Forests and Forest Products Journal 18:1-4

Crown and Stem Diameter Growth Models for *Tectona Grandis* Stands in Ogwashi-Uku Forest Reserve, Delta State

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Abstract

Decision processes in forest management depend on reliable estimates of stand growth and yield models. Growth models of *Tectona grandis* at Ogwashi-Uku forest reserve of Delta State were applied to *T. grandis* stands. Growth data collected include height, diameter at breast height, crown depth and crown width. Five crown width models, two crown depth models and five stem diameter models were fitted into the growth data collected. The data collected were divided into two sets in ratio 9:1. The majority of the data (90%) were used for model development and the remaining data (10%) were used for model validation. Best models were selected based on the highest R^2 (coefficient of determination) and MSE (Mean Square Error) value. The best models for diameter at breast height, crown width and crown depth have R^2 and MSE values of 0.811 and 0.2618, 0.863 and 0.0223 and 0.950 and 0.0224 respectively. The model selected has been found suitable for fine-graining of coarse-grained habitat fragments, predicting greenbelts against soil percolation growth estimation as well as to enhance the sustainable management of *T. grandis* in Ogwashi-Uku forest reserve.

Keywords: Diameter at breast height, crown depth, crown width, model, sustainability.

Introduction: Forest and forest products will continue to contribute tremendously towards economic development of Nigeria (Akande *et al*., 1998). Throughout the tropics, people have depended on these products for food security and host of daily needs from medicinal to fibre (Etukodo, 2000). Growth refers to increase in dimensions of one or more individuals in a forest stand over a given period of time. A model is an abstract or a simplified representation of some aspect of reality (Vanclay, 1994). Ureigho (2013) stated that forest growth models are very useful tools in forestry for both management and decision making.

Diameter distribution is an effective method for describing stand properties because important variables such as volume, quality, product specifications are dependent on tree diameter. Ige *et al*.,(2014) noted that diameter at breast heights has a strong ability in predicting height. The size of a tree crown is strongly correlated with the growth of the tree. The crown displays the leaves to allow the capture of radiant energy for photosynthesis, thus measurement of the tree crown is often made to assist in quantification and understanding of the tree growth. The crown also has great visual impact in landscaping and beautification in urban forestry because it affects the perceived aesthetic value of a tree. Significantly, crown covers play key role in reducing soil percolation, problems that usually lead to gulley erosions by acting as speed breaks during rainfalls. It is also effective in forest-soil multifunctional regime of enhancing root pressure by evapo-transpiration that is crucial in the sustainable management of groundwater against degradation. The various crown dimensions include crown width, crown depth, and crown volume. Crown size has received increasing attention as a means of tree growth estimation (Bragg, 2001).

Measurement of tree crown width is more difficult and more time consuming than that of diameter at breast height (Arsar, 2004). The choice of *Tectona grandis* for this study is justified by its unique importance because of its utilitarian value as the preferred wood for electric pole, timber, naval construction, boat and bridges constructions as well as its ecological importance in the conservation of forest soil moisture regime. Keay (1989) described teak as large deciduous tree with a height of 30m and a girth of 3m. The leaves are 25-60cm long by 22-32cm broad. It is ovate to broadly elliptic, blunt or shortly acuminate at the apex. Philips (1995) described teaks as one of the world's most valuable timber and high interest is placed on the growth of this species. Therefore, the objective of the study is to develop and validate selected crown and stem diameter models fitted for *Tectona grandis* in the study area for optimum management.

Materials and Methods

The research was carried out in Ogwashi-Uku forest reserve, Ogwashi-Uku, Delta State, Nigeria. It has a total area of 258ha, with less than 10% occupied by natural forest, and *Tectona grandis* plantation of years 2001, 2003 and 2006 for watershed protection, erosion control and timber production. It is located in the Lowland rainforest ecological zone of the State (FORMECU, 1999) that is currently under intense degradation due to urbanization and agricultural expansions. It is bounded in the North East by Oshimili North Local Government Area, South East by Oshimili South Local Government Area and in the North by Aniocha North Local Government Area in the West by Ika North East and South Local Government Area. It is located on 6º00´ and 6º 25´N and 6º 15´ and 6º 25´E. In this study, stratified random sampling was used. Random selection of sample plots was done within each stand to ensure the validity of the usual test of significance of the final equation. It means in each stand; the number of plots was randomly selected. Sample plot size of 20 x 20m (0.04ha) was used. Diameter at breast height (cm) was measured at a standard position of 1.3m above ground level using diameter girth tape, the total height (m) was measured with the aid of a relaskop. Crown depth and width were also measured. The crown width was measured by projecting the edges of the crown to the ground and measuring the length along one axis from edge to edge the crown center and taking the average. While the crown depth is the length along the main axis from the tree tip to the base of the lowest branch that forms part of the canopy.

Models for crown width used in this study include:

$CW = b_o + b_1dbh$ equation (1)

$CW = b_o + b_2dbh + b_3$ equation (2)

$CW = b_o + b_2dbh + b_3dbh_3$ equation (3)

$CW = e^{(b_o + b_1 dbh)}$ equation (4)

$CW = b_o.e^{(b_1 .dbh)}$ equation (5)

Where CW = Crown width, b_o and b_1 are parameters to be estimated.

