CO_2eq., 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 CO_2 eq., and 17.60% carbon input, *Khaya grandiforlia* (29stems/ha), 202.63 kg/ha carbon, 743.65 kg/ha CO_2 eq., and 8.76% carbon input, *Diospyros dendo* (42stems/ha), 117.34 kg/ha carbon, 430.62 kg/ha CO_2eq., and 5.07% carbon input, *Strombosia pustulata* (63stems/ha), 30.56 kg/ha carbon, 112.17 kg/ha CO_2 eq., and 1.32% carbon input, *Xylopia villosa* (53stems/ha), 7.57 kg/ha of total carbon, 27.79 kg/ha CO_2 eq., and 0.33% carbon input. While, *Cola milleni* (1stem/ha) had the least total carbon concentration, CO_2 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 CO_2 eq., and 0.002% carbon input, *Enantia chloranta* (1stem/ha), 0.04 kg/ha carbon, 0.15 kg/ha CO_2 eq., and 0.002% carbon input, and *Erythrina suaveolens* (1stem/ha), 0.05 kg/ha carbon, 0.17 kg/ha CO_2 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

S/ 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	*Afzelia africana*	1	0.19	0.10	0.02	0.01	0.13	0.47	0.01
2	*Afzelia bella*	1	2.78	1.39	0.28	0.21	1.88	6.89	0.08
3	*Albizia ferruginea*	1	0.85	0.43	0.09	0.06	0.57	2.11	0.02
4	*Albyzia zigia*	1	0.27	0.14	0.03	0.02	0.18	0.67	0.01
5	*Allanblackia floribunda*	1	0.35	0.18	0.04	0.03	0.24	0.87	0.01
6	*Alstonia bonnei*	8	80.62	40.31	8.06	6.05	54.42	199.72	2.35
7	*Aningeria robusta*	8	7.14	3.57	0.71	0.54	4.82	17.69	0.21
8	*Antiaris africana*	1	0.13	0.07	0.01	0.01	0.09	0.32	0.01
9	*Baphia nitida*	13	17.43	8.72	1.74	1.31	11.77	43.18	0.51
10	*Berlinia grandiflora*	1	1.15	0.58	0.12	0.09	0.78	2.85	0.03
11	*Blighia sapida*	8	11.95	5.98	1.20	0.90	8.07	29.60	0.35
12	*Bombax buonopozense*	1	11.89	5.95	1.19	0.89	8.03	29.45	0.35
13	*Bosqueia angolensis*	12	20.02	10.01	2.00	1.50	13.51	49.59	0.58
14	*Brachystegia eurycoma*	5	63.93	31.97	6.39	4.79	43.15	158.37	1.87
15	*Brachystegia nigerica*	1	0.76	0.38	0.08	0.06	0.51	1.88	0.02
16	*Bridelia micrantha*	1	0.24	0.12	0.02	0.02	0.16	0.59	0.01
17	*Carapa procera*	1	2.99	1.50	0.30	0.22	2.02	7.41	0.09
18	*Ceiba pentandra*	9	895.99	448.00	89.60	67.20	604.79	2219.59	26.14
19	*Celtis mildbraedii*	1	2.55	1.28	0.26	0.19	1.72	6.32	0.07
20	*Celtis zenkeri*	10	67.56	33.78	6.76	5.07	45.60	167.36	1.97
21	*Chrysophyllum prunifolium*	1	0.38	0.19	0.04	0.03	0.26	0.94	0.01
22	*Cleistiopholis patens*	4	3.96	1.98	0.40	0.30	2.67	9.81	0.12
23	*Cola acumunate*	1	0.80	0.40	0.08	0.06	0.54	1.98	0.02
24	*Cola afzelii*	1	0.21	0.11	0.02	0.02	0.14	0.52	0.01
25	*Cola gigantea*	20	97.16	48.58	9.72	7.29	65.58	240.69	2.84
26	*Cola milleni*	1	0.01	0.01	0.00	0.00	0.01	0.02	0.00
27	*Cola mucuso*	1	0.43	0.22	0.04	0.03	0.29	1.07	0.01
28	*Cordia millenii*	8	15.95	7.98	1.60	1.20	10.77	39.51	0.47
29	*Dallium guinensis*	1	2.38	1.19	0.24	0.18	1.61	5.90	0.07
30	*Daniella ogea*	6	7.50	3.75	0.75	0.56	5.06	18.59	0.22
