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Carbon Sequestration in Above-Ground Biomass of Coniferous and Broad-Leaved Plantation Tree Species in Southeastern Nigeria

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Abstract

Global warming is a prevalent climatic phenomenon threatening the existence of man on the earth, and forests have been identified to play an important role. Excessive carbon dioxide (CO_2) at the lower region of the atmosphere is the principal gas causing global warming. Forest trees have great physiological capacity to sequester carbon, thereby purifying atmosphere of excessive CO_2 and ultimately mitigating global warming. There is dearth of information on carbon sequestration potentials of most tree species in planted forests. Thus, the above-ground of biomass and sequestered carbon in the 22 year old planted forests of *Pinus caribaea* (coniferous) and *Nauclea diderrichii* (broadleaved) were evaluated by fitting the collected mensuration data (diameters at breast height and tree heights) to allometric functions. Subsequently, the estimated biomass and carbon values of the trees were subjected to descriptive statistical and linear regression analyses. The results showed that the mean standing biomass of *P. caribaea* varied between 0.12 ton/tree and 0.020 ton/tree, while that *N. diderrichii* varied between 0.19 ton/tree and 0.34 ton/tree. The mean sequestered carbon in *P. caribaea* varied between 0.06 ton/tree and 0.1 ton/tree, while that of *N. diderrichii* varied between 0.09 and 0.17 ton/tree. The analysis of variance of the regression of diameter at breast and sequestered carbon of both tree species were highly significant ($P<0.05$), with coefficients of determination of 0.95 and 0.9911 respectively for *P. caribaea* and *N. diderrichii*. Following the higher mean standing biomass and mean sequestered carbon in *N. diderrichii* than *P. caribaea*, it is recommended that *N. diderrichii* should be preferred for forest plantation establishment meant for environmental service of mitigating global warming nay climate change mitigation.

Key words: Global warming, Planted forests, Trees, Standing biomass, Sequestered carbon.

Introduction

Climate change is a contemporary harmful challenge threatening, the existence of man. The phenomenon is characterized with consistent unfavourable climate as exemplified in the rising earth temperature, which is otherwise, referred to as global warming. Human activities are among the principal causes of climate change and widespread deforestation has been identified as one of the most prominent activities. IPCC (2007) reported that there has been increase in the earth's temperature by 0.76°C in the last century and this is expected to increase by 2°C by year 2050. The consequences of global warming include increase in incidence of carcinogenic diseases, flooding as a result of ocean rise and melting of the polars' ice in Polar Regions, aggravated drought in the continental hinterland and loss of bio-resources of food and medicine (Label and Kane, 1989; Odjugo, 2009).

The concentration of some gases at the lower part of the atmosphere (troposphere) causes global warming (Flavin, 1989). However, the principal gas causing global warming is carbon dioxide (CO_2). Other gases include methane, nitrous oxides and methylchloroform. Excessive CO_2 in the troposphere absorbs earth infra-red radiation (heat emitted from the earth surface) and prevent it from escaping into space, thereby raising global temperatures. The burning of fossil fuels (petroleum fuels) and deforestation are the major anthropogenic activities generating excessive CO_2. Burning of fossil fuels releases about 5 billion tonnes of CO_2 into the atmosphere yearly (Sato, 2008), while tropical deforestation releases 1.5 billion tonnes of carbon per annum into the atmosphere. Forests are a critical factor in the mitigation of global warming, because of its large compartmentalized capacity to sequester carbon through CO_2 fixation for biomass production. According to Abad (2015), forests have five carbon pools, namely; aboveground biomass, belowground biomass, deadwood, litter and soil organic matter. However, forest trees have been identified as the principal sinks of CO_2 through fixation for physiological processes of photosynthesis and biomass production, particularly wood production, (Sukhdev, 2010; Adekunle and Olagoke, 2010).

