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BIOMASS AND CARBON STOCK ASSESSMENT OF A TROPICAL RAIN FOREST ECOSYSTEM IN NIGERIA

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ABSTRACT

Okomu National Park is the smallest National Park in Nigeria. It is managed mainly for wildlife conservation and has a lot of tree biodiversity. The potential of its forest for carbon sequestration has not been explored, therefore this study was undertaken to assess above-ground and below-ground biomass of the forest. To achieve this, line transect sampling method was used in the collection of field data. A total of fourteen (14) 50 m X 50 m temporary sample plots were laid. Trees with diameter at breast height (dbh) greater or equal to 20 cm were enumerated within the 50 m X 50 m plots. Relevant tree variables were measured and core samples were obtained from the trees. Tree variables measured include: diameter at breast height (dbh); diameter at the base (db); diameter at the middle (dm); diameter at the top (dt); total height (h); and merchantable height (mht). The core samples were dried in the laboratory until a constant weight was attained and analyses were carried out on data collected for the biomass and carbon estimation. The result obtained showed that the average above-ground biomass (ABG) was 268,023.76 kg/ha while the average for below-ground biomass (BGB) was 67,005.94 kg/ha. Carbon estimated for AGB was 134.01 tons/ha while that of BGB was 33.50 tons/ha. The total carbon estimated for AGB and BGB was 3,387, 820 tons. This indicates that carbon stock of the National Park is highly significant, this can be of great economic value if properly harnessed.

Keywords: Above-ground biomass; Below-ground biomass; Climate Change; Forest.

Introduction

Climate change has become a global reality. As a result, countries around the world are battling the daunting effect of the phenomenon in every sphere of life. One of the most viable, recognized and widely acceptable means of tackling climate change is carbon sequestration through forest tree species (FAO, 2010; Brack 2019). The role of forests as a long-term carbon pool for assimilation of atmospheric Carbondioxide (CO_2) is being increasingly realized by concerned stakeholders, thereby necessitating studies for assessing the use of forest resources to sequester carbon as part of a global mitigation effort (Ram 2008; Sheikh *et al.* 2014; Köhl *et al.* 2015; Karki *et al.* 2016; Pukkala 2018). Forests are very crucial in global carbon budget because of their dominance in the terrestrial carbon-cycle, they represent the largest carbon stock of terrestrial ecosystem making them a point of focus of carbon accounting research (Saugier *et al.* 2001; Ram 2008; Mackey 2016; Harris *et al.* 2017). However, despite the fact that forests are pertinent to the issue of climate change, they are continuously subjected to degradation and in some cases total destruction due to ignorance, population increase, industrialization, increase in the demand for forest and forest products, fire, poverty and many more.

There is no better alternative to combating climate change than through effective forestation because this has been established as one of the cheapest ways of achieving this purpose (United Nation 2010; Frances and Busch 2017). Tropical forests are particularly important because they contribute significantly to global carbon fluxes. According to a review by the Prince's Charities - International Sustainable Unit - ISU (2015), the existing level of CO_2 absorption within secondary and primary tropical forests is providing a vital mitigation services. Annually, about 1.2-1.8 GtC is being removed by tropical forest thus accounting for about 10-15 % of carbon mitigation potential. In Nigeria however, there has been a lot of degradation in the nation forests including Government forest reserve areas. The few places where mature forest can be found are the nation's National Parks and biosphere reserves. This study therefore assessed the carbon stock in Okomu National Park which is one of the nation's few intact lowland rainforest. The main objective of the study was to estimate the carbon content in above-ground biomass (AGB) and below-ground biomass (BGB) of the forest with a view to provide information on biomass and carbon stock of Okomu National Park.

Materials and Method

Study Area

Okomu National Park is a lowland rainforest located at the heart of Okomu forest reserve in Ovia South-West Local Government, Edo State, Nigeria, with a total size of 202.24 km^2 (Nigeria Park Service, 2016). The park has four range namely: Igowan range, Arakhuan range, Julius creek range and Babui creek range (Ijeomah *et al.*, 2015). The Park lies between longitude 5.187 °E and 5.431 °E and latitude 6.278 °N and 6.435 °N as shown in Figure 1.

