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Carbon Stock in Teak Stands of Selected Forest Reserves in Southwestern Nigeria

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Abstract

The ability to accurately and precisely measure the carbon stored and sequestered in forests is increasingly gaining global attention in recognition of the role forests have in the global carbon cycle, particularly with respect to mitigating carbondioxide emissions. Carbon stock was therefore estimated in Gambari, Osho and Shasha forest reserves in Southwestern Nigeria using forest inventory-based approach. Five 20 x 20 m sample plots each were laid in the *Tectona grandis* stands in the study locations making a total of fifteen plots. All the trees within a plot were measured for diameter at breast height (dbh), total height and merchantable height. The tree that had its dbh closest to the mean dbh was selected for destructive sampling to estimate its biomass. Four regression equations were developed out of which the one that had the best technical performance was selected to estimate biomass for all the trees measured. The mean plot biomass in each location was calculated and used to obtain biomass per hectare. Half of this value gave carbon per hectare value for each location. Carbon stocks per hectare were 14.84t, 29.36 t and 24.36 t in Gambari, Osho and Shasha respectively. Assuming the total areas of the reserves were covered by trees, it would mean large amount of Carbon would be stored and this would have great implications on carbon that would be sequestered from the environment. This would in turn mitigate the effect of CO_2 being released from other sources especially expansion of agricultural lands and fossil fuel burning.

Keywords: carbon estimation, forest inventory, regression equations, *Tectona grandis*

1. Introduction

The multiple functions and values of forests are seldom realized by an individual or a single community (Bennett, 2008). Nonetheless, the people who value forest for its services such as carbon reservoirs, modifiers of climate and weather patterns, sources of plants with potential pharmaceutical use are different from those who want to exploit it basically in meeting their daily needs such as fuelwood, fibre, food and other biological products. Therefore as a result of these conflicting demands, human activities heighten pressures on forest ecosystems. Anthropogenic activities have been attributed to causing great increases in CO_2 in the atmosphere (Turner, Moss, & Skole, 1993; Ojima, Galvin, & Turner II, 1994; Dale, 1997; American Petroleum Institute, 1999; Food and Agriculture Organization of the United Nations [FAO], 2001). These anthropogenic activities release carbon into the atmosphere mainly through fossil fuel burning and deforestation as a result of advancement in technology coupled with growing human population. The main source of CO_2 emissions in developed/industrialized countries is through fossil fuel burning while deforestation is the main source in developing countries. Worldwide, the most significant anthropogenic activity that affects forest carbon sequestration is deforestation particularly that of the tropical forests. Moreover, the highest rate of forest loss is said to be occurring in Africa (Barnsley, 2009) whereas the capacity of forests to serve as a practical means of removing excess carbon from the atmosphere is still relevant today as forests safeguard more carbon in biomass and soils than the entire earth's atmosphere (FAO, 2007). Nevertheless, the amount of carbon being sequestered annually is uncertain in part because of an absence of data (International Tropical Timber Organization [ITTO], 2002) and because of difficulties in measuring sequestration especially in developing countries yet forest ecosystem plays very important role in the global carbon cycle. Forests are multifaceted ecosystems with numerous interrelated components each of which stores carbon. These components include: trees (living trees, dead trees, roots, stems, branches and foliage), understorey vegetation (shrubs and herbs), forest floor (fine woody debris, tree litter and humus) and soil. Forest stores about 80% of all above-ground and 40% of all below-ground terrestrial organic carbon (Intergovernmental Panel on Climate Change [IPCC], 2001). The role of forests in carbon sequestration is no more obscure; however, disturbances in the forest due to natural and human influences lead to increasing release of carbon into the atmosphere than the amount being used by vegetation during photosynthesis.

Different methods have been proposed and used since the 1970s for estimating biomass in forests. Some methods were based on the total biomass whereby both above- and below-ground biomass were estimated whereas some other methods focused only on the above-ground biomass. Above-ground biomass estimation may be sufficient for tropical forests especially with regards to carbon estimation because according to Brown (1989), tropical forests tend to carry relatively more of their biomass in the standing crop than do temperate forests particularly when not limited by water. Brown (2002) also opined that the biomass of understorey and fine litter are a small fraction of the total carbon in most forests with the exception of open woodlands and young successional forests. From the foregoing, aboveground biomass is sufficient for estimating carbon in tropical forests. An understanding of standing carbon stock in forest trees is an important knowledge base for forest management aimed at mitigating climate change, biodiversity loss as well as resolving conflicts on different land-uses.

