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Evaluation Of Some Coppiced Plantation Species In A Derived Savanna Zone, Nigeria

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ABSTRACT

Growth models of *Tectona grandis* and *Gmelina arborea* at Bende Local Government Area of Abia State were tried in the Teak and *Gmelina* stands. Individual growth data were collected from ten (10) sample plots (n=267) being the sum total of trees randomly selected from both Teak and *Gmelina* plantation. Variables of data measured include diameter at the base, height, diameter at the middle, diameter at breast, diameter at the top and merchantable height. Volume was computed from measured variables. Four height growth models and five volume yield models were inputted into the data obtained. The collected data were divided into two parts in ratio 9:1. Most of the data (90%) were utilized for model development while the remaining (10%) for validation. Model 3 (Ratkowsky equation) and model 8 (Newnham, equation) for both height and volume respectively on comparison with mean square error (MSE) and coefficient of determination (R^2) had the best fit The models selected were found satisfactory for the estimation of growth and yield as well as to enhance the suitable management of teak and *Gmelina* coppiced as well as meeting the demand of timber for the growing population in Bende Local Government Area of Abia State.

Keywords: Models, Yield tables, Volume, growth and Height

INTRODUCTION

Forestry and forest products have for a long time contributed tremendously towards the economic development of Nigeria (Akande *et al*, 1998). It was reported that throughout the tropics, people have relied on these products for food security and host of daily needs from medicinal to fibre and food security (Etukodu, 2000). In the tropical forest trees are the dominant component and they produce timber which is known as the major forest products (Akande *et al*, 1998).

It is worthy to note that one of the most crucial rationale for the establishment of forest plantation is as a result of steady rise in the consumption of industrial and cooking wood concurrently. Natural forest grows too slowly to meet bulk forest products demand (Marsch, 1962). For more than 10 years, the record of rise in population growth led many to take note of rising demand for forest-derived resources.

Leslie (1992), recommended that the population of the forest area would "have to be increased by 30 percent in the immediate future", so as to satisfy needs for plantation management (De Lungo *et al*., 2006). Economic process has always relied on wood, and exploitation of it, have shaped structures (Kangas *et al*, 2003).

Coppice could be defined as growth of small trees or a forest coming from shoots or suckers. Coppicing is a traditional method of woodland management which takes advantages of the fact that many trees make new growth from stump or root if cut down (Rackham, 1980). In a coppiced wood, young tree stems are repeatedly cut down to near ground level. In successive growth years, so many new shoots will appear, and after some number of years the coppiced tree is ready to be harvested, and the cycle begins again

(Hamilton, 2006).
There is a challenge whether it will be physically possible to meet demands placed on uneven aged forest. Therefore, plantation is clearly a part of the solution to this growing dilemma.
Vanclay (1994) define stand models as abstraction of forest stand to natural dynamics which may circumscribe other changes, mortality and growth in stand structure and composition Models of growth and yield , which depend on functions of data obtained from a sample of the population of interest are the tools that have been mostly utilized to make available decision support information necessary to provide basic operational needs for evaluating different scenarios of forest management (Mohren and Burkhart, 1994).With satisfactory inventory and other resource data, growth models provide a dependable way to scrutinize silvicultural, harvesting options and to examine the sustainable timber yield for different management strategies and areas (Vanclay, 1994).
Individual tree diameters and heights are vital measurement in the estimation timber site index, forest inventories, volume and other important variables related to the growth and yield of forest, carbon budget models and succession (Peng, 2001).
Yield prediction is an essential activity in the management of forest especially for the production of commercially important outputs such as fuel wood and sawn timber. Sometimes it is important to forecast the future growth and structure even before the establishment of plantation or at every early stage (Vanclay, 1994). Plantation forestry play a significant role for wood production hence the objection of the study was to evaluate the predictive ability of some models in meeting timber needs.

