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MODELING VOLUME FROM STUMP DIAMETER OF *Terminalia ivorensis* (A. CHEV) IN SOKPONBA FOREST RESERVE, EDO STATE, NIGERIA

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ABSTRACT

This study is based on the relationship between tree volumes (V) and stump diameter (D_{st}). Empirical equations were developed for estimating tree volumes of *Terminalia ivorensis* from stump diameters, for determining relationship between volumes of *Terminalia ivorensis* trees. The purpose is to develop a model for *Terminalia ivorensis* stands in Sokponba Forest Reserve and to adopt it for sustainable forest management in many other forest reserves in Nigeria. Eighteen temporary sample plots, each of size 20m x 20m (0.04ha) were randomly established and 196 *Terminalia ivorensis* trees selected from each of the sample plots. A series of regression equations were all fitted to the data generated and analyzed with the aid of Genstat Computer system. The regression equations were fitted for choosing the best model after critical consideration of model diagnostic criteria such as the coefficient of determination (R^2), variance ratio and overall standard error of the various equations. Out of the several regression equations fitted, the non-linear (quadratic) model of stump diameter was considered to be the best. The equation is V = - 34.23 + 39.7509Dst - 6.5416D^2st, with R^2 = 0.69, RMSE = 0.00992 and F- ratio = 85.875; indicating the significant status of the model for predictive purpose. Residual analysis showed conformity with the assumption of independence of errors in regression analysis and that error is normally distributed. The result of data validation between predicted and observed values from a set of measurements from 48 trees using the paired t-test showed no significant difference (P>0.05). The study showed that stump diameter is appropriate for tree volume estimation and sustainable forest management of *Terminalia ivorensis* in Nigeria.

Keywords: *Terminalia ivorensis*, tree volume, stump diameter, volume equation, predictive purpose.

INTRODUCTION

The tropical rainforest is one of the major vegetation types of the globe (Richards, 1996; Whitmore, 1998), occupying a total area of 1818.43 million hectares and representing 47% of the total land area occupied by all forest types of the world (FAO, 2003). According to Turner (2001), the tropical rainforest is the most diverse of all terrestrial ecosystems, containing more plants and animal species than any other biome; and in Nigeria alone, over 4600 plant species have been identified (Sarumi *et al.*, 1996). *Terminalia ivorensis* (Combretaceace) is a tree species found in lowland rainforest zone of Nigeria. It is a tree species that is widely distributed throughout tropics (Keay, 1964). In spite of the diversity of this tree, the species is becoming locally endemic or rare and patchily distributed (Richards, 1996), thus the overall timber volume per unit area of this species is generally low, and thereby necessitating logging over large area to meet the ever increasing demand. In view of the great value of timber of *Terminalia ivorensis* species and the grave consequences of unregulated logging activities and over exploitation, adopting effective management principle has become imperative for its sustainability.

Effective forest management requires estimate of growing stock, such information will guide a forest manager in timber valuation as well as allocation of forest area for harvest. For timber production, an estimate of growing stock is often express in form of timber volume, which can be estimated from easily measurable tree dimension (Akindele and LeMay, 2006). According to Avery and Burkhart (2002), volume equations are used to estimate average content of standing tree of various sizes and species.

One of the concerns of a forest manager is the determination of available timber resources of particulars species in a forest at given future date. In order to obtain inventory information for the purpose of planned management for the forest and also for full objective of such operations, one of the principal parameters is the volume of standing trees (Ero, 1974). Where unauthorized logging operation exists, the forest manager is still interested in determining the volume of trees illegally removed and even when trees are legally removed, the stump can still serves as reference were measurement of diameter at breast height (dbh) and tree height cannot be made. Consequently, volume table or equation based on diameter at breast height (dbh) cannot be used directly.

Therefore, the objective of this study is to develop a tree volume model for *Terminalia ivorensis* in Sokponba Forest Reserve, Nigeria from stump diameter and there from facilitate the estimation of tree volume directly from measurements of stump diameter for *Terminalia ivorensis*.

METHODOLOGY

This study was carried out in the *Terminalia ivorensis* plantation in Sokponba Forest Reserve (latitude 06^0 04'N; longitude 05^0 32'E). The forest reserve is within

the moist high forest area of Nigeria (Keay, 1989). The area has a mean annual rainfall of 2162mm and maximum and minimum temperature of 26^0C and 16.40^0C respectively (Oguntala, 1980).The geology formation is a tertiary of the posteolian period called the Benin sands (Oguntala, 1980). Eighteen temporary sample plots each of size 20m x 20m (0.04ha in size) were randomly established from a 42- year old *Terminalia ivorensis* plantation. A total of 196 trees were measured from the eighteen temporary plots. In each plot, the outside bark stump diameter (Dst) of the tree was measured at 15cm above ground (since past survey exploitation shows that no tree is cut at this point). Dbh (taken at 1.3m from ground), tree height (taken at fixed top diameter of 7cm), outside bark diameter at base, middle and top position were all measured. Individual tree was calculated using the Newton's formula (Husch,*et al*,1982) as follows:

$V = h/6(A_b + 4A_m + A_t)$

Where V = tree volume (m^3), h = tree height (m), A_b = cross section at the base, A_m = cross section at the middle, A_t = cross sectional area at the top.