According to Akbari (2002) a tree in a forest removes 4.5 – 11kg of carbon per annum simply growing and using carbon dioxide in the process of photosynthesis. Forest plantation establishment and protection is an effective and efficient measure to combat global warming and indeed mitigating climate change. According to Tewari *et al*. (2008) forests are a much cheaper and easier reservoir for storing carbon than industrial capture and storage. This paper, therefore, is a report of a study on evaluation of sequested carbon in the standing biomass of planted forests of *Pinus caribaea* (Coniferous tree) and *Nauclea diderrichii* (broadleaved tree) in the tropical rainforest belt of Southeastern Nigeria.

Methods

The study was carried out on the *Pinus caribaea* plantation at Ekempon in Odukpani Local Government Area, Cross River State and *Nauclea diderrichii* plantation at the Arboretum of the Department of Forestry and Wildlife, University of Uyo, Akwa Ibom State, Nigeria.

The *P. caribaea* plantation, which covers 10 ha at a planting-distance of 2.5m x 2.5m was established in 1991. The area lies between latitudes 4 07'N and 5° 01'N and longitudes 7° 10'E and 8° 20'E. The vegetation is tropical rainforest. The area has a mean annual temperature of 30°C, annual rainfall of 2,510mm and 75.2% mean relative humidity. The soil is clay-loam with a pH of 4.7. The *Nauclea diderrichii* forest, which covers 5.6 ha at a planting distance of 2.5m x 2.5m was established in 1995. The area lies within the tropical rainforest zone between latitudes 4° 58'N and 5° 05' N and longitudes 7° 54'E and 8° 00'E. The annual rainfall of the area is about 2,450mm, mean annual temperature varies between 28.48°C and 30.18°C and mean relative humidity is 74.8%. The soil is silty loam in texture with a pH of 6.7.

Data Collection

One hectare sample plot was marked out in the core areas of each of the planted forests with the full stock of tree stands. The sample plot was divided into sixteen (16) 25m x 25m sub-plots. Four (4) sub-plots were randomly selected for enumeration of trees. Subplot trees were randomly selected, labeled with red gloss marker and their diameters at breast height (dbh) were measured. Two mean dbh trees, (trees that had dbh closest to the mean dbh) in each sub-plot were identified and measured for height using Sunto Clinometers. Subsequently, average height was calculated for each tree species from the heights of the mean trees. The eight (8) mean trees in each forest were chosen for the estimation of above-ground biomass and sequestered carbon.

Estimation of Standing Biomass and Sequestered

The standing biomass of each tree was estimated using the allometric functions of Terakunpisut *et al* (2007) developed for tropical rainforest and dry evergreen forest trees. The functions are expressed as follows:

$$Ws = 0.0509\ (D^2H)^{0.919}$$

$$Wb = 0.00893*(D^2H)^{0.977}$$

$$W_I = 0.0140*\ (D^2H)^{0.669}$$

Where,

Ws = Stem biomass (tons/individual tree)

Wb = Branch biomass (tons/individual tree)

WI = Leaf biomass (tons/individual tree)

D = Diameter at breast height (cm)

H = Height (m)

The stem, branch and leaf biomass together constituted the standing biomass of individual tree.The sequestered carbon in the standing biomass of individual tree was estimated by multiplying 0.5 conversion factor with the estimated standing biomass, which implies that 50% of the standing biomass is carbon (Dixon *et al*., 1994; Chaturvedi, 1994 and Terakunpisut *et al*., 2007).

Data Analysis

The data collected and obtained were subjected to descriptive statistical and linear regression analyses using Microsoft Excel. The linear regression analysis had diameter at breast height (dbh) as explanatory variable (X) and estimated sequestered carbon as response variable (Y). Analysis of variance was employed to verify the significance or non-significance of the regression at 0.05 level of probability.