MATERIAL AND METHODS

Study Area

The study was carried out in the Eastern Research Station Umuahia, Abia State, Nigeria. Umuahia is located in the South eastern region of Nigeria. It lies within latitudes 5° 36’ 49’’N and longitude 7° 31’ 38’’ E.
The rainfall decreases from 2200mm in the South to 1900mm in the North. The relative humidity is usually high throughout the year, reaching a maximum during the rainy season when values above ninety percent are recorded (Kalu, 2001)
The sampling design adopted in the research was stratified random sampling and the different ages of trees constituted the strata, and sample plots which were randomly selected were allocated in each stratum. The representative plots were then randomly selected from the sampling units within each stratum. Coppiced was used, since trees have been felled, but they have regenerated. This has helped in knowing the rate at which the trees were regenerating and their ability to meet timber need within the couple of years.
The following tree parameters were measured:
DBH (cm) was measured at a standard position of 1.3m above the ground with the aid of Diameter Girth tape.
Total height (m) was measured using 50m distance tape and relaskop
Merchantable Height (m) was obtained with the aid of relaskop and 50m distance tape and
Diameters at the top, base, and middle were used for the computation of volume

Data Analysis

Data collected was analyzed using regression analysis and STATISTICA Package was used to achieve this to enable the selection of best models. The best models were selected based on the comparison of highest R^2 value (coefficient of determination) and the lowest MSE (mean square error) values. Newton’s formula was used for volume estimation as presented by Husch *et al.*, (1982). The stem volume for sample trees was computed as;
$V= h/_6 (Ab + 4Am + At)$
Where:
V= stem volume (m^3) h = merchantable height (m)
Ab = cross-sectional area of diameter at base (m)
Am = cross sectional area of diameter at the middle (m)

At= diameter at the top (m)
The formula below was used for basal area estimation

$$BA = \frac{\pi D^2}{4}$$

Where D = DBH
n = 3 .1429
The age and dimension of the plantation are presented in the table 1 below:

Table 1: Age and dimension of the plantation

Variables	**Stratum l(Teak)**	**Stratum 2** (Gmelina)
Age (years)	29	29
Area (hect)	5.32	5.32
Number of plots	5	5
Tree number	134	133
Location	Bende-Abia	Bende-Abia

Models applied in this study
The Height Growth Models that were examined in the course of the study

Table 2: Height Growth Models applied in the location

S/N	Models	Source	
1.	$H = 1.3 + e^{a+b/dbh+1}$	Wykoff *et al*, (1982).	Equation 1
2.	$H = 1.3 + a(1 - e^{adbh})$	Yang *et al*.,(1978)	Equation 2
3.	$H = 1.3 + e(^{a} + ^{b} / ^{dbh+c})$	Ratkowsky (1990)	Equation 3
4.	$H = 1.3 + a(1 - e^{bdbhc})$	Temesgen and Gadow (2004)	Equation 4

Where:
H = total tree height (m)
dbh = diameter outside bark at breast height (cm)
a, b, c, e, = Parameters estimated.

Volume yield models evaluated in the location

Table 3: The volume yield models evaluated

S/N	Models	
5.	$V = a+dbh^2h$	Equation 5
6.	$V =a + bdbh^2 + ch + dbh^2hd$	Equation 6
7.	$V = a+dbh^b +h^c$	Equation 7
8.	$V = a+ bdbh^{c+} h^d$	Equation 8
9.	$V = adbh +(b+ch^1)$	Equation 9

Where:
V = Volume (m^3)
dbh = diameter at breast (cm)
height h = total height (m)
a,b,c,d = Parameter to be estimated
The mean square error (MSE)
This measures the spread of data and therefore an indication of the precision of the predicted response. MSE is expressed as:

$$MSE = \frac{RSS}{n-p}$$

n = number of observation
p = number of parameter in the model (B_0)
RSS = Residual sum of square

Coefficient of determination (R^2)
This measures the proportion of variation in the dependent that has been accounted for by the relationship to the independent variables in each equation.
Suitable models are those with large values of R^2 with least value of MSE.
It is imperative to subject the models that were verified suitable in the proceeding section to a process of validation. This is necessary before output obtained from them can be utilized for decision making with confidence.
Models validation requires that some data are set aside or that new data are obtained for the test (Akindele, 1990). Ureigho, (2004) used 10% of her data for validation set, while the rest were used in calibrating the models. In this research, 10% of the data were employed for validation set, while the rest were used in calibrating the models.

