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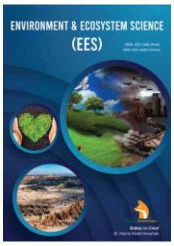

RESEARCH ARTICLE

FLORISTICS, CARBON STOCK QUANTIFICATION AND SEQUESTRATION ABILITY OF AN ENCROACHED FOREST IN AKWA IBOM STATE UNIVERSITY, IKOT AKPADEN, SOUTHERN NIGERIA

Richard Ekeng Ita [a]*, **Felix Okpako Ogbemudia** [b], **Emem Okon Mbong** [c]

[a]*Department of Biological Sciences, Ritman University, Ikot Ekpene, Akwa Ibom State, Nigeria*
[b]*Department of Botany and Ecological Studies, University of Uyo, Akwa Ibom State, Nigeria.*
[c]*Department of Environmental Biology, Heritage Polytechnic, Ikot Udota, Eket, Akwa Ibom State, Nigeria*
**Corresponding Author Email: alwaizfwesh247@yahoo.com*

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ABSTRACT

This study assessed the floristics, carbon stock and sequestration ability of an encroached forest in Akwa Ibom State, Southern Nigeria. Ten plots within the forest were chosen and ten belt transects were established. Trees species were identified in each plot. Litter boxes were placed in each plot at 10 m for litter collection. Soils were collected from the plots at different depths. AGB (aboveground biomass), BGB (belowground biomass), AGC (aboveground carbon) and BGC (belowground carbon) were calculated using appropriate allometric equations. Twenty-two woody species were present in the forest. The values for AGB, AGC, BGM and BGC were 119.31 Mg ha^{-1}, 59.65 Mg C.ha^{-1}, 24.46 Mg ha^{-1} and 12.23 Mg C.ha^{-1}, each. The total carbon stock (TCS) and biomass in the litter were 9.37 MgCha^{-1} and 20 Mg ha^{-1}, respectively. The carbon stock in the litter followed this order: leaf (4.10±0.08 Mg C.ha^{-1}) > twigs (3.02±0.04 Mg C.ha^{-1}) > fine root (2.25±0.01 Mg C.ha^{-1}). The TCS in the soil was 33.73 MgCha^{-1} and followed this decreasing trend: 0-15 cm (23.80±2.65 MgCha^{-1}) > 0 – 30 cm (9.93±1.02 MgCha^{-1}). The TCS and carbon sequestration ability (CSA) of this forest were 125.61 Mg C.ha^{-1} and 458.31 Mg CO$_2$ha^{-1}. The CSA of this forest followed this decreasing order: AGC pool (218.92 Mg CO$_2$ha^{-1}) > soil (121.11 Mg CO$_2$ha^{-1}) > litter (73.40 Mg CO$_2$ha^{-1}) > BGC pool (44.88 Mg CO$_2$ha^{-1}). These results validate this forest as having a considerable carbon sequestration ability, though, this ability is threatened by human disturbances.

ccKEYWORDS

Biomass, Carbon pool, Climate change, Deforestation, Forest ecosystem

1. INTRODUCTION

Climatic change resulting from high atmospheric CO$_2$ concentrations is one of the topical and most discussed issues in this contemporary era. On daily and yearly basis, anthropogenic activities and disturbances of varying intensities, release tons of CO$_2$ into the atmosphere than it can be removed using natural process, hence, causing an upsurge of CO$_2$ in the atmosphere. According to recent study, the average atmospheric CO$_2$ concentration globally, is 414.72 ppm, which is 40 % higher than the 280 ppm obtained during the preindustrial era (NOAA, 2019; IPCC, 2013). These precursors of climate change have dragged the interest and attention of ecologists to forests as sustainable means for reducing CO$_2$ emissions by sequestrating carbon.

Forests serve as carbon repositories, constituting about forty eight (48) percent of carbon terrestrially and more than fifty (50) percent of CO$_2$ fixed during photosynthesis (Mokany et al. 2006; Pan et al. 2011; Liu et al. 2014). According to a study, forests also have the highest level of biomass as well as higher sequestration rate of carbon, which have been documented regionally, and globally (Sullivan et al., 2017).

