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Estimation of Carbon Stock Monetary Value of a Tropical Rainforest in Nigeria

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Abstract
The study estimated the carbon stock contents of a lowland rainforest in Nigeria, Okomu National Park. Four major Carbon pools were estimated, they were: above-ground biomass; below-ground biomass: dead wood; and litter. Nested plot design was used for sample plot demarcation. All trees (living and dead) with Dbh ≥ 10cm were enumerated within the 50 m X 50 m and 20 m X 20 m plots, while the 1 m X 1 m quadrant was for litter samples collection. Core samples and sub-samples were collected from live tree and dead wood respectively. The total carbon stock estimated for the study area was 177.58 tons/ha, of which above-ground biomass accounted for 134.01 tons/ha and below-ground biomass was 33.50 tons/ha. Dead wood was 6.05 tons/ha while litter was 4.02 tons/ha. The Carbondioxide equivalent was estimated to be 651.14 tons/ha. The monetary value for the carbon stock estimated at \$ 4/tCO2 was \$ 52,674,679. Thus, carbon sequestration is one of the significant ecosystem services provided by mature rainforests.

Keywords: Carbon pool, Rainforest, Ecosystem Service, Climate Change, Forest Management
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1. INTRODUCTION

Okomu National Park is one of the Parks containing the remaining lowland rainforest ecosystem in Nigeria (Ejidike and Okosodo 2007). It is a mature forest housing a lot of biodiversity. The focus of management as with most National Parks has traditionally been focused on the conservation of wildlife species and most research studies on the Park has been focused on the same. This is evident in the studies conducted by Akinsorotan *et al.* (2011), Aremu *et al.* (2012), Obasogie and Ogunjemite (2014), Ojianwuna (2015), and Amusa (2016). The Park provided refuge for many threatened species, including the white-throated monkey (*Cercopithecus erythrogaster*) which is a major source of animal protein to people living in the surrounding communities and also sold commercially for financial benefits (Oates 1995, Ajayi 2011). In a study conducted by Morgan *et al.* (2011), the Park was classified as one of the exceptional priority conservation sites in Nigeria. However, Ogunjemite *et al.* (2007) and Aremu *et al.* (2012) stated that the Park is facing a major problem due to anthropogenic factors including illegal logging activities, poaching and habitat encroachment, overgrazing and deforestation. Out of the 202.24 km^2 of land constituted for the Park, only 181 km^2 is currently being managed actively by the Park management, this is because there is dispute on the remaining 21.24 km^2 of land.

This is not necessarily because the local people are not aware of the importance of the protected area. A study carried out by Ogunjimi *et al.* (2012) revealed that although the local people are aware of the importance and limits of the ecosystem of the Park, their low level of education as well as the need to satisfy their considerably large family are the reasons for their continued degradation and unsustainable exploitation of these resources. Local communities, according to Tessema *et al.* (2007), though viewed protected areas and wildlife resources as essential resources, are unwilling to aid conservation works due to perceive lack of benefit. Studies that contribute to the management of the Park as well as improving the livelihood of local communities in light of future climate change scenarios are lacking and are therefore needed as stated by Assaye (2014). The forest ecosystem which provides shelter for the wildlife species being protected in the Park also sequester a lot of carbon through photosynthesis and this can be traded as obtainable under REDD+ (Reducing emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks). The carbon credit which is obtainable through programmes like REDD+ will not only contribute greatly to the sustainable management of the Park but the improvement of the livelihood of the communities around the Park. However, assessing such funds will require monitoring the state and changes of the different carbon pools in the forest, as this is highly essential to carbon trading and marketing (Genene *et al.*, 2013). Presently, information on the stock of the different carbon pools in the Park and monetary value of the carbon stock is lacking. This constitute the major problem this study sought to address.

2. MATERIALS AND METHOD

2.1. Study Area

The lowland rainforest, Okomu National Park, is 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 lies between longitude 5.187 °E and 5.431 °E and latitude 6.278 °N and 6.435 °N as shown in Figure 1. The park has four range namely: Igowan range, Arakhuan range, Julius creek range and Babui creek range (Ijeomah *et al.*, 2015).