The pressures brought by climate change have intensified interest in biomass assessment which is instrumental to measuring biomass change that is, forest removal and forest accumulation at a specified period. This information is a necessity in any forest ecosystem in order to clear doubts as to whether changes are really occurring or not and in fact, biomass assessment needs to be carried out periodically for any ecosystem. The use of biomass information as summarized by Kueh and Lim (1999) are to quantitatively describe ecosystems and indicate the biomass resources available; quantify amount of nutrients in the ecosystem and hence elucidate nutrient cycling; determine energy fixation in forest ecosystems; provide estimates of the carbon content in forest; quantify increment in forest yield, growth or productivity and assess changes in forest structure. Carbon is approximately half of biomass therefore; carbon and biomass are used interchangeably in this study. Also, inventory data have been said to be the most practical means for estimating aboveground biomass as the data are generally collected at the required scales and from the population of interest in a statistically well-designed manner. This study therefore estimated carbon stock of Teak stands in three selected forest reserves in Southwestern Nigeria using inventory data.

2. Materials and Method

2.1 Study Areas and Stand Description

Three Forest Reserves (FR) in Southwestern Nigeria were used for this study thus: Gambari Forest Reserve (Latitudes 7°05' and 7°14'N, Longitudes 3°42' and 3°54'E) which is in the dry high forest zone and with a land area of 11,618ha; Osho Forest Reserve (Latitudes 7°00' and 7°45'N, Longitudes 3°25' and 5°00'E) which is a derived savanna and has a land area of 3,500ha; and Shasha Forest Reserve (Latitudes 7° and 7°30'N, Longitudes 4°20' and 4°50'E) which is in the moist high forest zone and with a land area of 30,834ha. Figure 1 shows the study areas.

Tectona grandis commonly known as Teak is an exotic tree species in Nigeria but it has been used extensively in regeneration programmes and its stands are found in the three study areas. Teak stands in Gambari and Shasha FRs are secondary regrowths. Teak trees in Gambari FR had been felled at least twice (the management could not state specifically the number of times felling had occurred) while those of Shasha had been felled at least once. However, teak trees in Osho FR had never been felled except in areas where illegal felling took place. Nevertheless, the three study locations usually undergo similar conditions such as annual fires during the dry season and at the onset of the rainy season in search of bush meat, slash and burn agriculture from taungya farmers and occasional grazing by animals especially during the dry season. A study of soils under the teak stands in the three locations did not show significant difference for soil chemical properties except for Calcium and Base Saturation (Faboye, 2012).

2.2 Method

Forest inventory-based approach was adopted to estimate biomass in the study areas. Five 20 x 20m sample plots were randomly laid in *Tectona grandis* stands making a total of fifteen plots for the study locations. The trees within a sample plot were measured for diameter at breast height (dbh), total height and merchantable height. The mean dbh for all the trees within a plot was calculated and the tree that had its dbh closest to the mean dbh was selected for destructive sampling in order to estimate its biomass.

The felled tree was partitioned into three components being the bole, branches and leaves. Five points along the tree bole at 0.1, 0.3, 0.5, 0.7 and 0.9 of the total height of the tree were marked. A wood disc of about 3cm thickness per each marked point was obtained. The tree bole was sawn into billets to facilitate easy weighing on the field in order to determine its fresh weight. The fresh weights of the branches were likewise determined. Also, the fresh weights of the leaves were determined.

Sample wood discs were then taken to the laboratory and air-dried for four weeks. Fresh branch of 1kg was also taken to the laboratory and air-dried for four weeks. Also, 1kg of fresh leaves were obtained from the field and taken to the laboratory and air-dried for four weeks. The weights of the various samples were taken at the end of the four weeks to obtain air-dried weight of samples. Likewise, wood discs were converted into 20 x 20 x 20mm cubes. Ten cubes were randomly selected representing both the heartwood and sapwood regions. Furthermore, samples of branches were sawn into smaller circular discs and ten of these were selected per branch. Initial weights of the cubes were determined on a sensitive weighing balance and the cubes were then oven-dried at 105^{o}C to a constant weight. The oven-dry weight was used to estimate the air-dry weight of discs and later used to estimate for the fresh weight of discs.

Similar procedure was followed to estimate the oven-dry weight of the branches and that of that of the leaves although leaves were oven-dried at 80^{o}C. The addition of the dry weight of bole, branches and leaves gave the biomass in “Kg” of the felled tree which was the mean tree. These procedures were followed for all the felled trees. The biomass of all the mean trees for all locations were then pooled together and used to develop regression equations.