Assessing forest's abilities to sequester carbon is very important in making informed decisions towards managing natural resources sustainably. Of all the ecosystems terrestrially, forests especially in tropical regions, are the most important having the highest diversity and playing pivotal role in cycling carbon across the globe (Lewis et al., 2015; Ngo et al. 2013). Approximately 200 to 300 Pg of carbon, which accounts for 39 % and 54 % of atmospheric and biotic pools, respectively, are stored in tropical forests (Le Quéré et al., 2016; Avitabile et al., 2016). Notwithstanding their importance, information on the sequestration abilities of various regions in the tropics are still incomplete or limited (Le Quéré et al., 2016), and this creates a lacuna in this aspect. Hence, there is a great need to quantify carbon in various pools extensively especially in tropical forests that are less studied, as this will bring to limelight their various contributions regarding sequestration of carbon. Between the years 1990 and 2015, forest cover has reduced drastically across the globe from 4.12 to 3.99 Trillion per hectare (Han et al., 2017). This negative trend is attributed to increasing deforestation, which is prevalent in many tropical areas of the world (Hansen et al., 2013). From 1980 to 2012, approximately 100 million hectare of forests in the tropics have faced decimation and conversion to croplands, and this accounts to about 0.4 % yearly (Hansen et al., 2013). In Africa especially in Nigeria, the cover of forest is estimated at about 10 % with primary forests constituting about 20, 000 hectares. According to FAO (2019), this figure was due to about 95 % of forest tracts being lost to intense deforestation with 5 % yearly rate from 2010 to 2015. Deforestation in Nigeria is primarily triggered by industrialization and increasing demand by the locals for forest resources due to upsurge in

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population.

Within the southern region of Nigeria, tree species exploitation has been on the increase due to high timber demand for building, wood and construction purposes. This uncontrolled exploitation leaves so many tree species facing threats of extinction. Among the encroached forest ecosystems in Southern Nigeria, this ecosystem houses distinct flora species ranging from trees, shrubs and herbs (Okon et al., 2021). Of all the forest tracts that were found around this vicinity, this ecosystem has been reported to be the diverse in species abundance. Previous study on species composition in this ecosystem revealed about 98 flora species comprising of 29 trees, 21 shrubs, 13 climbers, and 35 herbaceous species (Okon et al., 2021). Notable among the tree species are *Gmelina arborea*, *Baphia nitida*, *Tectona grandis*, *Pentaclethra macrophylla*, *Adenanthera pavonina*, and *Terminalia mantaly* just to list a few. Despite the rich flora diversity, this ecosystem especially the tree species, are seriously facing anthropogenic perturbations stemming from agricultural activities, cutting down of trees to give room for expansion and building of classroom blocks, indiscriminate and illegal logging of wood by locals inhabiting the fringes of this forest. As such, knowing the importance of plants especially in the wake of carbon cycling and climate change, is enough to enforce conservative and protective measures to halt the gradual decimation of this forest. It is also worthy to note that carbon sequestration studies within Akwa Ibom State in forest or other ecosystems lack depth and are under explored. Hence, this study aims at providing an understanding regarding the role of forest in sequestrating carbon and mitigating climate change. Here, our objectives include assessing the tree species diversity, characterizing the soil properties, estimating the AGB, BGB and stocks of carbon respectively, in various carbon pools (vegetation, soil, and litter) in the ecosystem.

2. Methods

2.1 Study Area

This study took place in an encroached forest ecosystem within the confines of Akwa Ibom State University, Ikot Akpaden, Mkpat Enin Local Government Area of Akwa Ibom State, Nigeria. This forest is situated at longitude 7°46’0”E and latitude of 4°37’21”N with 22.7m above sea level. The area is characterized by a tropical climate comprising of dry and wet seasons. The wet season spans between March and middle of November whereas the dry season spans between November and March. This area has relative humidity ranging from 75 to 95 % with a peak value in January. The average temperature of the area alternates between 26 and 36°C. The vegetation of the area is luxuriant consisting of dominant tree species like *Tectona grandis*, *Baphia nitida*, *Gmelina arborea*, *Adenanthera pavonina*, *Pentaclethra macrophylla* and *Terminalia mantaly*. Anthropogenic activities and perturbations around and within this forest are on the rise, posing serious threats to flora species. On the fringes of this forest, are intensive agricultural activities, which are encroaching gradually into the forest.

2.2 Vegetation Sampling

Ten plots within the forest were randomly chosen for this study. In each of the plot, ten belt transect were established. The soil and vegetation (trees) were systematically sampled with a 10 m x 10 m quadrat at a spacing distance of 15 m along the established belt transect. Woody species were identified and their respective densities, height and DBH were enumerated and measured, respectively.