2.2. Data Collection

Nested plot design was adopted for the study and fourteen temporary plot sizes of 50 m X 50 m were laid within which sub-plots sizes of 20 m X 20 m and 1 m X 1 m were marked out, using line transect method. Trees with dbh ≥ 20 cm were enumerated within the 50 m X 50 m plots and core samples were collected from those trees using increment borer. Core samples collected were weighed on field and labelled appropriately. In addition, all dead trees/wood encountered were also enumerated within these plots. The dead wood included both standing and lying dead wood. Standing dead trees were classified into three categories based on the presence or absence of leaves, twigs and big branches as recommended by Genene *et al.* (2013). On the hand, lying dead wood were classified based on their healthiness as either sound, intermediate or rotten using the machete test. Samples obtained from the dead wood were measured using water displacement method and labelled appropriately

Trees with dbh between 10 cm and 19.9 cm were enumerated with the 20 m X 20 m sub-plots while the 1 m X 1 m sub-plots were adopted for the collection of litter. The litter was weighed and sub-samples were collected. A total of 531 live trees, 33 standing dead wood and 62 lying dead wood were enumerated within the 50 m X 50 m plots while 199 live trees were measured within the 20 m X 20 m. All samples collected were later dried in the laboratory and values obtained were used for further analysis.

2.3. Data Analysis

Live tree volume, core volume and core density were estimated using Equations 1,2 and 3 respectively.

$$\boldsymbol{V = \frac{\pi}{24} h \left(D_b^2 + 4D_m^2 + D_t^2\right)} \quad \text{…………………………………………… Equation 1}$$

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 π is 3.142.

$$CV = \frac{\pi d^2}{4}\ x\ L \quad \text{………………………………………………………… Equation 2}$$

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

WCD=M/CV ………………………………………………………… Equation 3

Where WCD is Wood core density (g/cm^3), M is Wood Mass (g) i.e. mean dry weight of the two core samples that were obtained from each tree, and CV is Core Volume (cm^3).

Above ground biomass was calculated using Equation 4 while below ground biomass was estimated using simple default value of 25% (for hardwood species) of the total above ground biomass as recommended by IPCC (2006). The carbon contents of AGB and BGB were estimated by halving their biomass and converting them to tonnes per plot (tons/plot) by dividing it by 1000.

$$\boldsymbol{B = V \times WCD \times BEF} \quad \text{…………………………………………… Equation 4}$$

Where B is 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.

Biomass of dead standing tree in categories 1 and 2 were discounted by 3% to correct for absence of leave. Smalian volume equation given in Equation 5 was used for category 3 of dead standing tree and lying dead wood. The biomass was then estimated using Equation 6.

$$V = \pi h \frac{d_b^2 + d_t^2}{8} \quad \text{………………………………………................ Equation 5}$$

Where V is Volume of bole (m^3), h is height (m), d_b is Diameter at the base (m) and d_t is Diameter at the top (m)

$$Biomass(kg) = Density\ (kg/m^3) \times Volume\ (m^3) \quad \text{………………….. Equation 6}$$

The dry mass of the litter sample was estimated from the dry to wet ratio of the sub-sample using Equation 7.

$$Dry\ Mass\ of\ sample(kg) = \frac{sub{-}sample\ dry\ mass(kg)}{sub{-}sample\ wet\ mass\ (kg)} \times Fresh\ Mass\ of\ sample(kg) \quad \text{……… Equation 7}$$

The result obtained was divided by 2 to obtain the amount of carbon in the litter, this was then expressed in tonnes per plot by dividing it by 1000. The resulting value was multiplied by 10,000 (the number of 1m X 1m in a hectare) to obtain the amount in tonnes per hectare.

