Inventory-based estimates of Above-Ground Tree Biomass Models for *tectona grandis* Linn. Plantation in Federal College of Forestry, Ibadan, Nigeria

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Abstract

Forest plays an important role in the global carbon cycle as carbon sinks of the terrestrial ecosystem. Accurate information on forest biomass is generally lacking and the use of harvest method to estimate biomass is expensive and laborious. This study is aimed at estimating above-ground tree biomass using allometric equations and standard method. Forest inventory based approach was adopted to estimate biomass and carbon stock of Tectona grandis in the study area. Five sample plots of 20mx20m were randomly laid in the plantation. Inventory data was collected for 103 trees and the parameters measured were height and diameter at middle. Allometric equations were developed at plot and pooled levels. The standard method gave a pooled biomass value of 105418.15kg/ha and carbon content of 52709.06kg/ha. Equation four (4) proves to be the most appropriate model with an R^2 *value of 0.998, which is recommended to predict the carbon sinks in the study location. This means that there were strong relationships among the growth parameters. Equation three (3) had the lowest* R^2 *value of 0.973, which means that the parameters manipulations are not good predictors of biomass considering all indicators. Conclusively, maintenance of the plantation, planting of more trees, and adequate silvicultural practices will have a positive impact on the biomass.*

Keywords: Carbon, Allometric Equations, *Tectona grandis*, Above-ground Tree Biomass

INTRODUCTION

Forests play an important role in global carbon cycling, since they are large pools of carbon as well as potential carbon sinks and sources to the atmosphere. Therefore, accurate estimation of forest biomass is required for greenhouse gas inventories and terrestrial carbon accounting (IPPC, 2003; Krankina *et al.*, 2004).Forests play a major role in the global carbon budget because they dominate the dynamics of the terrestrial carbon cycle. Studies are currently afoot for assessing the use of forest biomass sinks to sequester carbon as part of a global mitigation effort (Sedjo and Toman, 2001).

Globally, *Tectona grandis* ranks third among the tropical hardwood species in plantation areas and constitutes about 8 per cent of the plantations (Pandey and Brown, 2000). *Tectona grandis* is also suitable for multiple end uses, including construction, furniture and cabinets, railway sleepers, decorative veneer, joinery, ship and vehicle body building, mining, reconstituted timber, etc. (Bhat, 2000).

The carbon (C) sequestration potential of a forest ecosystem depends on initial soil organic carbon (SOC) content, stand growth rates, biological carrying capacity of the stand, stand age, and product utilization. In particular, Carbon sequestration and storage may be increased significantly, if forests are harvested and trees are converted into wood products. Making an effort to maximize the productivity of the restored forest is also worthwhile because forest Carbon pools can vary five-fold within a local edaphic gradient as a function of site quality (Burger and Zipper, 2002).

Carbon stock is typically derived from above-ground biomass by assuming that 50% of the biomass is made up by carbon and the most accurate method for the estimation of biomass is through cutting of trees and weighing of their parts. This destructive method is often used to validate others, less invasive and costly methods, such as the estimation of carbon stock using non-destructive in situ measurements and remote sensing (Clark *et al.,* 2001; Wang *et al.,* 2003).

An accurate estimation of forest biomass density is a prerequisite to resolving a long-standing controversy about the role of forest vegetation in the carbon cycle (Sedjo 1992; Brown *et al.,* 1999). However, accurate information on forest biomass and distribution are generally lacking (Schroeder *et al.,* 1997). In general, using harvest method in high biomass density areas is not practical and repeating these measurements is not feasible (Houghton *et al.,* 2009). However, the choice of area to be cut down and weighed is, in many instances, biased and simple extrapolation leads to inaccurate results (Higuchi and Carlvaho, 1994). To eliminate these problems, researchers have developed indirect methods to estimate the above-ground biomass. The study is aimed at estimating above-ground tree biomass using allometric equations and standard method for the *Tectona grandis* plantation in Federal College of Forestry, Ibadan, Nigeria.

METHODOLOGY

Study area

Federal College of Forestry is located at Ibadan Northwest Local Government Area of Oyo State. It lies between Latitude 7^{o}23.694`N and Longitude 3$^{o}$51.471`E. It has an annual rainfall of about 1400mm – 1500mm and average relative humidity of about 65%. The average temperature is 32˚C with two distinct seasons, which are dry, usually commences from November to March and rainy season (FRIN, Meteorological Report, 2014).