2.3 Collection, analysis and carbon stock in litter samples

Within each chosen plot, five litter boxes were randomly placed at a distance of 10 m to collect litter on weekly basis. The collected litter were sorted into various components, leaves, twigs and fine roots while other parts like fruits and trash were discarded. The litter were pooled for each plot based on the sorted parts, stored in ziplock bags and conveyed for carbon content determination in the laboratory. In the laboratory, the litter (leaves, twigs and fine roots) were placed in an oven to dry at 80°C to a point where a constant weight was achieved. The samples were milled and analyzed for organic carbon using the Loss on Ignition (Dean, 1974). The biomass of the litter was obtained through the multiplication of the carbon amount with the dry weight. The stock of carbon in the litter was gotten through multiplication of the estimates of organic carbon with 0.47 (a conversion factor) (IPCC, 2006).

2.4 Estimation of carbon stock in soil

With a soil auger, samples of soil were obtained at two distinct depths (0 to 15 and 15 to 30 cm) from each established transect. Samples from same plots were mixed into a composite sample, stored in ziplock bags that were well-labeled and conveyed for analysis in the laboratory. The samples of soil were allowed to air-dry before analysis. With the method of Walkley Black, the organic carbon in the soil was determined. The soil’s bulk density was derived as the ratio of the mass of oven-dried sample to its volume. The stock of carbon in the soil was calculated from the formula of (Ehrenbergerová et al., 2016) as shown below :

Soil Carbon $= C_{ox} \times BD \times SD$

Where, C_{ox} = oxidative carbon amount or content (%)

SD = Soil depth (cm)

BD = Bulk density of soil ($g.cm^{-3}$)

2.5 Biomass and carbon stock estimation in vegetation

Since this study did not adopt a destructive sampling technique for the vegetation, we adopted one of the allometric equations for pan moist and dry tropical forest by (Brown et al., 1989) in calculating the AGB of each woody species as shown in the formula below:

Above ground biomass (mg) $= \exp(-3.11+0.97 \ln(dbh^2 H)$

Where dbh = diameter at breast height (cm)

H = Tree height (m)

The BGB of woody species was determined using the ratios of root to shoot formulae of (Mokany et al., 2006) below:

If AGB $\leq$ 125 Mg ha^{-1} then, BGB = 0.205 x AGB

If AGB > 125 Mg ha^{-1} then, BGB = 0.235 x AGB

Where AGB = Aboveground biomass

BGB = Belowground biomass

The amount of carbon in the individual trees was expressed as 50% of the aggregate of above and below ground biomasses (IPCC, 2006).

The stock of carbon in the belowground of tree species was calculated using the formulae of (Liu et al., 2014) below:

If AGC $\leq$ 62.5 Mg ha^{-1}, then BGC = 0.205 x AGBC

If AGC > 62.5 Mg ha^{-1}, then BGC = 0.235 x AGBC

Where BGC = Belowground carbon

AGC = Aboveground carbon

2.6 Carbon sequestration ability of the forest

In assessing the forest’s ability to sequestrate carbon, the sum total of the carbon stock across the various pools was converted to carbon dioxide (CO_2) by multiplying by the atomic mass quotient of CO_2 to C ($^{44}/_{12}$) (Justine et al., 2015).

2.7 Density

Each woody species density was determined by enumeration in the respective plots using the procedures of (Cochran, 1963). The number of individual of each woody species was expressed as a proportion of the transect number to give the mean of each species. This mean value was then expressed in relation to the quadrat area to give rise to density (in m^2) which was further multiplied by 10, 000 to yield density in hectare.

2.8 Height

Heights of woody species were measured with a haga altimeter. At 15 meters from the tree base where there was a clear sighting of the crowns from the altimeter’s eyepiece, the upper altimeter reading was taken and recorded. The lower reading was also taken same way from the altimeter. Height of woody species were calculated as a expressed below;

$$\text{Height} \quad (\text{m}) \quad = \frac{(\text{upper reading+lower reading}) \times \text{horizontal distance from observer}}{\text{scale factor of the altimeter}}$$

2.9 Diameter at breast height (DBH)

The DBH of woody plants (in cm) was measured using a girthing tape at 1.3 m above the level of the ground.

2.10 Statistical Analysis

The means and standard errors of replicates were computed with Graphpad Prism 9.0.