31	*Diospyros dendo*	42	173.83	86.92	17.38	13.04	117.34	430.62	5.07
32	*Diospyros iturensis*	20	23.60	11.80	2.36	1.77	15.93	58.46	0.69
33	*Diospyros mespiliformis*	6	9.80	4.90	0.98	0.74	6.62	24.28	0.29
34	*Enantia chloranta*	1	0.06	0.03	0.01	0.00	0.04	0.15	0.00
35	*Entandrophragma cylindricum*	2	3.94	1.97	0.39	0.30	2.66	9.76	0.11
36	*Entandrophragma utile*	8	55.82	27.91	5.58	4.19	37.68	138.28	1.62
37	*Entandrophrama angolense*	1	0.28	0.14	0.03	0.02	0.19	0.69	0.01
38	*Erythrina suaveolens*	1	0.07	0.04	0.01	0.01	0.05	0.17	0.00
39	*Fagara leprieuri*	1	0.49	0.25	0.05	0.04	0.33	1.21	0.01
40	*Ficus capensis*	2	5.63	2.82	0.56	0.42	3.80	13.95	0.16
41	*Ficus exasperate*	1	9.79	4.90	0.98	0.73	6.61	24.25	0.29
42	*Ficus mucuso*	1	5.71	2.86	0.57	0.43	3.85	14.15	0.17
43	*Ficus thonningii*	3	53.77	26.89	5.38	4.03	36.29	133.20	1.57
44	*Funtumia africana*	1	0.13	0.07	0.01	0.01	0.09	0.32	0.00
45	*Funtumia elastica*	25	23.62	11.81	2.36	1.77	15.94	58.51	0.69
46	*Hexalobus crispiflorus*	1	0.80	0.40	0.08	0.06	0.54	1.98	0.02
47	*Hildegardia barteri*	1	0.20	0.10	0.02	0.02	0.14	0.50	0.01
48	*Hunteria umbellata*	14	54.53	27.27	5.45	4.09	36.81	135.08	1.59
49	*Irvingia gabonensis*	1	7.82	3.91	0.78	0.59	5.28	19.37	0.23
50	*Khaya grandifoliola*	29	300.19	150.10	30.02	22.51	202.63	743.65	8.76
51	*Khaya senegalensis*	1	7.23	3.62	0.72	0.54	4.88	17.91	0.21
52	*Lecaniodiscus cupanioides*	1	1.49	0.75	0.15	0.11	1.01	3.69	0.04
53	*Mallotus subulatus*	1	0.12	0.06	0.01	0.01	0.08	0.30	0.00
54	*Milicia excelsa*	1	0.85	0.43	0.09	0.06	0.57	2.11	0.02
55	*Milletia thonningii*	56	50.84	25.42	5.08	3.81	34.32	125.94	1.48
56	*Mitragyna stipulosa*	1	0.64	0.32	0.06	0.05	0.43	1.59	0.02
57	*Morusmeso zygia*	2	2.02	1.01	0.20	0.15	1.36	5.00	0.06

S/ 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
58	*Musanga cecropioides*	1	0.41	0.21	0.04	0.03	0.28	1.02	0.01
59	*Nauclea diderrichii*	10	90.15	45.08	9.02	6.76	60.85	223.32	2.63
60	*Nesogordonia papaverifera*	18	28.54	14.27	2.85	2.14	19.26	70.70	0.83
61	*Parinari excelsa*	3	8.33	4.17	0.83	0.62	5.62	20.64	0.24
62	*Phyllanthus angolensis*	1	21.68	10.84	2.17	1.63	14.63	53.71	0.63
63	*Phyllanthus discoideus*	8	32.86	16.43	3.29	2.46	22.18	81.40	0.96
64	*Phyllanthus mullerianus*	1	0.53	0.27	0.05	0.04	0.36	1.31	0.02
65	*Piptadeniastrum africanum*	1	82.02	41.01	8.20	6.15	55.36	203.18	2.39
66	*Pterygota macrocarpa*	4	107.20	53.60	10.72	8.04	72.36	265.56	3.13
67	*Pycnanthus angolensis*	15	45.39	22.70	4.54	3.40	30.64	112.44	1.32
68	*Ricinodendron heudelotii*	19	35.25	17.63	3.53	2.64	23.79	87.32	1.03
69	*Spondias mombin*	1	0.55	0.28	0.06	0.04	0.37	1.36	0.02
70	*Sterculia rhinopetala*	23	93.89	46.95	9.39	7.04	63.38	232.59	2.74
71	*Sterculia tragancantha*	18	71.68	35.84	7.17	5.38	48.38	177.57	2.09