The Models for crown depth used in this study are:

$Cd = a + bdbh + cdbh^2$ equation (6)

$Cd = a + blogdbh + b/dbh$ equation (7)

Where:

Cd = Crown depth

dbh = diameter at breast height

a,b and c are parameters to be estimated in the equation

Models for diameter at breast height used in the study are:

$dbh = 1.3a\,(1-e^{bh})^c$ equation (8)

$dbh = 1.3a\,(1-e^{bdbh})^c$ equation (9)

$dbh = bi\,(1-e^{b2h})$ equation (10)

$In\ dbh = bo + b_1dbh + b_2dbh^2$ equation (11)

Where dbh is diameter at breast height

H = height

A,b,c are parameters to be estimated

Data Analysis

Data were analyzed using regression analysis. Best models were selected based on the highest R^2 value (Coefficient of determination) and lowest MSE (Mean Square Error). Models selected were validated as reported in Ureigho (2004) where 10% of the data were used for validation set while the rest of the data were used in calibrating the models.

Results

The following results were obtained from the regression analysis of crown and stem diameter models.

Table 1: Crown width models

Models	R^2	MSE	b_o	b_1	b_2	b_3
$CW = b_o + b_1dbh$	0.824	0.4092	6.4854	0.0336		
$CW = b_o + b_1dbh + b_2dbh + b_3$	0.843	0.3614	3.2427	0.0168	3.2427	
$CW = b_o + b_1dbh + b_2dbh + b_3dbh_3$	0.863	0.0223	7.3347	0.0067	0.0001	2.5707
$CW = e^{(b_o + b_1 dbh)}$	0.852	0.0226	1.9080	0.0037		
$CW = b_o.e^{(b_1 .dbh)}$	0.853	0.0225	6.7240	0.0037		

The quality of model was judged by the highest R^2 value and lowest mean square error. Based on this, the model with the highest R^2 value and lowest MSE was chosen. Five crown width equations were used to check for the model of best fit. The R^2 values ranged from 0.824 to 0.863 and MSE ranged from 0.0223 to 0.4092. Equation 3 $CW = b_o + b_1dbh + b_2dbh + b_3dbh_3$ had the highest R^2 value and lowest mean square error with values 0.863 and 0.0223 respectively gave the best fit. The results of crown depth models used based on their R^2 value and MSE are as follows:

Table 2: Crown Depth Models

Models	R^2	MSE	a	B	C
$Cd = a + bdbh + cdbh^2$	0.950	0.0224	7.3979	0.0029	0.0001
Cd = a + blogdbh + b/dbh	0.894	0.1346	3.0666	1.2495	0.3933

The R^2 value ranged from 0.950 and 0.894 and MSE, 0.1346 and 0.0224. Equation 6 $Cd = a + bdbh + cdbh^2$ which had the highest R^2 value and lowest MSE with values 0.950 and 0.0224 respectively gave the best fit.

Table 3: Stem Diameter Models

Models	R^2	MSE	A	bo	b_1	b_2	C
$dbh = 1.3a\ (1-e^{bh})^c$	0.750	0.3676	6.8383				4.7702
$dbh = 1.3a\ (1-e^{bdbh})^c$	0.749	1.5560	6.3287		1.8096	3.7271	2.4196
$dbh = bi\ (1-e^{b2h})$	0.811	0.2618		1.2287	5.5105	2.0713	
$In\ dbh = bo + b_1dbh+b_2dbh^2$	0.758	0.4912	2.3832	22.9923	-0.2116	0.0011	

The R^2 values ranged from 0.749 to 0.811 while the MSE ranged from 0.2618 to 1.5560. Equation 11 $In\ dbh = bo + b_1dbh+b_2dbh^2$ which had the highest R^2 values and lowest MSE of 0.811 and 0.2618 respectively gave the best fit.

Discussion

Crown width, depth and stem diameter models were fitted to data collected to select the best models. MSE and R^2 values were used as a measure of best fit. A lower MSE and highest R^2 value suggests a better fit. For the crown width model equation 3 was found suitable and could be used to predict crown width for management of teak. This finding agrees with (Bragg, 2001 and Bechtolf, 2003). Crown width is an essential determinant of the total canopy cover in the management of forest patchments and in the creation of corridors for the migration of biodiversity between patchments, especially in the management of fragmented habitats. This to a large extent assists in the fine-graining of coarse-grain habitats in fragments. Consequently, model (equation 3) is significant for the degraded study area of the Ogwashi-uku forest reserve as it could be apt in the prediction of linkages of forest patches from within towards the forest edges where patches of natural indigenous species occur.

Furthermore, this model (equation 3) could also be critical in predicting the possible tracts of greenbelts within fragmented patches for the management of perceived flash flood paths in control of gulley erosion in the degraded forest reserve. Such greenbelts could also find application in the provision of recreational opportunities and enhanced scenery and land values which are one of the proposals by the Delta State Government in the current study area of the Ogwashi uku forest reserve to erect a Tourism and Wildlife Park (Egwunatum *et al*, 2014).

For crown depth, model 6 gave the best fit. This is consistent with Schwinning and Weener (1998), Comes and Allen (2007) who made use of the model to predict the relationship between crown radius and crown depth of Douglas-Fir. This model (equation 6) could be quite significant for the prediction of the effect of soil percolation on the forest reserve as a result of the crown depth. Thus the crown depth, acting as multiple speed breaks at the different levels, moderates the rainfall speed that declines with increasing depth downward. This therefore provide edaphic shield that supports soil aggregate stability and preserve soil organic matter which is the principal binding agent.

For stem diameter models model 11 gave the best fit. The study reveals that models with more variables performed better in the stem diameter, crown depth and crown width. The study has identified the best stem diameter, crown depth and crown width. This can be applied in the plantation at Ogwashi-Uku forest reserve and has provided significant information on the growth of *Tectona grandis* in the study area. The validation results also showed that these models gave the best fit, hence could be used for growth predictions with confidence.

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