Residual graphs and scatter diagrams were plotted to portray the relationship between tree volume and stump diameter, tree volume and diameter at breast height and stump diameter and diameter at breast height. Series of regression equations were fitted to the data based on the relationship between variables. The equations were assessed and compared on the basis of their correlation coefficient, coefficient of determination, variance ratio and standard error of estimate.

RESULTS AND DISCUSSIONS

The results obtained by fitting the series of equations are shown in Table-1. For volume-stump diameter relationship, the stump diameter was taken as the independent variable, while volume taken as dependent variable. All parameters were found to be significant at 5% level. The non linear quadratic model gave the best performance according to the values of the statistics used to compare the models in the fitting phase. Consequently, this model was selected with the regression equation was

$V= -34.23 + 39.75D_{st} - 6.54D^2st.$

Where Vis volume of tree; $D_{st=}$ stump diameter. R^2 =0.69; F. ratio = 85.88; MSE (mean square error) = 0.0099. Non-linear quadratic curve provides a better estimate of volume of tree with large diameters (diameter > 20 cm) (Salis *et al*., 2006).

Terminalia ivorensis shows variation in growth attribute contrary to expectation as shown in Table-2. This variation could be due to lack of maintenance of the plantation since the time of establishment, large gaps exist between the trees, suggesting that there was no beating up at the early stage of plantation establishment. The stump diameter in the data set ranges from 1.32 to 1.69m. Merchantable volume also varied with minimum and maximum being 12.7 and 29.79m^3, respectively. The correlation coefficients between the variables are presented in Table-3. The table shows that there is a strong linear relationship between stump diameter and diameter at breast height (Figure-2); this suggests that stump diameter could serve as substitute to diameter at breast height in tree volume estimation. Similar results have been reported for pines and oaks (Bylin, 1982), teak (Osho, 1983) and Bald cypress (Parresol, 1998).

A scatter diagram of the residuals over the range of independent variable is presented in Figure-1. The graph revealed that assumption of independence of residuals is valid and it shows conformity with the assumption of independence of errors in regression analysis, which means error, is normally distributed.

The relationships between the variables are depicted graphically in Figure-2. As it could be observed from the figures all the relationships were positive indicating that an increase in the value of one variable is associated with an increase in value of another variable. The scattered diagram shows linearity between variables. This is true for merchantable tree volume, according to Akindele and LeMay (2006), which is reported that equations are not conditioned to pass through the origin if the dependent variable was merchantable, rather than total tree volume. Avery Burkhart (2002) also reported similar occurrence for merchantable volume prediction with negative intercepts.

Predicted volumes were generated from the chosen equations of stump diameter. Validation of the equation was done by testing for significant difference between the predicted tree volume and the actual (observed) tree volume. The paired t-test showed that there is no significant difference ($p > 0.05$) between them.

Table 1. Model statistics and parameter estimates from volume-stump diameter prediction estimates.

Function	Model statistics		Parameter estimates		
code	R2	F-ratio	b_o	b_1	b_2
1	0.662	168.21	-22.51	29.49	-
2	0.675	88.10	-127.49	169.24	-46.345
3	0.690	85.88	-34.23	39.75	-6.542
4	0.657	164.88	-28.22	9.75	-
5	0.441	67.82	-2.14	2.24	-
6	0.444	33.91	1.65	4.72	-3.040

Table 2. Summary statistics for *Terminalia ivorensis* in Sokponba forest reserve.

Variable	Min	Max	Mean	Standard deviation	Standard error
Stump diameter (cm)	1.32	1.79	1.53	0.098	0.00992
Diameter at breast height (cm)	1.25	1.58	1.43	0.088	0.00903
Tree volume (m^3)	12.70	29.79	22.5	3.5	0.4

Table 3. Correlation matrix for the tree growth of *Terminalia ivorensis* in Sokponba forest reserve.