Reconnaissance survey was undertaken in the study location to obtain preliminary first-hand information of the situation in the plantation. The trees in each sample plot were marked in order to avoid leaving out any tree and also for easy identification. Forest inventory-based approach was adopted to estimate biomass and carbon stocks in the area. Five (5) sample plots of 20m×20m were randomly laid in the plantation (Aghimien *et al.*, 2015).

Measurement of Tree Parameters

This is the vertical distance between the ground level and the tip of a tree. It can be obtained by taking the reading at the top (RT) and reading at the base (RB). The height was measured using Spiegel relascope (Aghimien *et al.*, 2015). The formula for obtaining the total height (TH) using the metric scale is:

$$H = RT - RB \qquad \text{(i)}$$

Where; H = Height

RT = Reading at the top

RB = Reading at the base.

Diameter at Middle

This is the diameter measurement taking for a standing tree at height 1.3m above the ground level. Measuring the (DBH) with the use of the Diameter tape will give true value of the diameter (Aghimien *et al.*, 2015).

Computation of Volume

The volume of the trees was computed using;

$$V = SHF \qquad \text{(ii)}$$

Where;

S = cross sectional area at the base ($\pi d^2/4$)

H = tree height

F = form factor (0.5)

Estimation of Biomass

Total above Ground Biomass (TAGB) was calculated using direct method with the formula below;

Above Ground Biomass = Volume × Wood density

The density value of teak was obtained from the secondary database at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Determination of Carbon Content

The mean plot biomass for this specie in the study area was calculated and this was multiplied by 0.04 (20m x 20m / 10000) to obtain the biomass per hectare. Half of the value gave carbon value per hectare for the location (Aghimien *et al.*, 2015).

Allometric Equations Development

The following allometric equations were used in estimating the Total Above-Ground Biomass (TAGB) for teak plantation is listed below (Aghimien *et al.*, 2015);

(i) AGTB $= a + bD^2H$ (iii)
(ii) AGTB $= a + bDD^2H$ (iv)
(iii) AGTB $= a + b(D^2H)^2 D^2$ (v)
(iv) AGTB $= a + b DH + (D^2H)^2D^2$ (vi)
(v) AGTB $= a + b D^2H + (C/D^2)$ (vii)

Where,

AGTB = Above-ground Tree Biomass
D = Diameter at breast height (1.3m) outside bark (cm)
H = Height of tree (m)
a, b = Coefficients

RESULTS AND DISCUSSION

Table1 shows the trend in biomass value, carbon value, basal area and volume in plots 1-5. The minimum and maximum biomass in the plots value was found to be 76789.75kg/hectare and 140759.00kg/hectare respectively, the minimum and maximum carbon value was found to be 38394.88kg/hectare and 70379.50 kg/hectare respectively, the minimum and maximum basal area was found to be $0.62m^2$ and $1.16m^2$, respectively and the minimum and maximum volume was found to be $4.81cm^3$ and $8.79cm^3$ respectively. The general value for the biomass value, carbon value, basal area and volume are; 105418.15kg/hectare, 52709.06kg/hectare, 0.81 and 6.58, respectively. It also shows that plot 1 had the highest value in all the three parameters while plot 3 had the lowest values in all the parameters.

Table 1: Biomass/Carbon stock estimation using standard method

Plots	Basal Area (m^2)	Volume (m^3)	Biomass value (kg/hectare)	Carbon (C) Value (kg/hectare)
1	1.16	8.79	140759.00	70379.50
2	0.71	5.72	91584.75	45792.28
3	0.62	4.81	76789.75	38394.88
4	0.75	6.02	96681.75	48340.88
5	0.79	7.57	121275.50	60637.75
Total	0.81	6.58	105418.15	52709.06

The difference of biomass amount in every plot is caused by the number of trees and diameter in every age class. Despite having the same age class, it has different content of biomass and carbon due to variation in soil and environmental factors (Aghimien *et al.*, 2015).

Preparation of allometric equation table

On the basis of coefficient of determination (R^2), the best fit model was computed. Multiple regressions were used to work out the relationship between AGTB, DBH and height. The best fit equation was determined using SAS software.