The total carbon stock in tonnes per hectare for the study area was estimated by summing up the carbon in tonnes per hectare of all the pools estimated, the formula is given in Equation 8.

$$Ct_{\frac{tons}{ha}} = Cab_{\frac{tons}{ha}} + Cbg_{\frac{tons}{ha}} + Csdw_{\frac{tons}{ha}} + Cldw_{\frac{tons}{ha}} + Cl_{\frac{tons}{ha}} \quad \text{…………………………………… Equation 8}$$

Where Ct is Total carbon (tons/ha), Cab is Estimated Carbon in Above-ground biomass (tons/ha), Cbg is Estimated

Carbon in below-ground biomass (tons/ha), Csdw is Estimated Carbon in standing dead wood (tons/ha), Cldw is Estimated Carbon in Lying dead wood (tons/ha), and Cl is Estimated Carbon in litter (tons/ha).
The estimated total carbon in tons/ha obtained was used to estimate the Carbondioxide equivalent in tons/ha using Equation 9 as stipulated by IPCC (2006).

$tCO_2e = Ct_{ton/ha} \times {}^{44}/_{12}$ ………………………………………… Equation 9

Where tCO_2e is Total Carbondioxide equivalent in tons/ha, and $Ct_{tons/ha}$ is Total carbon (tons/ha).
The total carbon and Carbondioxide equivalent for the entire stand were then estimated using Equations 10 and 11 respectively.

$Ct_{stand} = Ct_{tons/ha} \times 20224ha$ ……………………………………. Equation 10

Where Ct_{stand} is Total Carbon for the stand (tons), and $Ct_{tons/ha}$ is Total carbon (tons/ha).

$CO_2e_{stand} = tCO_2e \times 20224ha$ ……………………………………. Equation 11

Where CO_2e_{stand} is Total Carbondioxide equivalent for the stand (tons) and tCO_2e is Total Carbondioxide equivalent in tons/ha
The price for the carbon stock was estimated by multiplying the total Carbondioxide for the whole stand by \$4 as done by Assaye (2014). This is given in Equation 12.

$Carbon\ Price = CO_2e_{stand} \times \$4$ …………………………………… Equation 12

3. RESULTS AND DISCUSSION

The total carbon stock estimated for the various pools was 177.58±8.91 tons/ha. The values estimated for AGB, BGB, SDW, LDW and litter were 2,710,256.24 tons, 677,564.06 tons, 59,047.37 tons, 63,367.54 tons and 81,220.19 tons respectively, giving a total of 3,591,455.39 tons for the entire stand, details are presented in Table 1. The results, as illustrated in Figure 2, shows that AGB had the highest carbon stock constituting about 75 % of the total carbon stock, this was followed by BGB constituting about 19 % of the total estimated carbon stock. Dead wood (comprising of LDW and SDW) and litter had the least values.

Total carbon stock (177.58 tons/ha) obtained was higher than 127.3 tons/ha predicted for lowland National Parks by Nigeria R-PP (2013) and the estimated 115 tons/ha reported by Pandey (2012) for World Heritage Sites in Tropical Forests. It was also higher than 77.64 tons/ha estimated by Pragasan (2015) for a forest in India, 120 tons/ha reported by Lai (2005) for a tropical ecosystem, 123.58 tons/ha reported by Jibrin *et al*. (2014) for a riparian forest in Nigeria. The value obtained was also higher than 123.05 tons/ha (dbh ≥ 10cm) reported by Zaragoza *et al*. (2016) for a secondary tropical forest and the 138 tons/ha recorded by Pandey (2012) for a rainforest in Madagascar. It was closely comparable to 160 tons/ha and 186.43 tons/ha reported by GRCL (2015) and Karki *et al*. (2016) for some tropical forests and 198.4 tons/ha (dbh > 10cm) estimated by Alves *et al*. (2010) in a lowland forest in Brazil. Kupsch *et al*. (2014), Hunter *et al.* (2013), Berta *et al.* (2015), Glenday (2006) and Alder and Van Kuijk (2009) however reported higher values of 271.3 tons/ha, 288 tons/ha, 324.89 tons/ha, 360 tons/ha, 372 tons/ha, for similar forests in Cameroon, Brazil, Ethopia, Kenya and Guyana respectively.