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3. RESULTS

3.1 Woody species inventory of the forest

The inventory of woody species in the forest as shown in Table 1, revealed 22 species in 15 families. *Baphia nitida* (1066.67±36.52 st/ha) had the highest density while *Dracaena arborea* (133.33±8.02 st/ha), *Ficus hispida* (133.33±7.05 st/ha), and *Xylopia aethopica* (133.33±8.65 st/ha) had the least density values. With regards to Diameter at Breast Height (DBH), *Adenanthera pavonina* (8.33±0.96 cm) and *Rauvolfia vomitoria* (1.20±0.05 cm) had the highest and least values, respectively. The tallest plant was *Gmelina arborea* (14.17±0.44 m) while *Pentaclethra macrophylla* (2.33±0.44 m) was the shortest species.

Table 1: Woody species inventory of the forest

Plant species	Family	Density (st/ha)	Diameter at breast height (DBH) (cm)	Height (m)
Adenanthera pavonina L.	Fabaceae	666.67±22.25	8.33±0.96	5.63±0.63
Alchornea cordifolia Mull.Arg	Euphorbiaceae	400±20.30	5.00±0.74	5.80±0.15
Alstonia boonei De Wild.	Apocynaceae	266.67±10.50	5.60±0.76	4.35±2.30
Anacardium occidentale L.	Anacardiaceae	400±20.20	6.20±0.79	8.17±0.44
Anthocleista vogelli Planch.	Gentianaceae	400±19.08	2.05±0.04	5.00±0.58
Anthonotha macrophylla P.Beauv.	Fabaceae	400±19.99	3.50±0.06	4.33±0.88
Baphia nitida Lodd	Fabaceae	1066.67±36.52	2.51±0.08	3.00±0.5
Calophyllum inophyllum L.	Calophyllaceae	800±28.63	2.53±0.04	6.80±0.68
Canarium schweinfurthii Engl.	Burseraceae	266.67±11.63	4.25±0.26	5.83±0.44
Dracaena arborea (Willd.) Link	Dracaenaceae	133.33±8.02	1.52±0.03	5.17±0.72
Ficus hispida L.f.	Moraceae	133.33±7.05	2.10±0.01	3.00±0.50
Gmelina arborea Roxb.	Lamiaceae	933.33±30.62	7.20±0.87	14.17±0.44
Hura crepitans L.	Euphorbiaceae	266.67±11.62	7.50±0.88	8.33±0.60
Maesoboytra barteri (Baill.) Hutch	Phyllanthaceae	933.33±30.06	1.85±0.01	3.10±0.31
Mangifera indica L.	Anacardiaceae	266.67±9.65	2.50±0.06	4.00±0.28
Musanga cecropioides R.Br. & Tedlie	Urticaceae	266.67±10.58	4.00±0.08	8.33±0.44
Nauclea diderrichii (De Wild & T.Durand) Merr.	Rubiaceae	533.33±26.30	6.32±0.78	4.00±0.5
Pentaclethra macrophylla Benth.	Fabaceae	266.67±12.05	6.30±0.72	2.33±0.44
Rauvolfia vomitoria Afzel.	Apocynaceae	533.33±25.01	1.20±0.05	5.47±0.52
Tectona grandis L.f.	Lamiaceae	266.67±12.65	5.20±0.42	6.32±0.23
Terminalia mantaly H. Perrier	Combretaceae	266.67±10.54	3.25±0.30	7.17±0.44
Xylopia aethopica (Dunal) A. Rich.	Annonaceae	133.33±8.65	2.10±0.01	6.50±0.29

± Standard error

3.2 Biomass and carbon stock of tree species

Table 2 shows the biomass and stock of carbon of woody species in the ecosystem. The total AGB in the ecosystem was 119.31 Mg ha^{-1}. *Gmelina arborea* had the highest aboveground biomass (26.88 Mg ha^{-1}) while the least value of 0.33 Mg ha^{-1} was observed in *Rauvolfia vomitoria*. The aggregate belowground biomass (BGB) in the ecosystem was 24.64 Mg ha^{-1}). *Gmelina arborea* and *Rauvolfia vomitoria* also had the highest (5.51 Mg ha^{-1}) and least (0.07 Mg ha^{-1}) BGB values, each. The total stock of carbon in the aboveground was 59.65 Mg Cha^{-1}. *Gmelina arborea* and *Rauvolfia vomitoria* had the highest (13.44 MgCha^{-1}) and least (0.17 Mg C.ha^{-1}) aboveground carbon (AGC) values, each. For the BGC stock, an aggregate value of 12.23 Mg C.ha^{-1}.was recorded in the forest. *Gmelina arborea* and *Rauvolfia vomitoria* also had the highest and least values of 2.76 and 0.03 Mg C.ha^{-1}, each.