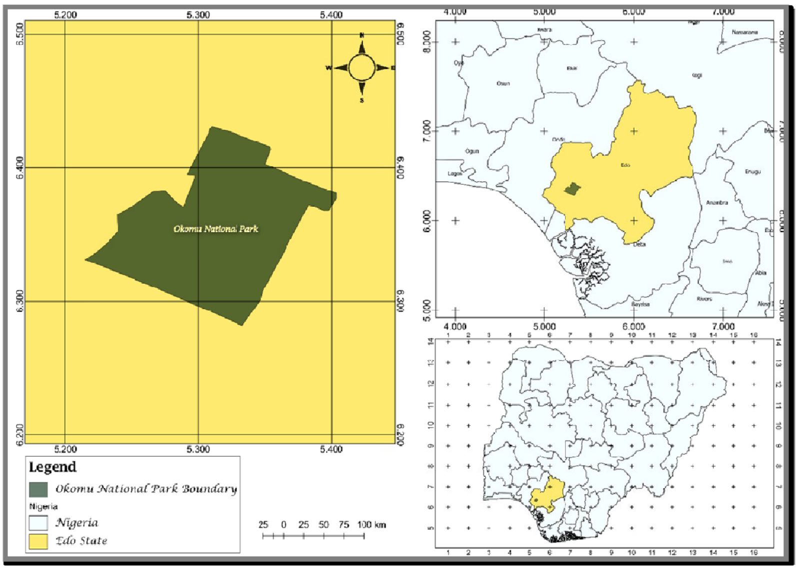

Figure 1: Boundary Map of Okomu National Park

Sampling Procedure and Tree Variable Measurement

Sampling was made by line transect method. Plots were laid alternately with 50 m interval between alternate plots. Fourteen (14) temporary sample plot sizes of 50 m X 50 m were laid and all trees with dbh = 20 cm were enumerated within the plots. Tree variables measured include: diameter at breast height (dbh); diameter at the base (db); diameter at the middle (dm); diameter at the top (dt); total height (h); and merchantable height (mht).

Non-destructive method was used to collect samples from live trees for carbon stock assessment. Core samples were obtained from enumerated trees using increment borer. The core samples were obtained at two points diametrically opposed at the dbh using an increment borer without removing the bark of the tree. The fresh weight and length of the core samples were measured on field. The samples were labelled and kept in polythene bags for moisture content preservation. They were oven dried at the laboratory at a constant temperature of 75 °C until a constant weight was attained.

Data Analyses

Volume Estimation

The volume of each tree was estimated using Newton's formula (Equation 1).

$$\boldsymbol{V = \frac{\pi}{24} h \left(D_b^2 + 4D_m^2 + D_t^2\right)} \; \ldots \; 1$$

Where V is Volume (m^3), h is height (m), D_b is Diameter at the base (m), D_m is Diameter at the middle (m), D_t is Diameter at the top (m), and p is 3.142.

The volume of individual trees were summed up to obtain volume per plot. The mean volume per plot was used to compute volume per hectare by multiplying it with the number of sample plots in a hectare (that is, four 50 m X 50 m plots in 1 hectare).

Wood Density Estimation

The wood core density was obtained by dividing mass by the core volume as given in Equation 2.

$$WCD = \frac{M}{CV} \quad \ldots\ldots \; 2$$

Where WCD is Wood core density (g/cm^3), M is Wood Ma

two core samples that were obtained from each tree, and CV is Core Volume (cm^3) which was estimated using the formula given in Equation 3.

$$CV = \frac{\pi d^2}{4} \; x \; L \; \ldots\ldots \; 3$$

Where d (cm^2) is 0.45 cm, that is, diameter of the core sample (diameter of the increment borer used), and L is mean length of the two core samples that were obtained from each tree (cm).

The result obtained was expressed in kg/m^3. The mean plot value of WCD obtained was multiplied by 4 (number of 50m X 50m in one hectare) to obtain the WCD per hectare.

Above-Ground and Below-Ground Biomass Estimation

The stem wood biomass was estimated by multiplying volume with wood density (Reyes *et al.* 1992; Pearson and Brown 1932). The stem wood biomass was then expanded to total above-ground biomass of tree (Equation 4) including leaves, twigs, branches, bole and bark using biomass expansion factor (Bohre *et al.* 2013; Goslee *et al.* 2015).

$$\boldsymbol{AGB = V \times WCD \times BEF} \quad \ldots\ldots\ldots \; 4$$

Where AGB is Above-ground biomass (kg), V is Stem Wood Volume (m^3), WCD is Wood Core Density (kg/m^3) and BEF is Biomass Expansion Factor (2.292). The mean BEF value of 2.292 was used for this study as prescribed by Nigeria R-PP (2013) for lowland Rainforest National Parks.