When compared with values for other National Parks and World Heritage sites as estimated by Pandey (2012), total carbon stock of the study area was higher than that obtained for Sundarbans National Park (56.3 tons/ha) in India and Sangay National Park (67.5 tons/ha) in Ecuador. It was also higher than those estimated for Tikal National Park (85 tons/ha) in Guatemala, Canaima National Park (92 tons/ha) in Venezuela, and Lorentz National Park (100 tons/ha) in Indonesia. It was higher than the estimated values for Manu National Park (134.4 tons/ha), Peru, Chitwan National Park (140.7 tons/ha), Nepal and Gunung Mulu National Park (167 tons/ha), Malaysia. It was however in the range reported for Sangha Trinational (163 tons/ha), (bordering Cameroon, Central African Republic and Republic of Congo) and Taï National Park (188 tons/ha), Cote d'Ivoire. The Carbondioxide equivalent of carbon estimated followed the same trend since it was a derivate of estimated carbon. The carbon stock of the Park also falls within the high carbon density area (158-408 tons/ha) as classified by Ravilious *et al*. (2010). Given that the forest is a regenerating forest, it has a high capacity to sequester even more carbon with improved management.

The result obtained for the financial estimate is presented in Table 2, the total monetary value for the carbon stock estimated at \$ 4/tCO2 was \$ 52,674,679. The estimated monetary value of carbon stock obtained for the Park was greater than US\$ 40,709,088 estimated by Assaye (2014) for Awash National Park but lesser than US\$ 62,184,364 reported for Simien Mountains National Park by Assaye (2015). These values are subjective depending on estimated carbon stock per hectare, size of area being assessed and the price per tonne adopted. However, the value obtained for the Park has the potential of providing adequate funds through programmes such as REDD+ if carbon stock is incorporated as a management objective. This will help in providing additional funds for the management of the Park and also make available financial incentives for forest dependent communities, thereby reducing the pressure on the forest.

4. CONCLUSION

For the carbon stock estimations of Okomu National Park, above ground biomass accounted for the largest proportion of carbon within the Park, followed by below ground biomass, and then Dead wood (Both standing and lying dead wood). Litter accounted for the least carbon stock within the Park. The carbon stock estimated for the National Park is highly significant and falls within the high Carbon density area. More so, since the forest is a regenerating forest, higher values can be attained with good conservation efforts. The monetary value of carbon stock obtained for the Park was very high and if accessed could be useful in funding management cost as well as providing incentives for forest dependent communities around the Park.