Table 2: Biomass and carbon stock of woody species

Plant Species	AGB (Mg ha^{-1})	AGC (Mg C.ha^{-1})	BGB (Mg ha^{-1})	BGC (Mg C.ha^{-1})
Adenanthera pavonina	14.57	7.28	2.99	1.49
Alchornea cordifolia	5.57	2.79	1.14	0.57
Alstonia boonei	5.25	2.63	1.08	0.54
Anacardium officinale	11.79	5.89	2.42	1.21
Anthocleista vogelli	0.86	0.43	0.18	0.09
Anthonatha macrophylla	2.10	1.05	0.43	0.22
Baphia nitida	0.77	0.39	0.16	0.08
Calophyllum inophyllum	1.73	0.87	0.36	0.18
Canarium schweinfurthii	4.08	2.04	0.84	0.42
Dracaena arborea	0.49	0.25	0.10	0.05
Ficus hispida	0.55	0.27	0.11	0.06
Gmelina arborea	26.88	13.44	5.51	2.76
Hura crepitans	17.38	8.69	3.56	1.78
Maesoboytra barteri	0.44	0.22	0.09	0.05
Mangifera indica	1.01	0.51	0.21	0.10
Musanga cecropioides	5.13	2.57	1.05	0.53
Nauclea diderrichii	6.12	3.06	1.25	0.63
Pentaclethra macrophylla	3.60	1.80	0.74	0.37
Rauvolfia vomitoria	0.33	0.17	0.07	0.03
Tectona grandis	6.53	3.27	1.34	0.67
Terminalia mantaly	2.97	1.48	0.61	0.30
Xylopia aethopica	1.16	0.58	0.24	0.12
Total	119.31	59.65	24.46	12.23

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3.3 Biomass and stock of carbon in the litter

Table 3 shows the biomass and stock of carbon in the litter. The total biomass in the litter was 20 Mg ha^{-1} whereas the stock of carbon was 9.37 MgCha^{-1}. The leaf litter had the highest biomass (8.52±0.96 Mg ha^{-1}) and carbon contents (4.10±0.08 MgCha^{-1}) while fine roots had the least values for biomass (4.50±0.05 Mgha^{-1}) and carbon (2.25±0.01 MgCha^{-1}).

Table 3: Biomass and stock of carbon in litter pool

Litter pool	**Biomass (Mg ha^{-1})**	**Carbon stock (Mg C.ha^{-1})**
Leaf	8.52±0.96	4.10±0.08
Twigs	6.98±0.54	3.02±0.04
Fine root	4.50±0.05	2.25±0.01
Total	20.00	9.37

3.4 Carbon stock in soil

Table 4 shows the carbon stock across the various layers of the soil. The aggregate carbon stored by the soil was 33.73 MgCha^{-1}. The top soil (0 – 15 cm) stored the highest amount of carbon (23.80±2.65 MgCha^{-1}) while the least amount of carbon (9.93±1.02 MgCha^{-1}) was stored in the subsoil (15 – 30 cm).

Table 4: Carbon stock in the soil layers

Soil depths	Carbon stock (Mg C.ha^{-1})	% total
0 – 15 cm	23.80±2.65	70.56
15 – 30 cm	9.93±1.02	29.44
Total	33.73	100

3.5 Carbon sequestration ability of the forest

Table 5 shows the carbon sequestration ability of the forest. The aboveground carbon pool had the highest carbon storage ability (218.92 Mg CO_2ha^{-1}) while the below ground carbon pool had the least carbon storage ability (44.88 Mg CO_2ha^{-1}). An aggregate of 125.61 Mg C.ha^{-1} was stored by this forest helping in climate change mitigation with a carbon sequestration ability of 458.31 Mg CO_2ha^{-1}

Table 5: Carbon sequestration ability of the forest

Carbon pool	**Carbon stock (Mg C.ha^{-1})**	**Sequestration ability (Mg CO_2ha^{-1})**
Above ground	59.65	218.92
Below ground	12.23	44.88
Litter	20.00	73.40
Soil	33.73	121.11
Total	125.61	458.31

