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RELATIONSHIP BETWEEN BOLE HEIGHT, DIAMETER AT BREAST HEIGHT AND LOCAL VOLUME TABLE OF *Pinus caribaea* IN ENUGU NGWU PLANTATION ENUGU STATE, NIGERIA

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ABSTRACT
The study was carried out to evaluate the relationship between bole height, diameter at breast height and local volume table constructed for pine plantation in Enugu Ngwo, Enugu State, Nigeria. Twelve permanent sample plots of 20 x 20m (0.04ha) were laid in the plantation of *Pinus caribeae* with age series between 34 and 36 years. Complete enumeration and measurement of all trees were carried out in each sample plot. The growth data set collected include diameter at breast height (cm) total and merchantable height (m), diameter at the base, middle and top which were used for volume computation. Five height and five volume models were fitted in the data collected from the plantation. The data collected were split into two sets in the ratio, 9:1. The majority of the data (90%) was used for model development while the remaining data (10%) was used for model validation. Model 2 for height with a R^2 value of 0.8056 and MSE of 0.0125 while for volume model 10 with R^2 value of 0.9009 and MSE of 0.0395 respectively gave the best fit based on the comparison of lowest mean square error (MSE) and highest coefficient of determination (R^2). The result of the study shows that bole height has a strong linear relationship with diameter at breast height. The study was able to predict the growth of pine which will serve as a useful tool for effective management, planning and decision making of the plantation.

KEYWORDS: Height, Diameter at breast height, volume, models, forestry.

INTRODUCTION

Forestry and forest products would continue to contribute tremendously towards the economic development of Nigeria (Akande, 1998). Throughout the tropics, people have depended on these indigenous flora and fauna for food, security and daily needs from medicine to fibre (Etukodo, 2002). Individual tree heights and diameter are essential forest inventory measurement for estimating timber volume and site index (Russel, 2008). One of the most vital tools for sound management is the information on the volume of trees obtained able from forest stands (Russel *et al*., 2008). Diameter at breast height (DBH), is a standard method of expressing the diameter of the trunk or bole of a standing tree and is the commonest dedrometric measurements (Brack, 2009). Diameter at breast height is used in estimating the amount of timber volume in a single tree or stand of trees utilizing the allometric correlation between stem diameter, tree height and timber volume (Mackie, 2006). A volume table is a table showing the average volume of trees, sawn timber or logs for one or more given characteristics such as diameter at breast height or diameter at breast height and height or DBH, height and form or taper (Lendermann, 2004). Volume tables are based on diameter and /or height and/ or tree form. They are often derived via volume equations that are statistically developed to elimate height and form class measurement. The word "Local" is used because it is applicable to small forest areas (Pang, 2000). The volume is based on the actual volume measurements of some standing trees of all diameter classes. It is based on the assumption that individuals of the same species with the same DBH or DBH and height have an average of the same volume [given identical growing conditions] (Brack, 2009). *Pinus Caribea* (Pine) which is known to perform well in plantation under favorable conditions was used in this study because of its unique importance as fuel, pulpwood, timber resin and land reclamation (Lamb, 1993). The broad objective of this paper was to assess the relationship among bole height, diameter at breast height and local volume table. The specific objective was to examine the contribution of stand attributes or equations in estimating bole height, diameter at breast height and local volume table.

MATERIAL AND METHODS

STUDY AREA

The study area is the Enugu-Ngwo Pine plantation in Enugu State, Nigeria. Enugu-Ngwo is situated on Udi escarpment at an altitude of about 396.24m, longitude 07^0 27' E and Latitude 06^0 26' N of the equator. Ainslie (1935) described it as a table land that forms the main water shed between the lower Niger and the Cross Rivers. The sampling design used for data collection was stratified random sampling method. The sampling units differ in terms of age constituting the strata. Sample plots of 20 x 20m (0.04ha) were randomly laid in each stratum and complete enumeration and measurement of all trees were carried out in each sample plot. The growth data set collected include diameter at breast height (cm), total and merchantable height (m), diameter at the base, middle and top (cm) which was used for volume computation.

Models Tried

The following models were tried in the curse of this study
Models for height

$H = 1.3\ D^2/(b_0 + b_1)^2$ ---------- equation 1
$H = C + b \log D$ ---------- equation 2
Log $H = a_0 + a_1$ (Log D) ---------- equation 3
$H = 1.3 + bD + CD^2$ ---------- equation 4
$H = 1.3 + b_0D + b1D^2$ ---------- equation 5
where
H = height (m)
D = Diameter at breast height (cm)
e = base of natural logarithm
a,b,c and d are parameters in the equation
models for volume
$v = a + bD + CD^2 H$ ---------- equation 6

$v = a + bD + CD^2H + d\ (D^2H)^2$ ---------- equation 7
$v = a + b_0 + CH + dD^2H$ ---------- equation 8
$v = a + bD + CD^2 + dD^2H$ ---------- equation 9
$\log v = a + b\log D + C \log H$ ---------- equation 10
where
V = volume; D= diameter at breast height over bark (cm);
H = height (m),
a, b, c and d = parameters in the equation