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FIGURES

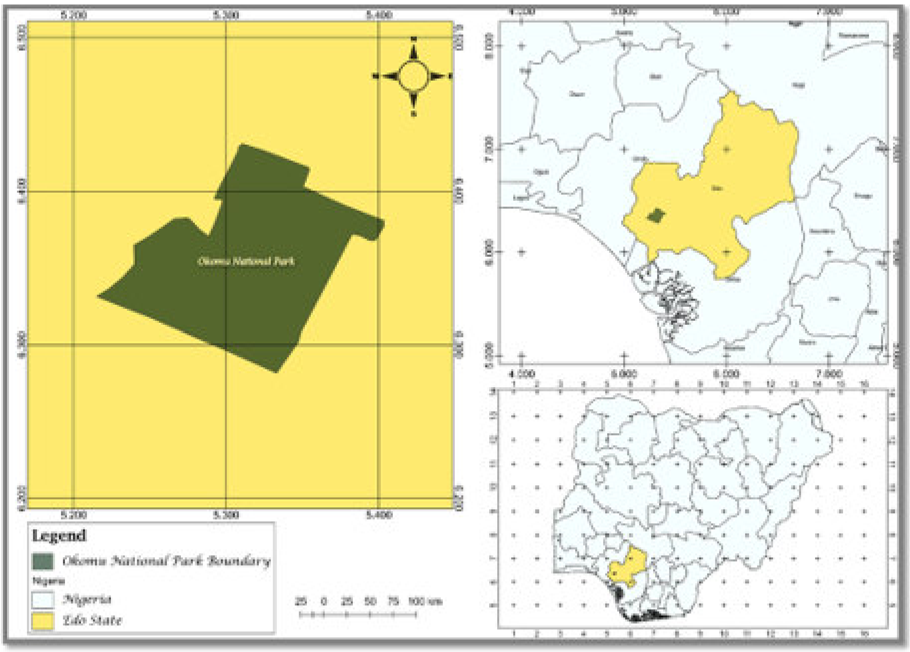

Figure 1: Boundary Map of Okomu National Park

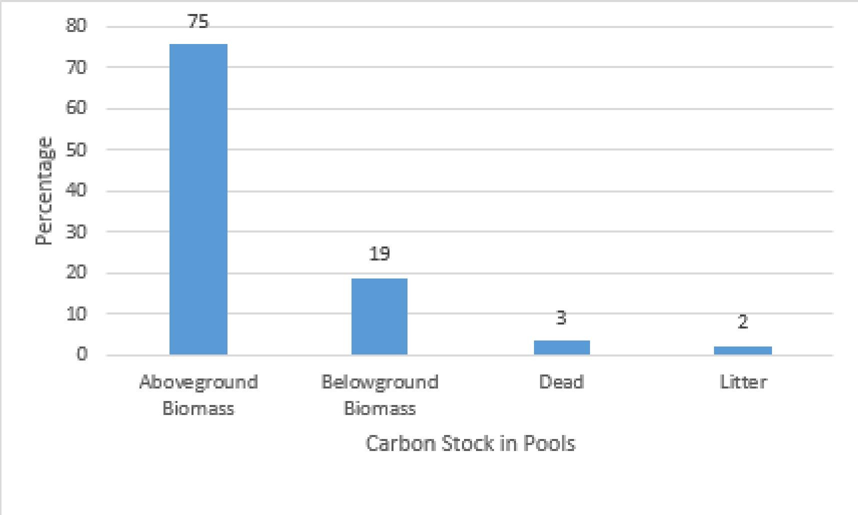

Figure 2: Comparison of Carbon Stock in different Carbon Pools

TABLES

Table 1: Carbon Stock and Carbondioxide Equivalent of the Carbon Pools

Total Number of Plots	Cab tons/ha	Cbg tons/ha	Csdw tons/ha	Cldw tons/ha	Cl tons/ha	Ct Tons/ha	tCO2e
14	1876.17	469.04	40.88	43.87	56.22	2486.17	9115.97
Avg	134.01	33.50	3.41	3.13	4.02	177.58	651.14
Per ha	134.01	33.50	2.92	3.13	4.02	177.58	651.14
Per Stand	2710256.24	677564.06	59047.37	63367.54	81220.19	3591455.39	13168669.78
Mean	134.01	33.50	3.41	3.13	4.02	177.58	651.14
Std Dev	56.36	14.09	4.57	8.54	1.71	68.21	
C1(95%)	29.52	7.38	2.39	4.47	0.90	35.73	

Table 2: Monetary value of Carbon Stock

Plot No	tCO_2e	Price Equivalent ($)
1	1, 174.40	4, 697.59
2	679.32	2, 717.27
3	629.02	2, 516.08
4	593.69	2, 374.76
5	762.35	3, 049.42
6	846.84	3, 387.34
7	681.37	2, 725.48
8	239.73	958.91
9	568.81	2, 275.26
10	440.15	1, 760.61
11	907.09	3, 628.36
12	813.31	3, 253.23
13	520.93	2, 083.72
14	258.96	1, 035.84
Total	9, 115.97	36463.88
Per ha	651.14	2604.56
Per Stand	13, 168, 669.78	52, 674, 679.12

*tCO_2e = Total Carbondioxide equivalent of Carbon