Variable	Stump diameter	Diameter at breast height	Tree volume
Stump diameter	1.000		
Diameter at breast height	0.9676	1.000	
Tree volume	0.998	0.998	1.000

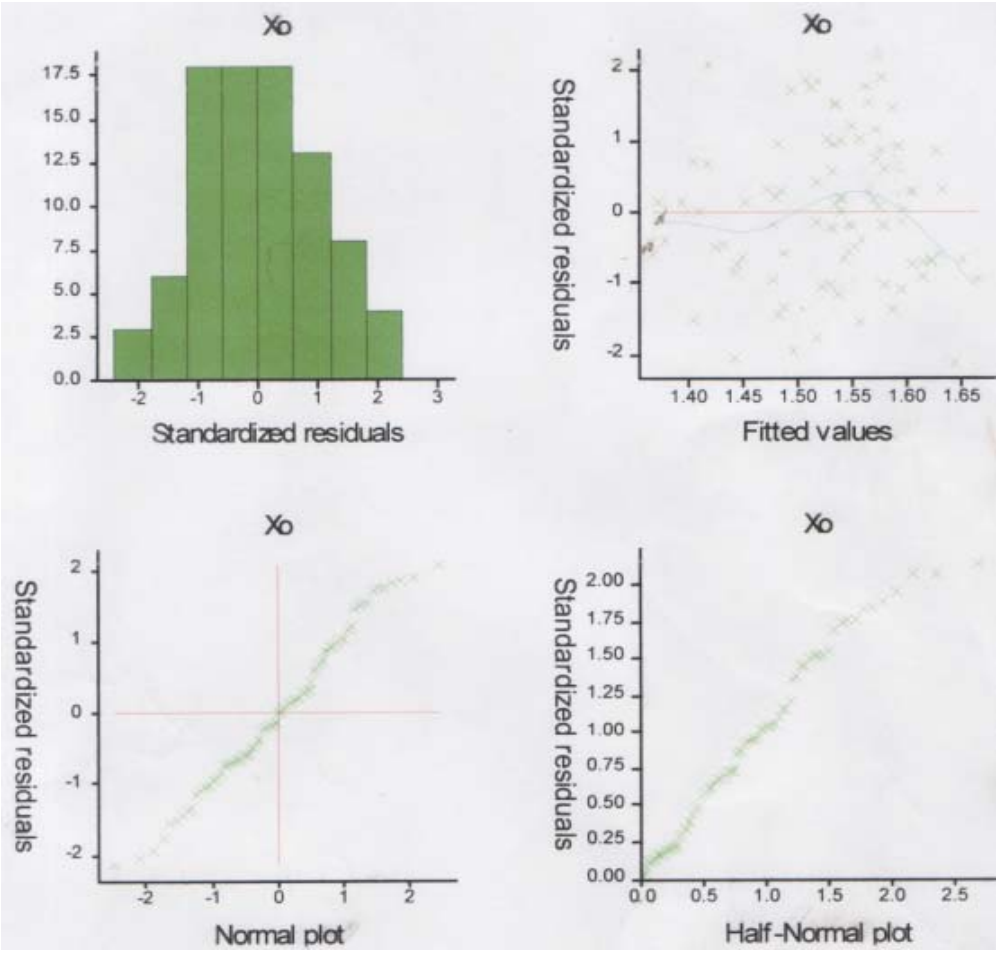

Figure-1. Residual graph showing the assumption of independence of error.

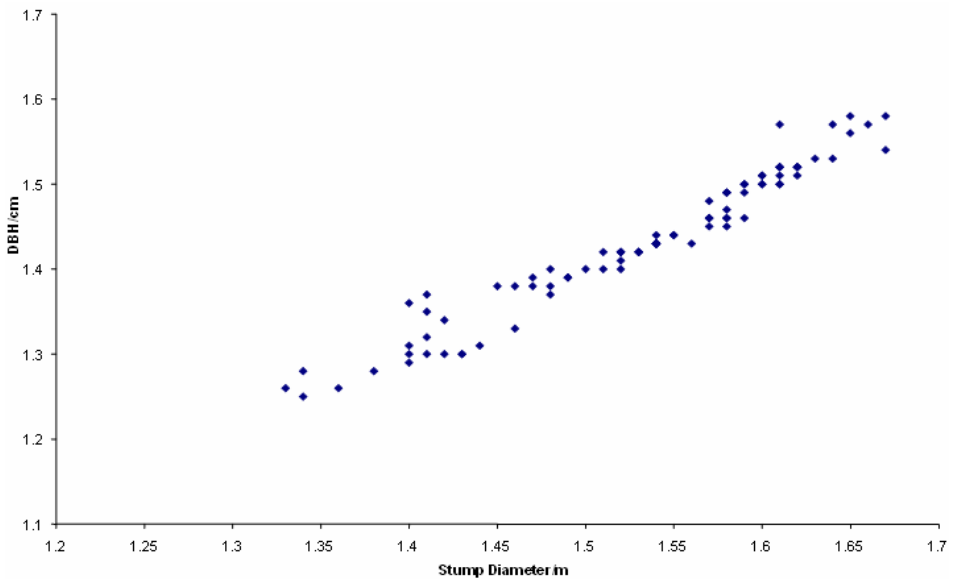

Figure 2. The relationship between DBH and stump diameter of *Terminalia ivorensis*.