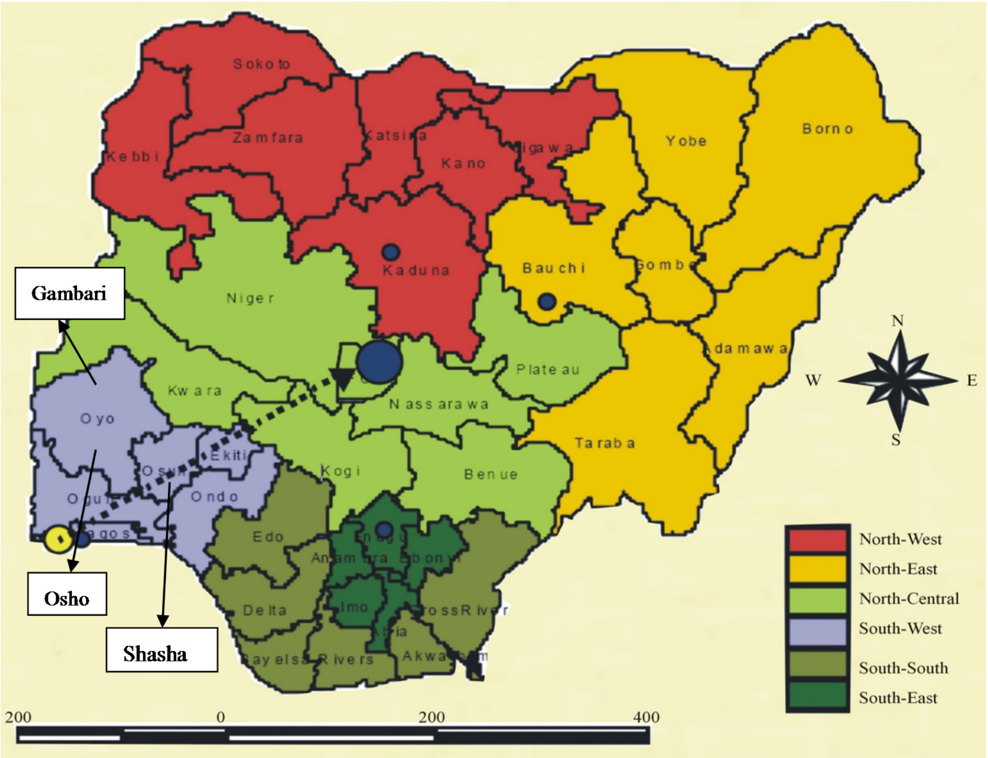

Figure 1. Map of Nigeria showing the study areas

Source: mstbstoiclr.890.com.

3. Results and Discussion

3.1 Cumulative Frequency Distribution of Teak in the Study Locations

Cumulative frequency distribution for *Tectona grandis* trees in the three study locations are shown in Table 1. Also, data of mean trees across the study locations are shown in Table 2 while Table 3 shows the results of mean diameter of tree for each sampled plot in the study locations as well as basal area per hectare and number of trees per hectare.

Table 1. Cumulative frequency distribution table for *Tectona grandis* trees in the study locations

Diameter Class	Study Locations		
	Gambari	**Osho**	**Shasha**
10-20	0	0	0
20-30	45	5	25
30-40	160	65	135
40-50	335	250	300
50-60	415	435	415
60-70	440	605	465
70-80	440	740	500
80-90	440	845	515
90-100	440	945	520

Table 2. Inventory data of mean trees across the study locations

Location	DBH	BA	Biomass	ln_Biomass
Gambari	44.4	0.15	70.61	4.26。
Gambari	42.8	0.14	59.59	4.09
Gambari	39.0	0.12	36.28	3.59
Gambari	41.8	0.14	55.41	4.01
Gambari	45.0	0.16	82.51	4.26
Osho	63.8	0.32	136.98	4.92
Osho	57.3	0.26	153.52	5.03
Osho	50.4	0.20	105.62	4.66
Osho	56.4	0.25	158.56	5.07
Osho	55.6	0.24	123.60	4.82
Shasha	46.0	0.17	69.92	4.25
Shasha	44.6	0.16	27.03	3.30
Shasha	53.9	0.23	44.56	3.80
Shasha	51.8	0.21	107.91	4.68
Shasha	39.7	0.12	19.41	2.97

Where DBH = diameter at breast height, BA = basal area, ln_Biomass = natural logarithm of biomass

Table 3. Mean diameter at breast height for sampled plots, basal area per hectare and number of trees per hectare

Location	AV_DBH	BA_HA	N_HA
Gambari	44.3	82.40	525
Gambari	42.9	92.95	625
Gambari	39.0	45.81	350
Gambari	43.3	52.04	325
Gambari	45.6	63.15	375
Osho	66.5	125.60	350
Osho	47.5	69.05	375
Osho	50.0	175.85	875
Osho	56.2	161.73	625
Osho	56.1	131.93	500
Shasha	52.1	133.18	600
Shasha	46.7	96.73	525
Shasha	54.4	110.40	450
Shasha	53.2	139.90	575
Shasha	40.1	61.80	450