72	*Strombosia pustulata*	63	45.28	22.64	4.53	3.40	30.56	112.17	1.32
73	*Terminalia superba*	14	603.28	301.64	60.33	45.25	407.21	1494.48	17.60
74	*Treculia africana*	1	0.37	0.19	0.04	0.03	0.25	0.92	0.01
75	*Trichilia heudolotii*	2	4.54	2.27	0.45	0.34	3.06	11.25	0.13
76	*Trichilia monadelpha*	1	0.08	0.04	0.01	0.01	0.05	0.20	0.00
77	*Trichilia prieureana*	2	27.02	13.51	2.70	2.03	18.24	66.94	0.79
78	*Uapaca togoensis*	1	3.57	1.79	0.36	0.27	2.41	8.84	0.10
79	*Xylopia aethiopica*	2	1.75	0.88	0.18	0.13	1.18	4.34	0.05
80	*Xylopia villosa*	53	11.22	5.61	1.12	0.84	7.57	27.79	0.33
81	*Zanthoxylum zanthoxynoides*	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 Wienner index value were recorded in 2014, whereas this study recorded 81 tree species with higher Shannon Wienner 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 CO_2 equivalent (8490.18CO_2eq/ha) estimated in this study reveals the contribution of the reserve in cleaning the atmosphere from CO_2 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 km^2) 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 km^2), 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.

REFERENCES

1. Lal R. Sequestration of atmospheric CO_2 in global carbon pools. Energy and Environmental Science. 2008; 1:86–100.
2. Pareta K, Pareta U. Forest carbon management using satellite remote sensing techniques: A case study of Sagar District (M. P.). International Scientific Research Journal. 2011;3(4):335-348.
3. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004a; 304:16-27.
4. Orji G. Assessing the impacts of urbanization on wetlands in Lagos state (A Case Study of Ikorodu LGA) BSc. Project submitted to Department of Geography, University of Lagos. 2014;1- 50.
5. IPCC. Climate change 2007: The physical science basis: Working group i contribution to the fourth assessment report of the IPCC; Cambridge University Press: Cambridge UK; 2007.
6. Luckai N, Larocque GR. Challenges in the application of exiting process- based models to predict the effect of climate change on C pools in forest ecosystems. Climatic Change. 2002; 55:39–60.
7. Malhi Y, Baker TR, Phillips OL, Almeida S, Alvarez E, Arroyo L, et al. The above-ground coarse woody productivity of 104 Neotropical forest plots. Global Change Biology. 2004; 10:563-591.

8. Hagedorn F, Landolt W, Tarjan D. Elevated CO2 influences nutrient availability in young beech-spruce communities on two soil types. Oecologia. 2002; 132:109–117.
9. Robertz P, Sune. Effects of long-term CO2 enrichment and nutrient availability in Norway spruce. II Foliar chemistry, Trees. 1999; 14:17-27.
10. Food and Agriculture Organization of the United Nations. Soil carbon sequestration for improved land management. World Soil Resources Report 96. FAO: Rome, Italy; 2001.