Results

The mean diameter at breast height (dbh) of *Pinus caribaea* ranged between 25cm to 34cm (Table 1), while that of *Nauclea diderrichii* varied between 32cm to 45cm (Table 2). The average height of *P. caribaea* was 26.7m, while that of *N. diderrichii* was 28.2m. The average standing biomass of a stand of *P. caribaea* varied between 0.12 ton/tree to 0.20 ton/tree (Table 2), while the mean standing biomass of *N. diderrichii* varied between 0.19 tons to 0.34 ton/tree (Table 1). The mean sequestered carbon in a *P. caribaea* stand varied between 0.60 ton/tree and 0.1 ton/tree (Table 1), while that of *N. diderrichii* varied between 0.095 ton/tree and 0.17 ton/tree (Table 2). The regression equation obtained for *P. caribaea* was $Y = -0.056 + 0.004X$. The analysis of variance of the regression revealed high significance (Table 3) with a coefficient of determination (R^2) of 0.98. The regression scatter-diagram is shown in Figure 1. The regression equation obtained for *N. diderrichii* was $Y = -0.089 + 0.005X$, and the analysis of variance revealed high significance (Table 4). The R^2 was 0.996, and the regression scatter-diagram is shown in Figure 2.

Table 1: Mean diameter at breast height, standing biomass and sequestered carbon in planted forests of *Pinus caribaea* in Southeastern Nigeria

S/N	Dbh (cm)	Standing biomass (tons/tree)	Sequestered carbon (tons/tree)
1	27	0.13	0.065
2	26	0.13	0.065
3	25	0.12	0.06
4	26	0.13	0.065
5	30	0.16	0.08
6	32	0.18	0.09
7	33	0.20	0.1
8	34	0.20	0.1

Table 2: Mean diameter at breast height, standing biomass and sequestered carbon in planted forests of *Nauclea diderrichii* in Southeastern Nigeria

S/N	Dbh (cm)	Standing biomass (tons/tree)	Sequestered carbon (tons/tree)
1	38	0.26	0.13
2	36	0.23	0.115
3	32	0.19	0.095
4	35	0.22	0.11
5	42	0.30	0.15
6	40	0.28	0.14
7	45	0.34	0.17
8	43	0.31	0.155

Table 3: Analysis of variance for determining the significance of regression of dbh and sequestered carbon in above-ground biomass of *Pinus caribaea* stand in southeastern, Nigeria

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.001909	0.001909	300.4712*	2.36E-06
Residual	6	3.81E-05	6.35E-06		
Total	7	0.001947			

*Significant at 0.05 level of probability. $R^2 = 0.980$.

Table 4: Analysis of variance for determining the significance of regression of dbh and sequestered carbon in above-ground biomass of *Nauclaea diderrichii* stand in Southern Nigeria

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.004481	0.004481	1653.802*	1.48E-08
Residual	6	1.63E-05	2.71E-06		
Total	7	0.004497			

*Significant at 0.05 level of probability. $R^2 = 0.996$.