The mean plot value of AGB obtained was multiplied by four (number of 50 m X 50 m in one hectare) to obtain the AGB per hectare. The below ground biomass was then calculated using simple default value of 25% (for hardwood species) of the total above-ground biomass as recommended by IPCC (2006). The average values of AGB per hectare and BGB per hectare obtained were then multiplied by 20,224ha (size of the forest stand) to obtain the total above-ground biomass and below-ground biomass for the stand, respectively.

Above-ground and Below-ground Carbon Estimation

The above-ground and below-ground carbon were calculated by dividing its biomass by 2 as given in the guidelines of IPCC (2006), and later expressed in tonnes per plot (tons/plot) by dividing it by 1000. The mean plot value obtained was thereafter multiplied by four (number of 50m X 50m plots in one hectare) which gave the tons per hectare equivalent. Total above-ground and below-ground carbon for the entire stand was thereafter estimated by multiplying their average per hectare values by 20,224 ha (size of the forest stand).

Results and Discussion

Five hundred and thirty-one (531) individual trees were enumerated within the sample plots. The average number of stems per hectare estimated was 152. The highest and lowest mean dbh recorded were 47.20 cm and 31.24 cm, respectively giving an average dbh of 36.50 cm for the entire sample plots. However, the tree with the largest dbh enumerated was 131.1 cm. More so, tree height ranged between 4.65 m and 54 m with an average height of 20.01 m across the entire sample plots. The overall average volume per hectare was 216.30 m^3 with plot 1 contributing the highest value (301.51 m^3/ha) while plot 8 contributed the least value (76.27 m^3/ha).

In addition, the average basal area per hectare estimated for the plots was 19.34 m^2, plot 6 had the highest estimated value (30.13 m^2) while plot 8 had the least value (10.70 m^2).

Diameter at breast height (dbh) and height measurement are very important in carbon pool estimation because aside from their usefulness in estimating volume and basal area, they can also be used for developing allometric equation which could be beneficial for future carbon study (Pearson *et al.* 2007; Goslee *et al.* 2015; and Phalla *et al.* 2018). The estimated values for basal area and volume were lower compared with those reported for similar sites by Adekunle *et al*. (2013), Etigale *et al*. (2014) and Aigbe *et al* (2017). This could be attributed to the targeted tree dbh classes (dbh = 20cm) in this study compared to that of these studies (dbh = 10cm). McElhinny (2002) noted that Information on basal area is very important because it is indicative of stand volume and biomass which has implication for carbon stock

Aboveground biomass estimated was within the range of 80,682.22 kg/ha and 497,278.64 kg/ha with an average of 268,023.76 kg/ha while the range for BGB was 20170.56 kg/ha and 124,319.66 kg/ha with an average of 67,005.94 kg/ha as shown in Table 1. Total AGB and BGB estimated for the stand were 5,420,512,472.10 kg and 1,355,128,118.02 kg, respectively. The average biomass estimated was higher than 1372.25 kg/m^3, 1196.01 kg/m^3 and 1213.04 kg/m^3 reported by Oladoye *et al*. (2018) for *Nauclea diderrichii* plantation in Omo forest reserve, Nigeria. This might be due to the diversity of tree species encountered in the study area compared with the single tree species estimated by Oladoye *et al*. (2018).

Table 1: Above-ground and Below-ground Biomass

Plot Number	Number of Tree/ha	MDbh (cm)	Avg Ht (m)	TV/ha (m^3)	BA/ha (m^2)	AGB/ha (Kg/ha)	BGB/ha (Kg/ha)
1	120	46.50	20.95	308.51	23.26	497278.64	124319.66
2	144	38.68	19.12	234.10	21.16	273651.88	68412.97
3	128	39.51	21.16	246.88	18.59	256299.26	64074.82
4	120	33.69	22.29	134.42	12.28	175659.71	43914.93
5	132	47.20	17.99	253.50	27.44	324363.37	81090.84
6	196	38.34	17.82	218.16	30.13	359201.44	89800.36
7	160	32.57	20.96	267.39	17.98	293956.49	73489.12
8	112	33.69	20.10	76.27	10.70	80682.22	20170.56
9	160	33.83	19.37	224.55	15.79	239229.92	59807.48
10	144	33.22	19.14	170.23	15.61	189948.33	47487.08
11	192	36.60	20.67	254.16	25.26	387226.32	96806.58
12	164	33.68	23.68	272.99	19.64	349025.03	87256.26
13	216	32.30	18.15	198.04	19.79	221392.17	55348.04
14	136	31.24	19.81	169.02	13.07	104417.83	26104.46
Average	152	36.50	20.09	216.30	19.34	268023.76	67005.94