11. UNFCCC. Report of the conference of the parties on its ninth session, held at Milan from 1 to 12 December 2003. Addendum. Part two: action taken by the conference of the parties at its ninth session; 2004. Available:http://unfccc.int/resource/docs/cop9/06a02 (Accessed June 14, 2019).
12. Angelsen A, Brockhaus M, Kanninen M. Realising. REDD+: National strategy and policy options. Center for International Forestry Research (CIFOR), Bogor, Indonesia; 2009. Available:http://www.cifor.cgiar.org /Knowledge/Publications/Detail?pid=2871
13. Ayoubi S, Khormali F, Sahrawa KL, Rodrigues de Lima AC. Assessing impacts of land use change on soil quality indicator in a Loessial in Golesian Province, Iran. Journal of Agriculture and Science Technology. 2011; 13:727- 742.
14. Larsen JB, Nielsen AB. Nature-based forest management-where are we going? Elaborating forest development types in and with practice. Forest Ecology and Management. 2007; 238:107-117.
15. Vesterdal L, Schmidt IK, Callesen I, Nilsson LO, Gundersen P. Carbon and nitrogen in forest floor and mineral soil under six common European tree species. Forest Ecology and Management. 2008; 255(1): 35-48.
16. Deheza M, Bellassen V. Getting carbon value out of the forestry and wood sectorIn Annex I Countries: The French Example. In CDC Climate Research. 2010;20.
17. Binkley CS, Brand D, Harkin Z, Bull G, Ravindranath NH, Obersteiner M, et al. Carbonsinks by the forest sector-options and needs for implementation. Forest Policy Econ. 2002; 4:65–77.
18. Gupta J, Olsthoorn X, Rotenberg E. The role of scientific uncertainty in compliance with the Kyoto protocol to the climate change convention. Environ. Sci. Policy. 2003; 6:475–486.
19. Okali DUU, Ola-Adams BA. Tree population changes in treated rainforest at Omo forest reserve, South Western Nigeria. Nig. Jour. of Tropical Ecology. 1987; 3:291-313.
20. Adebisi AA. A case study of Garcinia kola nut production-to-consumption system in J4 area of Omo forest reserve, South-west Nigeria. Sunderlandt, Ndoye O, Eds. Forest products, livelihoods and conservation: case studies of non-timber forest product systems. 2004;115-132.
21. Magurran AE. Measuring biological diversity. Oxford: Blackwell Publishing. Main-Knorn M, Cohe WB, Kennedy RE, Grodzki W, Pflugmacher D, Griffiths P,Hostert P. 2013. Monitoring coniferous forest biomass change using a Landsat trajectory-based approach. Remote Sensing of Environment. 2004; 139:277–290.
22. Wang ZM, Zhang B, Song KS, Liu DW, Li F, Guo ZX, Zhang SM. Soil organic carbon under different landscape attributes in croplands of Northeast China. Plant, Soil, and Environment. 2008; 54:420-427.
23. Guendou SG, Lehtonen A. Guidance for tree measurement in tropical forest ecosystems using non-destructive sampling to develop stem biomass and volume models. Vantaa, Finland: Finnish Forest Research Institute; 2014.
24. Husch B, Charles IM, Thomas WB. Forest mensuration. New York: The Ronald Press Company. 2003;410.
25. Wood Density Database; 2014. Available:http://www.worldagroforestrycentre.org/sea/Products/AFDbases/wd/index.htm (Accessed 17 April 2019).
26. Zanne AE, Lopez-Gonzalez G, Coomes DA, Ilic J, Jansen S, Lewis SL, et al. Towards a worldwide wood economics spectrum. Dryad digital repository. Dryad digital repository: Global Wood Density Database; 2009. Available:http://dx.doi.org/10.5061/dryad.234 Retrieved July 3, 2019.

27. Mitchard ETA, Feldpausch TR, Brienen RJW, Lopez Gonzalez G, Monteagudo A. Markedly divergent estimates of Amazon forest density from ground plots and satellites. Global Ecology and Biogeography. 2014; 23:935-946.
28. IPCC. Forest lands. Intergovernmental panel on climate change guidelines for national greenhouse gas inventories. Eds. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K. Japan: Institute for Global Environmental Strategies (IGES). 2006; 4: 83.