4. DISCUSSION

The floristic inventory of the forest revealed a rich array of tree species in various genera and families. The 22 woody species encountered in this study is somewhat small when comparison is made to the numbers recorded in other forest ecosystems. For instance, 30 woody species were reported each, in Ikot Efre Itak Forest, Nigeria (Ita 2020) and Ibodi Monkey Forest (Komolafe et al. 2020), 43 tree species were reported in Oyo Forest Reserve, Nigeria (Haastrup et al. 2020), while 70 tree species were reported in ICIMOD Knowledge Park, Godavari (Karki et al. 2016). These disparities in species abundance may point to variations in ecological gradients, geographic as well as physiographic coverages. The low woody species in this study are related to issues like anthropogenic encroachments and disturbances, deforestation and logging. Marked variations in vegetation parameters like DBH and height were observed across the woody species. These, according to Swamy et al. (2003), are functions of site quality and age differences. Ceulemans et al. (1992) also attributed the differences in height of tree species to growth forms and genetic variations. The highest and least DBH values observed in *Adenanthera pavonina* and *Rauvolfia vomitoria* may justify their growth forms, tree size, age and maturity stage. This agrees with the reports of Krinard and Johnson (1987). All the woody species in this study had mean DBH values of less than 10 cm. This is an indication that this forest is made up of young trees with greater growth and carbon sequestration potentials.

Variations were observed among species regarding their biomass (AGB and BGB) and carbon stock (AGC and BGC). This may infer that biomass apportionment and carbon sequestration abilities differ greatly among woody species. Arubasa & Odiwe (2019) also attributed these variations in biomass to density disparity and tree growth. The aggregate AGB (119.31 Mg ha^{-1}) recorded in this study is somewhat low when compared to ranges reported in other moist tropical forests. In Cameroon, an AGB of between 238 and 314 Mg ha^{-1} was reported in a tropical forest (Brown et al. 1989) whereas in a moist tropical forest, Djomo et al. (2011) reported a mean AGB of 264±48 Mg ha^{-1}. However, this study's AGB value is high when comparison is made to values obtained for regrowth forest (74.68 tha^{-1}), cocoa plantation (39.10 tha^{-1}) and tree fallow (1.28 tha^{-1}) physiognomies in Ibodi Monkey Forest, (Komolafe et al. 2020). The low AGB value in this study when likened to several studies may point to the small size and number of trees. The highest and least values in AGB recorded by *Gmelina arborea* and *Rauvolfia vomitoria*, respectively, may be attributed to their large and small DBH (Singh 2014). The DBH accounts for 95% of the entire plant biomass and trees with a large diameter contribute greatly to the AGB in plants (Houghton et al. 2001; Chave et al. 2004; Gibbs et al. 2007).

Just like in the biomass, the same ranking of carbon storage in plants had resulted. *Gmelina arborea* and *Rauvolfia vomitoria* also sequestered the largest and least amount of carbon (both AGC and BGC) in the forest. This portrays a positive relationship between these variables implying that every increase in biomass will also trigger an increase in carbon (Chanan, 2012). The largest percentage of carbon sequestered by this tree species may be attributed to its large DBH and height. This justifies the findings of other scholars in related studies. For instance, Huston & Marland (2003) reported that sequestration of carbon relies not only on productivity rates but also on the tree size and proportion of stem biomass for long term locking. Pandya et al. (2013) reported that as the diameter of species increases, its biomass and carbon storage capacity increases which also promote more carbon sequestration rate. It is worthy to note that aside from the DBH, tree height also provides the necessary advantage required for carbon removal from the atmosphere by trees during photosynthesis. This is evidenced in this study as *Gmelina arborea* was not the species with the largest DBH but was the tallest species in the ecosystem and this culminated to its high value in AGC. The differences in AGC and BGC among species can be explained by their differences in biomass production (Olorunfemi et al. 2019; Komolafe et al. 2020). The AGC reported in this study is low when compared to values obtained from other forest ecosystems. In a non-Dipterocarp Forest, an AGC of 120 Mg C ha^{-1} was reported (Hertel et al. 2009). Saatchi et al. (2007) reported values between 150 Mg C ha^{-1} and 200 Mg C ha^{-1} in old forests of South America. In a perturbed tropical forests, 76.50 Mg C ha^{-1} was reported in Sri Lanka (Brown & Lugo 1992) while a value of 223 Mg C ha^{-1} was documented in a fairly perturbed tropical forests in Malaysia and Cameroon (Brown & Lugo 1992). The low value of AGC in this study may be linked to intense anthropogenic invasions in the forest like incessant logging, clearing and building construction. Conversely, the AGC value in this study is higher than the total values (57.52 tCha^{-1}) reported for Ibodi Monkey Forest, Nigeria (Komolafe et al. 2020), W National Park (49.05 ± 29.58 MgC ha^{-1}), Bontioli wildlife reserve (48.67 MgC ha^{-1}) and Nazinga game ranch (47.82 ± 24.11 MgC ha^{-1}) in Burkina Faso, West Africa (Balima et al. 2021). Also, the total stock of carbon in this study ranks higher than values reported in protected natural vegetation (50.74 tons/ha) and communal grazing land (37.11 tons/ha) of Gra-Kahsu National forest, Alamata, Ethiopia (Atsbha et al. 2019). It was also observed that the amount of biomass and carbon apportionment varied in the litter components. The leaf litter had the highest carbon stock and biomass while the fine roots had the least values for biomass and carbon in the ecosystem. Similar finding was reported by Bhattarai & Mandal (2018). They reported a 69% carbon stock in leaf litter than in non-leaf litter, which had 31%. These differences in carbon stock and biomass in the litter, may pinpoint disparity in storage abilities of these variables in litter components.