RESULTS AND DISCUSSION

The results for the heights model used based on their proportion of variation accounted for R^2 value and mean square error (MSE) for test as follows.

Table 4: Results of height models for Teak plantation

Model Number	R^2	MSE	a	b	c
1	0.514687	0.645	-2.41	-175.87	
2	0.4028	0.0565	-0.289	0.604	
3	0.7267	0.0234	-1.931	16.436	-1.931
4	0.521	0.0453	5.41	6.6999	

The status of a model was determined by its highest R^2 value and lowest mean square error (MSE) and based on this fact, the model which had the highest R^2 value and lowest MSE was chosen. Four height models were used to evaluate model that gave best fit in the teak plantation. The values of R^2 were from 0.7267 to 0.4028 while MSE was from 0.0234 to 0.0645. Equation 3 (Ratkowsky equation) with 0.7267 and 0.0234 gave the highest R^2 and lowest MSE values respectively was considered to have the best fit.
Results for volume models evaluated on the basis of their proportion of variation accounted for value and mean square error (MSE) as presented below.

Table 4: Results of height models for Teak plantation

Model Number	R^2	MSE	a	b	c	d
5	0.9548	0.0156	0.3216			
6	0.96313	0.0045	147.246	1.084	27.087	0.330
7	0.93735	0.0536	1.5642	1.389	1.468	
8	0.9464	0.0734	-11.9019	3.029	3.580	1.016
9	0.93318	0.0835	-68.91	12.47		

On comparison with the proportion of variation accounted for R^2 and MSE, the model that satisfy the above criteria of highest and lowest values respectively was chosen as best fit. Five volume equations were utilized to assess the model with best fit in teak plantation. The R^2 value and MSE were similar for all the equations fitted in the data. The R^2 value varied from 0.96313 to 0.93318 and MSE ranged from 0.0045 to 0.0835. The R^2 value for Equation 6 was highest R^2 value and lowest MSE with 0.96313 and 0.0045 respectively was qualified to have the best fit.
Results of height growth models for *Gmelina arborea* plantation
The model that came out best was chosen based on their proportion of variation accounted for value as well as the (MSE) for *Gmelina* are as follows:

Table 6: Results of Height models for *Gmelina arborea* plantaion

Model Number	R^2	MSE	a	b	c
1	0.6548	0.2456	3.42	135.45	
2	0.7084	0.2854	0.386	0.503	
3	0.7945	0.0154	1.831	14.435	1.832
4	0.6354	0.1586	6.45	5.484	

The model was graded based on its highest (R^2) value and lowest (MSE) and based on this fact, the model with the highest R^2 height models were used to check for the models that fit best. The R^2 value and MSE error were similar for the four equations.

The R^2 value varied from 0.7945 to 0.6354 while MSE from 0.0154 to 0.2854. Equation 3 (Ratkwosky equation) with the highest R^2 value and smallest MSE, 0.7945 and 0.0154 respectively satisfy the criteria the model that fit best.
The result for volume models used on comparison of their proportion on variation accounted for and MSE values for *Gmelina* are presented below;

Table 7: Volume Models for *Gmelina coppiced plantation*

Model Number	R^2	**MSE**	**a**	**b**	**c**	**d**
5	0.9348	0.1436	0.4226			
6	0.9731	0.0042	9.9019	2.038	1.268	
7	0.9243	0.2454	1.5442	1.2848	26.084	0.3004
8	0.9253	0.2638	138.242	-1.089		
9	0.9331	0.2848	65.92	12.48	3.248	1.516

Five volume equations were inputted to data for each stand to choose the best models. The R^2 value and MSE were similar for all the equations where data were fitted.
The R^2 value obtained varied from 0.9731 to 0.9243 while MSE was from 0.0042 to 0.2848. Equation 6 which had the highest R^2 value and lowest MSE with 0.9731 and 0.0042 respectively had the best fit.