The following regression equations were developed with the data obtained from mean trees:

$$\ln B = 2.56 + 0.04Dbh \quad (1)$$

$$R^2 = 0.87 \text{ and } SE = 0.40$$

$$\ln B = 9.68 + 0.01BA \quad (2)$$

$$R^2 = 0.88 \text{ and } SE = 0.53$$

$$\ln B = 8.29 + 0.05AVDbh \quad (3)$$

$$R^2 = 0.83 \text{ and } SE = 0.62$$

$$\ln B = 10.52 + 0.01BA - 0.0018N \quad (4)$$

where lnB = natural logarithm of Biomass, Dbh = diameter at breast height, BA = Basal area, AVDbh = Mean Dbh, N = number of trees per hectare, R^2 = Coefficient of determination and SE = Standard Error.

All the equations developed have high R^2 values with relatively low SE, but Equation 1 was preferred because dbh is an easily measurable parameter and where proper rules are followed, the same value could be obtained by different individuals irrespective of the number of times this is repeated coupled with the fact that it has the least SE. Equation 1 was used to generate natural logarithm of biomass for each dbh and this was used to compute biomass for each tree. As earlier stated, the dbh of every tree within each sample plot was measured and this was substituted in equation 1 to estimate biomass for each tree. This was done for all the sample plots. The mean plot biomass for *T. grandis* in each location was then calculated and this was multiplied by 25 (the number of 20 x 20 m plots in a hectare) to obtain the biomass per hectare. Half of this value gave carbon per hectare value for each location.

3.2 Carbon Stock Estimation in the Study Locations

The highest value of 29.36t was obtained in Osho Forest Reserve followed by that of Shasha Forest Reserve with a value of 24.36t and the least value of 14.84 t was obtained in Gambari Forest Reserve (Table 4).

Table 4. Carbon per hectare values in *Tectona grandis* stands of the study locations

	Study Locations		
	Gambari	**Osho**	**Shasha**
Mean Plot Biomass (t)	1.19	2.35	1.95
Biomass per ha (t)	29.69	58.72	48.72
Carbon per ha (t)	14.84	29.36	24.36

Osho Forest Reserve had the highest value because the plantations had not been exploited whereas for the other two reserves, only coppices of minimum of second or even third rotation were left as gathered from the management of the reserves. Assuming the total areas of the three reserves were covered by trees, it would mean large amount of Carbon would be stored and this would have great implication on carbon that would be sequestered from the environment. This would in turn mitigate the effect of CO_2 being released from other sources especially fossil fuel burning and farming. Also, indiscriminate loss of biodiversity along with loss of forest services such as windbreak, erosion control and watershed protection can be forestalled through reforestation and afforestation in any area. Properly sited and well-managed plantations can produce and help to restore soil fertility, improve microclimates, protect land and water systems as well as supply a constant, cheap and uniform source of biological products (Bennet, 2008). FAO (2006) said that global carbon retention resulting from reduced deforestation, increased forest regrowth and more agroforestry could make up for about 15% of carbon emissions from fossil fuels over the next 50 years.

This study is in agreement with Chave et al. (2005) who opined that regression models are used to convert inventory data into an estimate of aboveground biomass. With the use of destructive sampling method in this study, the reuslt also aligns with the earlier report of Brown, Gillespie and Lugo (1989) who said that the predictive power of models depend on how well they are validated using tree biomass data obtained directly from destructive harvest experiments. Furthermore, the adoption of the regression equation that has diameter at breast height as the prediction variable for above-ground biomass and subsequently carbon is similar to that of Ilyas (2013). Ilyas (2013) reported that the best allometric equation for above-ground biomass and carbon stock of planted *Acacia mangium* was the one that related diameter at breast height with tree biomass. Likewise, Losi, Siccama, Condit and Morales (2003) stated that estimates of carbon stock in forest plantations are generally based on allometric equations relating either carbon or biomass to diameter at breast height (DBH). Therefore, the adoption of the equation that made use of diameter at breast height to generate biomass and subsequently carbon in this study is very valid.

4. Conclusion

The actual contribution of Forestry in Nigeria to global climate change may not be very obvious due to dearth of data for most of her forests especially Forest reserves in various states of the Federation. These Forest Reserves are supposed to be under strict monitoring but it is a known fact that the situation is very far from the ideal. This study has filled this gap to some extent by providing baseline data of Carbon stock for Teak stands of three Forest Reserves in southwestern Nigeria. Further studies of this type in the study locations can then measure changes in the carbon stock for the study locations. Forests still offer the only practicable means of removing some excess carbon from the atmosphere therefore the restoration of forests must be integrated with national development strategies.

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