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

In addition, the results revealed that average AGB carbon was 134,011.88 kg/ha while the average BGB carbon was 33,502.97 kg/ha. These values when converted to tonnes per hectare gave an average of 134.01 ± 7.38 tons/ha for AGB carbon with plot 8 having the least value (40.34 tons/ha) and plot 1 with the highest value (248.64 tons/ha), while the average BGB carbon was 33.50 ± 1.85 tons/ha, details are as given in Table 2. Total AGB carbon estimated for the entire stand was 2,710,256.24 ± 7.38 tons while BGB carbon was 677,564.06 ± 1.85 tons.

Table 2: Carbon in Above-ground and below-ground Biomass

Plot Number	AGC (Kg/ha)	BGC (Kg/ha)	AGC (tons/ha)	BGC (tons/ha)
1	248639.32	62159.83	248.64	62.16
2	136825.94	34206.48	136.83	34.21
3	128149.63	32037.41	128.15	32.04
4	87829.85	21957.46	87.83	21.96
5	162181.69	40545.42	162.18	40.55
6	179600.72	44900.18	179.60	44.90
7	146978.24	36744.56	146.98	36.74
8	40341.11	10085.28	40.34	10.09
9	119614.96	29903.74	119.61	29.90

10	94974.17	23743.54	94.97	23.74
11	193613.16	48403.29	193.61	48.40
12	174512.51	43628.13	174.51	43.63
13	110696.08	27674.02	110.70	27.67
14	52208.92	13052.23	52.21	13.05
Average	134011.88	33502.97	134.01	33.50

AGC =Above-ground Carbon, BGC = Below-ground Carbon

The values (134.01 tons/ha for AGB and 33.50 tons/ha for BGB) are higher than the values (4.01tons/ha for ABG and 0.81 tons/ha for BGB) reported by Ibrahim *et al.* (2018) for a savannah forest in Nigeria. It was also higher than the values reported for Osho forest reserve (29.36 tons), Shasha forest reserve (24.36 tons) and Gambari forest reserve (14.84 tons), all in Nigeria as noted by Olayode *et al.* (2015). The value of carbon obtained for above-ground biomass for this study (134.01 tons/ha) was greater than the value reported by Sierra *et al.* (2007) for a primary forest in Colombia (116.7 tons/ha), but lesser than the values obtained by Sebastian *et al.* (2015) for two forest types in a lowland rainforest in Congo (163.5 tons/ha, 191.4 tons/ha). Lü *et al.* (2010), Glenday (2006) and Ngo *et al.* (2013) reported higher values of 159.7 tons/ha, 200 tons/ha and 329.61 tons/ha (dbh >10cm) for tropical rainforests in China, Kenya, and Singapore, respectively. The trend was the same for below ground biomass since it is usually estimated from above-ground biomass.

The differences observed in biomass and carbon of the study site compared to similar study site could be attributed to environmental variations as suggested by Rajput *et al.* (2017) and Daba and Soromessa (2018), and method of estimation employed as observed by Vashum and Jayakumar (2012) and Valbuena *et al.* (2016).

Above and below ground carbon are very significant in carbon pool study because they provide insight to carbon sequestration potential of the forest (Ibrahim *et al.* 2018; Aghimien, 2019). Total carbon (that is, AGC and BGC, excluding other pools) estimated for the park, which was 167.51 tons/ha, falls within the category of high carbon density area (158-408 tons/ha) as classified by Ravilious *et al.* (2010).

Conclusion

The study provided information on above-ground and below-ground biomass and carbon of Okomu National Park. The total biomass and carbon estimated (comprising of both above-ground and below-ground) for the study area were 6,775,640,590.12 kg and 3,387,820.30 tons, respectively. The result revealed that the Park is an important carbon reserve which can play a major role in climate change mitigation. The carbon stock estimated for the Park is significant and falls within the high Carbon density area. Since the forest is a regenerating forest, higher values can be attained with good conservation efforts. It is therefore recommended that the stakeholders concerned with the management of forest reserves and parks should actively incorporate carbon stock management as a core management objective for the Park. This will not only enhance the forest value but will also help in the achievement of sustainable cities and communities for the present and future generation.

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