Table 2: Pooled allometric equations

Allometric equation	Coefficient	R^2	Standard error of estimate	Significant Value
AGTB = a + b D^2H	a 0.41	0.98	0.00	0.00
	b 15.54		0.69	
AGTB = a+ bDD^2H	a 0.44	0.98	0.04	0.00
	b 15.54		0.70	
	c -1.12		1.74	
AGTB = a + b $(D^2H)^2D^2$	a 0.20	0.97	0.02	0.00
	b 6.02		0.00	
AGTB=a+bDH+C$(D^2H)^2$ D^2	a 4.55	0.99	0.00	0.00
	b 0.02		0.02	
	c 7.92		0.35	
	d 10.77		0.71	
AGTB = a+bD^2 H + (C/D^2)	a 0.42	0.98	0.01	0.00
	b 15.54		0.70	
	c 29.54		60.40	

The linear relationship between DBH and height among the trees (using general information value) taken for actual measurement was found to be significant with the values of R^2 being; 0.98, 0.98, 0.973, 0.99, and 0.98, respectively. The values of R^2 are closer to 1, which indicates that the more the values of R^2, the better the equation fit the data. With the 4^{th}allometric equation, single independent variable reduces the sum-of-squares variation of AGTB by 99.8%. Since R^2 was already high for the variable model, standard error between observed and expected value of DBH and height provides a more useful indicator of improvement. The t-value for the coefficient of DBH and height was significant at the 0.00 levels.

Table 3 shows that the correlations among the variables were high and low with positive and negative values. A high correlation exists between DBH and BA with a positive correlation value of 0.99. This means that as the value of DBH increases, that of BA also increases, which indicates that there is a strong relationship between DBH and BA. A low correlation exists between C.DBH and HT with negative correlation value of -0.11. This means that as the value of HT increases, that of C.DBH decreases, which indicates that there is a weak relationship between HT and C.DBH. A high correlation exists between DBH.HT and VOL with a positive correlation value of 0.96. This means that as the value of DBH.HT increases, that of VOL. also increases, which indicates that there is a very strong relationship between DBH.HT and VOL. A low correlation exists between C.DBH and DBH.HT with negative correlation value of -0.62. This means that as the value of C.DBH increases, that of DBH.HT decreases, which indicates that there is a weak relationship between C.DBH and DBH.HT. Also, high correlation exists between BA and DBH^2 with a positive correlation value of 1. This means that as the value of BA increases, that of DBH^2 also increases, which indicates that there is a perfect relationship between BA and DBH^2.

TABLE 3: Pearson correlation matrix

	DBH	HT	BA	VOL.	BIOMASS	DBH^2	C.DBH	DBH.HT
DBH	1							
HT	0.14	1						
BA	0.99*	0.14	1					
VOL	0.93*	0.43	0.95*	1				
BIOMASS	0.93*	0.43	0.95*	1	1			
DBH^2	0.99*	0.14	1	0.95*	0.95*	1		
C.DBH	-0.89*	-0.11	-0.82*	-0.77*	-0.77*	-0.82*	1	
DBH.HT	0.83*	0.45	0.87*	0.96	0.96*	0.87*	-0.62*	1

Where;
DBH = Diameter at breast height
HT = Total height
BA = Basal area
VOL. = Volume
C = Carbon

A low correlation exists between VOL. and C.DBH with a negative correlation value of -0.77. This means that as the value of VOL. increases, that of C.DBH decreases, which indicates that there is a weak relationship between VOL. and C.DBH. Consequently, a low correlation exists between DBH and HT with a positive correlation value of 0.14. This means that as the value of DBH decreases, that of HT also decreases, which indicates that there is a low relationship between DBH and HT.

A low correlation exists between DBH and C.DBH with a negative correlation value of -0.90. This means that as the value of DBH increases, that of C.DBH decreases, which indicates that there is a weak relationship between DBH and C.DBH. The sample size of trees selected for AGTB sampling is dependent on the variability of the resource and higher accuracies associated with higher costs (Kunneke *et al.,* 2014). Fewer sampled trees are necessary for species-specific models than for generic multi-species models (Picard *et al.* 2012).

Considering the findings above, the sample size used in this study to develop site and species-specific allometric models are sufficient to estimate the biomass of the selected species with reasonable accuracy. Yavasli (2013) and Samalca (2007) recommended that trees sampled for AGTB should follow an even distribution of size classes covering all size classes measured during the plot sampling and that allometric equations should not be applied beyond the valid regression range from which it was developed (Chave *et al.* 2005).

CONCLUSION

Among the multiple methods for estimating above-ground tree biomass models, the sample plots method is covered in detail because it is simple, reliable, widely applicable and cost-effective. The critical components of the procedure are sampling and field measurement. The data gathered enabled estimation of above-ground tree biomass stock, growth rate and stock changes. Adoption of plot methods enabled long-term and period measurement and estimation of carbon stocks over any selected period. Allometric equations at pooled level provided good estimates of above-ground tree biomass. Hence, maintenance of the plantation, planting of more trees, and adequate silvicultural practices will have a positive impact on the biomass.

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