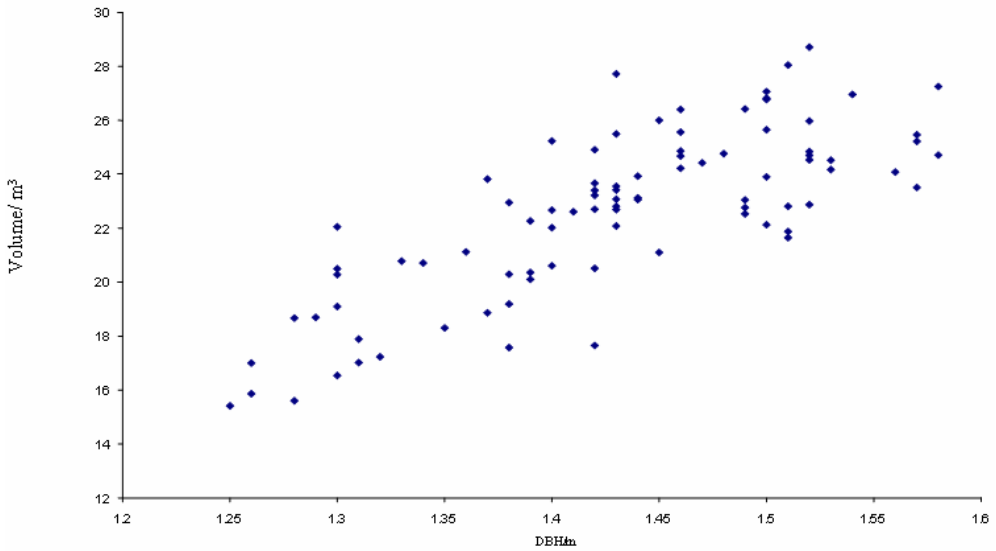

Figure 3. Relationship between volume and DBH of *Terminalia ivorensis.*

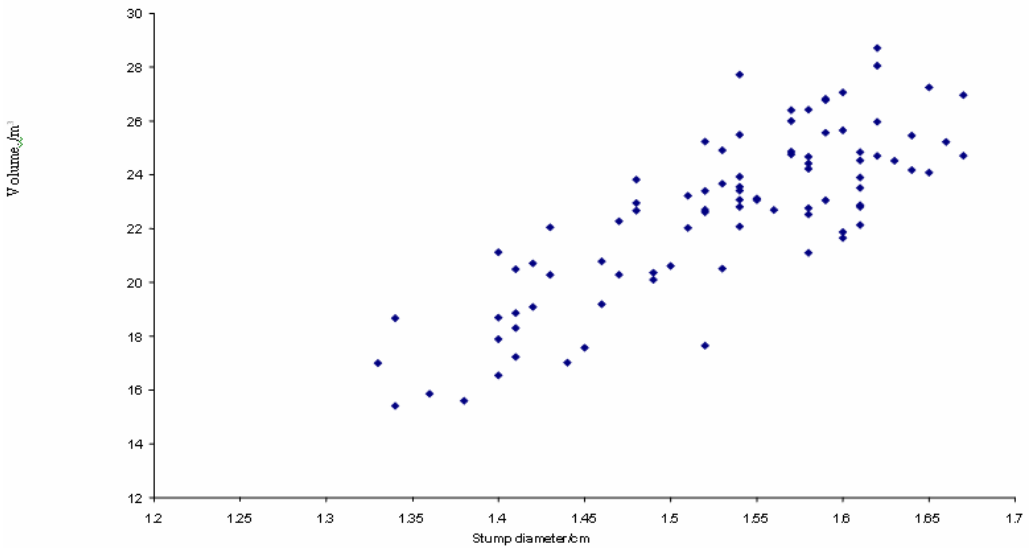

Figure 4. The relationship between volume and stump diameter of *Terminalia ivorensis*.

CONCLUSIONS

The study has shown that tree volume can be estimated for *Terminalia ivorensis* from stump diameter with reasonable accuracy and that non-linear regression was more efficient than linear regression for estimation of merchantable tree volume. The equation developed in this study can be very useful in planning and pre and post harvest stock assessment of *Terminalia ivorensis* in the study area and similar ecological conditions and whose stump diameter fall within the diameter range observed in this study. In the event that there is illegal felling of tree, the stump diameter left on ground can determine what is removed and offenders appropriately charged. The estimation of merchantable tree volume is essential for understanding of allowable cut cycles and for establishing sustainable forest management in forest estate.

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