Soil organic carbon (SOC) characterizes an important carbon pool in the ecosystem. Soil carbon in forests results from the stability between inputs from litter and soil heterotrophic respiration. In this study, the top layer of the soil (0 – 15 cm) had a higher carbon stock than the sub soil (15 – 30 cm). This finding corroborates with other researches (Swai et al. 2014; Bikila et al. 2016). In explaining the reduction in soil carbon with increasing depths, Thakuri (2010) attributed it to the presence of more decomposed litter, deadwood and logs on the top soil. The high SOC at the top soil in this study however, contrasts with the findings of Hiederer (2009) who reported a high SOC in the subsoil than the top soil. The soil organic carbon reported in this study is low in comparison to 332.60 tCha^{-1} obtained from similar ecosystem (Komolafe et al,. 2020). The low SOC value in this study may be as a result of differences in soil depth sampling and environmental factors.

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Comparatively, the vegetation pool had the highest amount of carbon than the soil and litter pools. This underscores the trees as main reservoirs for carbon forests. The high carbon in vegetation may be as a result of a high photosynthetic rates among trees where large amounts of carbon in the form of CO_2 are captured by plants from the atmosphere for onward storage and food manufacture. The low carbon stock in litter samples in this study, may substantiate the findings of Domke et al. (2016) that litter contribute a relatively small percentage to forest carbon stock budgets. In addition, Sun & Liu (2020) opined that about 5 % of carbon is stored in the litter and they play an indispensable role in circulating materials within forests.

From this study, it is clearly seen that this forest can store up to 125.61 MgC.ha-1 with a sequestrating ability of 458.31 Mg CO2ha-1. The aboveground and belowground pools sequestrated the highest and least carbon, respectively. This highlights the different sequestration abilities of the pools. The high sequestration rate of carbon in AGB is attributed to the dominance and presence of young growing trees in the forest. This agrees with the reports of Binyam (2012) and Nowak et al. (2013) that a forest comprising of young growing trees, tend to sequester large volumes of carbon. The result of this study suggests that this forest if properly managed, has a substantial ability for climate change mitigation via sequestration of large CO2

5. CONCLUSIONS

This study shows variations in the floristic variables, carbon stock and sequestration abilities of the forest. It also reveals the importance of floristic variables and individual contribution of trees to the AGC and BGC of the ecosystem. The aboveground pool stored the highest carbon while the below ground pool stored the least carbon. On the whole, this forest sequestered 458.31 Mg CO_2ha^{-1} which indicates that it has great potentials in mitigating climate change. From the foregoing, there is urgent need for this forest to be protected and conserved from impending decimation by the locals. This can be done by employing forest guards and creating a clear demarcation from the forest boundary to prevent further encroachment. Proper education and awareness should be organized for the locals stressing the importance of forest ecosystems and their potentials in mitigation of climate change and global warming.

AUTHORS' CONTRIBUTIONS

REI and FOO designed the study. FOO AND EOM contributed to literature review. REI, FOO AND EOM collected the data. REI and EOM analyzed the data. REI and FOO interpreted the data and discussed the results. All the authors read and approved the manuscript.

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