Table 8: Yield Prediction for tree Volume using best models for teak

Age in Years	Volume in (m^3 (cube)
10	120.01
20	130.25
30	150.45
40	165.45
50	180.85
60	190.10
70	210.45
80	220.85
100	240.25
120	254.25
140	265.45
160	270.15
180	280.35
200	295.35

Table 9: Yield Prediction for tree Volume using best models for *Gmelina*

Age in Years	Volume in (m^3 (cube)
10	140.01
20	150.25
30	170.45
40	185.45
50	200.85
60	210.45
70	230.85
80	240.85
100	260.25
120	274.25
140	285.45
160	290.15
180	300.35
200	315.35

The tables above showed the prediction for both height and volume respectively for the next 200 years. Since yield tables are essential tools used for long term planning, then this information is important for valuation and strategic planning for future purposes in Bende local government area in Abia State.

DISCUSSION

The growth models were evaluated with the data obtained and analyzed using STATISTICA package. MSE and the proportion of variation accounted for, denoted as MSE and R^2 value respectively, were used to assess the fit. A lower MSE and higher R^2 value suggested a more suitable fit. Four height equation were fitted to data to select the best model for Teak, of the four height equations, equation 3 had the lowest MSE value and the highest R^2 value, thus equation 3 worked best. This is in line with Flewelling and De jang (1994) who used Ratkowsky function (1990) to estimate missing height in the British Columbia permanent sample plot data set.

The volume models, five equations were evaluated to choose the best model. Model 6 had the lowest MSE value and highest R^2 value, which had the best fit. This agrees with Newnham, (1967) who used same model for the prediction of total stem volume for red pine in Eastern Canada.

For *Gmelina,* four height equations were evaluated to choose the model of best fit. Of the four height equations, equation 3 gave the lowest MSE and highest R^2 value, thus equation 3 performed best. This agreed with Flewelling and De Jang (1994), who used Ratkowsky's function (1990) to estimate missing height in British Columbia permanent sample plot data sets.

Also for volume models, five equations were evaluated to choose the model of best fit *for Gmelina.* Equation 6 had the lowest MSE and highest R^2 value, which gave the best fit. This fit agrees with Newnhan (1967), who put the model into use for prediction of total stem volume for red pine in Eastern Canada.

The plantation was first established in 1970, and the first cut was done in 1982, the data obtained was at the time the plantation was first cut till date. This was done in order to compare the growth rate of both *Gmelina arborea and* Teak and their ability to coppiced at short time; to meet timber needs in the nearest future. From the findings, it was observed that *Gmelina arborea* grew faster than *Tectona grandis.* Which indicate that *Gmelina arborea* species would be able to meet timber need within a short period, if properly managed than *Tectona grandis*. Hence much effort should be given to *Gmelina* species so as to meet up with the demand for timber for the fast growing population.

CONCLUSION

Forest growth models are very essential in forestry for effective management and in making the right decision. This study thus identifies the best models for volume and height respectively where observed to have the best fit, for both Teak and *Gmelina* Coppiced plantations. The Ratkowsky equation and Newnham equation for height and volume respectively were observed to be most suitable in the study.

The models which gave the best fit are those with the highest proportion of variation accounted for R^2 value and lowest mean square error (MSE). The height and volume models have been able to provide vital information significant information on the growth rate of *Tectona grandis* and *Gmelina arborea.*

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