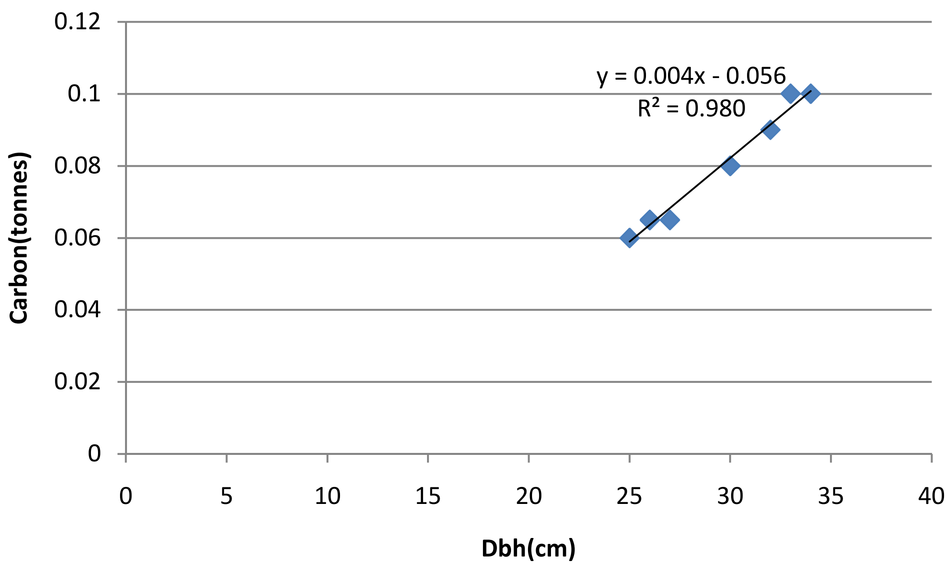

Figure 1: Relationship between dbh and sequestered carbon in *P. caribaea*

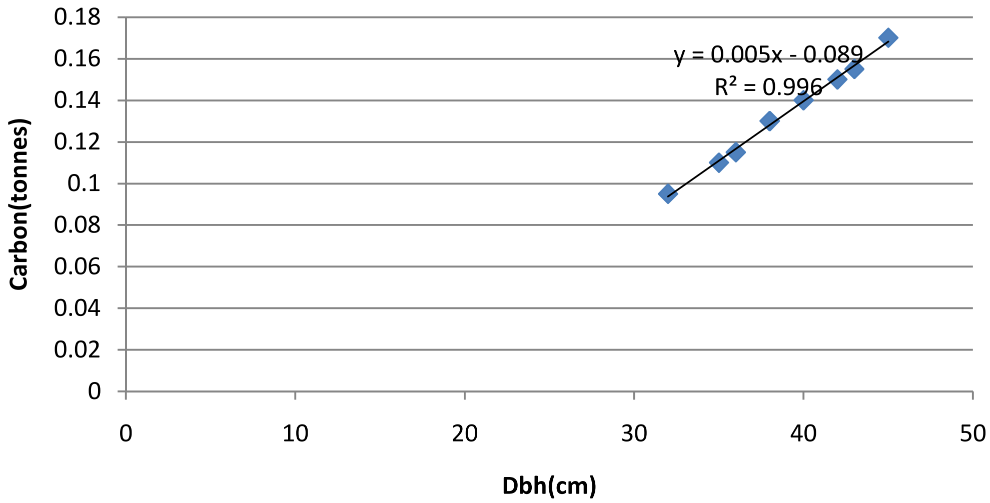

Figure 2: Relationship between dbh and sequestered carbon in *N. diderrichii*

Discussion

The rate of carbon sequesteration by a tree species is a function of its photosynthetic and growth rates. The rate of growth is dependent on genetics, climatic and edaphic factors. The climatic and edaphic (soil) factors of the area where these tree species are grown are generally favourable for tree growth. Fast-growing tree species have been observed to sequester high quantities of carbon within the few years of their establishment in plantations (Kilawe *et al.,* 2001). The higher mean diameter at breast height and higher mean height of the 18 years old stand of *N. diderrichii* compared to the mean diameter at breast height and mean height of the 22-year old stand of *P. caribaea* implies that *N. diderrichii* grows faster than *P. caribaea*. This accounts for the higher range of mean sequestered carbon in the standing biomass of *N. diderrichii* than *P. caribaea*. This is simply because the bulk of above-ground biomass of a tree is stored in the bole and the highest proportion of carbon stock in a tree is stored in the bole (Fuwape and Akindele, 1997 and Akindele, 2004). Olajide *et al.,* (2012) observed that Teak (*Tectona grandis*) had the highest dbh and height growth among other tree species in contiguous planted forests of the same age and also had the highest value of sequestered carbon in standing biomass. The regression equations indicated that the bigger the stem diameter of a tree the higher the amount of carbon sequestered in its above-ground biomass and vice versa. The high coefficients of determination of the regression equations imply that the equations are reliable for estimating the carbon sequestered in the standing individual of the tree species in the study area.

Conclusion

The rate of growth of a tree species would dictates the volumes of biomass accumulation and sequestered carbon as revealed by this study. *Nauclea diderrichii* possesses higher potential for carbon sequestration because of its faster growth while compared to *Pinus caribaea*, and should be preferred for the establishment of forest plantation to combat global warming nay climate change.

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