Available:http://www.ipccnggip.iges.or.jp/public/2006gl/
Retrieved August 25, 2018.
29. NIACS (Northern Institute of Applied Carbon Science). Estimating carbon mass in northern forests. NIACS Briefing (Janowiak MK.- Briefing contributor), 410MacInnes Drive, Houghton; 2008.
Available:MI499313phttp://www.nrs.fs.fed.us/ niacs
30. Cairns MA, Brown S, Helmer EH,Baumgardner GA. 'Root biomass allocation in the world's upland forests' In: Oecologia. 1997; 111:1-11.
31. Annissa MA, Surendra B, Keredin TS, AJ Solomon Raju. Assessment of biomass and carbon sequestration potentials of standing *Pongamia pinnata* in Andhra University, Visakhapatnam, India. Biosci. Disc. 2013;4(2):143-148.
32. Sundarapandian SM, Swamy PS. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. Journal Tropical Forest Science. 2000; 12:104-123.
33. Parthasarathy N. Tree diversity and distribution in undisturbed and human impacted sites of tropical wet evergreen forest in southern Western Ghats, India. Biodiversity and Conservation. 1999;8: 1365-1381.
34. Jimoh SO, Adesoye PO, Adeyemi AA, Ikyaagba ET. Forest structure analysis in the oban division of cross river national park, Nigeria. Journal of Agricultural Science and Technology. 2012;2.5:510-518.
35. Ola-Adams BA. Biodiversity inventory of omo biosphere reserve. GEBR Project Report, Nigeria National MAB Committee. Journal of Tropical Forest Science. 2014; 12:104-123.
36. UNEP-WCMC(United Nations Environment Programme World Conservation Monitoring Centre). State of the world's protected areas: An annual review of global conservation progress. UNEPWCMC; 2008.
37. Wittmann F, Zorzi BT, Tizianel FAT, Urquiza MVS, Faria RR, Sousa NM, et al. Tree species composition, structure, and aboveground wood biomass of a riparian forest of the lower Miranda river, Southern Pantanal, Brazil. Folia Geo-botany. 2008; 43:397–411.
38. Ramachandran A, Jayakumar S, Haroon RM, Bhaskaran A, Arockiasamy DI. Carbon sequestration: Estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. Current Science. 2007;92: 323–331.
39. Adekunle VAJ, Narayanan KN, Awadhesh KS, Singh NK. Volume yield, tree species diversity and carbon hoard in protected areas of two developing countries, Forest Science and Technology. 2014;10(2):89-103.
DOI: 10.1080/21580103.2013.860050
40. Clark DA, Brown S, Kicklighter DW, Chambers JQ, Thomlinson JR, Ni J, et al. Net primary production in tropical forests: An evaluation and synthesis of existing field data. Ecol Appl. 2001; 11:371– 384.
41. Rajkumar M, Parthasarathy N. Tree diversity and structure of andaman giant evergreen forests India. Taiwania. 2008;53: 356–368.
42. Chukwu VE, Olajuyigbe SO. Estimation of tree biomass in three age-series of *Tectonagrandis*Linn. F In Gambari Forest Reserve, Nigeria. J. For. Sci. Env. 2017; 2(1):9 – 15.
43. Brown S. Measuring carbon in forests: Current status and future challenges. Environmental Pollution. 2002; 116:363-372.
44. Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, et al. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia. 2005; 145:87–99.
45. Ogana FN, Imaledo EA, Danladi WA. Indirect forest carbon assessment method for sustainable forest management. Proceedings of NTBA/NSCB Joint Biodiversity Conference; Unilorin. 2016.32-36.
46. Gibbs HK, Brown S, Nile JO, Foley JA. Monitoring and estimating tropical forest

carbon stocks: Making REDD a reality. Global Change Biology. 2007;9(4):500–509.
47. Day M, Baldauf C, Rutishauser E, Sunderland TCH. Relationships between tree species diversity and above-ground biomass in Central African rainforests: Implications for REDD. Environmental Conservation. 2013; 41:64–72.

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