Data Analysis
The ten height and volume equations (Tables 1 and 2 were fitted to data for each stand measurement to select the model of best fit. Data were fitted using linear and non-linear regression procedure. Models with lowest mean square error (MSE) and highest coefficient off determination (R^2) suggest a best fit. Although the individual MSE and R^2 value for each equation vary from stand to stand, a good equation should fit well on the average. The average of the mean square error is used as a measure of overall performance of an equation. The MSE for all equations were compared in the study to the select the best equations. Volume was estimated by the use of Newton's formular as used by Husch *et al*. (1982) and the equation is given as
$v = h/6\ (A_b + 4A_m + A_t)$
where
v = Steam volume (m^3), h = Merchantable height
A_b = Cross sectional area at the base of tree
A_m = Cross sectional area at the middle of tree
A_t = Cross sectional area at the top of tree

RESULT AND DISCUSSION
Height growth model
Table 1 shows the result of the height models fitted into the data. The height growth estimated had R^2 values which ranged from 0.7105 to 0.8056 with MSE which ranged from 0.0125 to 0.9845. Equation 2 had the lowest MSE and highest R^2 values respectively. This findings agreed with that of Hericksen (1980) who worked on data of Douglas-Fir trees obtained from a forest in Northern Pennsylvania, U.S.A and found that the model gave the best fit. The result shows that equation 2 for height was found suitable and could be used to predict height for the management of pine. The ranges of R^2 and MSE values indicate that *Pinus caribaea* is doing well in Enugu-Ngwo pine plantation.

TABLE 1. Height growth estimates of *Pinus caribeae* stands

Models	a_0	a_1	b_0	b_1	b_2	c	R^2	MSE
$H=1.3 + D^2/(b_0 + b1)$			0.0455	0.1646			0.7105	0.9436
$H = c + b \log D$			11.7090			20.7690	0.8056	0.0125
$\text{LogH}= a_0 + a_1$ (LogD)	0.6650	0.0900	1.2347			-8.500	0.7150	0.9562
$H = 1.3 + bd - CD^2$							0.7251	0.8316
$H = 1.3 + b_1D - b_2D^2$				0.6187	0.2084		0.7100	0.9845

Volume Models
Table 2 shows the result of volume models fitted into the growth data collected. The volume model estimates had R^2 values which ranged from 0.7123 to 0.9009 with MSE which ranged from 0.0243 to 0.4243. Equation 10 gave the best fit because it has the highest R^2 (0.9009) and lowest MSE (0.0243) value. This fit agreed with Segura and Kanninen (2005) who suggested that allometric models be used to estimate stem volume for individual trees in a tropical humid forest comprising different species in costa Rica. These ranges indicated that *Pinus caribeae* trees in Enugu-Ngwo were doing well

TABLE 2. volume estimates of *Pinus caribeae* in the study area

Models	a	b	c	d	R2	MSE
$V= a + bd + CD^2 + H$	2.0030	-38.8976	0.4118		0.8427	0.024
$V= a + bD + CD^2H + d\ (D^2H)$	3.1560	-106.54	0.8613	11.0850	0.7146	0.3451
$V= a + bD + CH + dD^2H$	2.7658	-561.133	27.5002	3.1418	0.7123	0.2341
$V= a + bD + CD^2 + dD^2H$	5.4374	-253.66	-53.4730	4.0704	0.7321	0.4213
Logv= a + bLogD + CLogH	1.0772	0.7223	-0.5640		0.9009	0.0395

Yield Prediction
Table 3 & 4 show the yield prediction formulated using the best growth models for height and volume for the next 100 years. The results show that as ages of the trees increased, the volume also increased. The yield table would help the forest manager to predict into the future. The future benefits (yield) predicted from the yield table would motivate the forest manager into drawing management plans in order to achieve the yield predicted from yield table.

TABLE 3. Yield prediction for height using best model

Diameter at breast height (cm)	Height (m)
10	9.06
20	12.58
30	14.65
40	16.11
50	17.24
60	18.17
70	18.95
80	19.63
90	20.23
100	20.76

TABLE 4. Yield prediction for volume using best model

Diameter at breast height (cm)	Volume(cm^3)
10	391
20	780
30	1169
40	1559
50	1949
60	2339
70	2729
80	3119
90	3510
100	3900

Local Volume Table

This table shows the average relationship between the height, diameter at breast height and volume. It shows that as the height and diameter at breast height increases the volume also increase.

TABLE 5. Local volume table

Diameter at brea	Height (m)	Volume (m^3)
10	9.06	391
20	12.58	780
30	14.65	1169
40	16.11	1559
50	17.24	1949
60	18.17	2339
70	18.95	2727
80	19.63	3119
90	20.23	3510
100	20.76	3900

Forest growth models are very useful in forestry for both management and decision making. This study identified the best models for height and volume for pine plantation in Enugu-Ngwo, Enugu State. Equation 2 and 10 for height and volume models gave the best fit respectively because they have the highest R^2 and lowest MSE values. These models are H= C + b log D and Log V = a + blogD + C Log H. These models could be used for yield prediction in Enugu-Ngwo of Enugu State. The results from the yield table should encourage individuals into establishing pine plantations because of the profit involved in the nearest future. The yield prediction would also help forest managers know what is expected in the future. This would enable the forest manager draw management plans as well as taking decisions towards achieving the predicted yield.

CONCLUSION AND RECOMMENDATION

The study has provided information on the growth of pine in Enugu-Ngwo, Enugu State plantation. The results show that the yield could be high if the plantation is properly managed.

It is therefore recommended that these models be adopted for sustainable management of the plantation. The result from the yield table would also encourage individuals establishing plantation because of the profit in the nearest future.

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