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VOLUME PREDICTION FOR *MILICIA EXCELSA* (WELW C.C. BERG.) TREES IN SELECTED INSTITUTIONS IN IBADAN, OYO STATE, NIGERIA

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ABSTRACT

The study develops equations for the prediction of stem volume of *Milicia excelsa* (Welw C.C. Berg.) in some selected institutions in Ibadan, Oyo State, Nigeria. Sequel to the relationship between stem volume (*sv*), diameter at base (*db*) and at breast height (*dbh*) from enumeration of 61 trees in selected institutions, equations were developed for estimating tree volumes of *M. excelsa*. Of all the equations developed, logarithmic for volume was the best fit equation containing the *db* and *dbh* as the predictors. The equation is $lnSV = 1.5924 + 1.4915lndb + 0.8600lndbh$ with coefficient of determination (R^2) and standard error of estimate being *0.9011* and *SEE = 0.3485* respectively. Residual analysis revealed that the assumption of independence of residuals is valid, and there is no evidence of an outlier. Validation of the equation was done by testing for significant difference between the predicted stem volume (PSV) and observed stem volume (OSV). The study showed that stem volume of *M. excelsa* can be predicted from *db* and *dbh* by using this equation with reasonable precision. The prediction equation developed in this work would be very useful and applicable where tree dimensions such as diameter at middle and top as well as the height of *M. excelsa* is difficult to assess and there is need to reduce the cost of inventory of such species.

Keywords: Volume equations, logarithmic equation, tree diameters, University of Ibadan, *Milicia excelsa,* Ibadan

INTRODUCTION

Milicia excelsa (Iroko) is one of the few important indigenous timber species in Nigeria. The wood of the tree possesses some favourable characteristics such as durable heartwood, workable and resistant to termites and marine borers (Ouinsavi and Sokpon, 2010). The gravity of the wood is about 0.55 g/cm^3 and therefore mainly used for outdoor construction work, furniture, boats, cabinet-work, panelling, frames and floors (Agyeman *et al.,* 2009). According to Putheti and Okigbo (2008), the bark, its ashes, leaves and latex are used in local medicine and the trees play a major role in many local cultures where they are considered sacred, or parts of the tree serve ceremonial purposes (Borokini *et al.*, 2012). Despite all these benefits that are derived from the *M. excelsa*, the population has been greatly reduced, with the few remaining trees found in Strict Nature Reserve (Adekunle *et al.,* 2010) and in a number of academic institutions where there is little or no indiscriminate tree felling activities (Borokini *et al.*, 2012). In order to guarantee the sustainability of the few trees left, it is important to carry out required management activities.

Sustainable forest management requires information on the growing stock. Such information guides the resource manager in valuation and allocation of forest areas. In timber production, estimates of the growing stock are often expressed in terms of timber volume, which can be estimated from easily measured dimensions of the tree (Husch *et al.*, 2003; Akindele, 2005). Stem volume prediction has been identified as one of the management tools employed by forest managers in ensuring accurate assessment of the volume of tree species.

Tree volume prediction is basically achieved with the use of volume tables or equations, in which some tree dimensions are incorporated as the predictors or independent variables. Such variables include: Tree total and merchantable height, Diameter at the base (*db*), Diameter at breast height (*dbh*), Diameter at middle (*dm*) and Diameter at the top (*dt*), Crown diameter (*cd*), Crown length (*cl*), among other variables. Over the years, studies have revealed that prediction of volume using height and crown variables had been very difficult, because of time and the financial cost involved in the acquisition of reliable data (Schumacher and Hall, 1933; Honer, 1965; Zianis *et al.,* 2005). To overcome this problem, volume prediction has been recommended. According to Zianis *et al.* (2005), most volume equations have been developed using diameter outside bark at base and at breast height as the predictor variables. The development of volume prediction for *M. excelsa* trees is needed to compliment many of the recent studies on this species which are on biological and silvicultural aspects (Braissant *et al.*, 2004; Bosu *et al.,* 2004; Agyeman *et al.,* 2009).

A preliminary survey (Borokini *et al.*, 2012) has revealed that majority of the remaining Iroko trees in the city of Ibadan are located in academic and research institutions. This is due to prevention of indiscriminate felling of tree in such locations. The study was therefore carried out to develop equations for the prediction of stem volume of *M. excelsa* in selected institutions in Ibadan. This information is necessary for management and conservation strategies.

MATERIALS AND METHOD

The study area

The study involves enumeration of *M. excelsa* trees located in selected institutions in Ibadan. Ibadan (7^{o} 23´ 47´´ N; 3^{o} 55´ 0´´ E) is located in Oyo State, Nigeria. The city ranges in elevation from 150m in the valley area, to 275m above sea level on the major north-south ridge which crosses the central part of the city. Ibadan has a tropical wet and dry climate with a lengthy wet season and relatively constant temperatures throughout the course of the year. Ibadan's wet season runs from March through October. November to February forms the city's dry season, during which Ibadan experiences the typical West African harmattan (Wikipedia, 2012). Trees of different species are scattered all over the city of Ibadan. Iroko tree is one of the indigenous trees with high esteem in the society due to its socio-cultural potentials.

Data collection

A reconnaissance survey to confirm the existence of Iroko trees within institutions in Ibadan was carried out. The institutions where Iroko trees were identified included University of Ibadan (UI), University College Hospital (UCH), National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation; Institute of Agricultural Research and Training (IAR & T), Moor Plantation; Federal College of Forestry (FCF), Jericho; and National Horticultural Research Institute (NIHORT), Idi-Ishin. Each of these institutions had their specific mandates including provision of health services; research, teaching and training; and plant conservation, breeding and improvement. Direct enumeration of the identified Iroko trees in each of the institutions was then conducted during the actual data collection stage of the study. Table 1 shows the coordinates of a representative *M. excelsa* tree in each study location. In each location, diameter at the breast height (*dbh*), tree total height (THT), merchantable height (MHT), diameter measurements at base, middle and top positions of all the trees were measured.

Table 1: Location coordinates of representative trees in the study locations

Institution	Latitude	Longitude
University of Ibadan, Ibadan (UI).	07º 26.641´	003º 54.062´
University College Hospital (UCH)	07º 24.069´	003º 54.554´
Federal College of Forestry, Jericho.	07º 23.884´	003º 51.767´
National Centre for Genetic Resources and Biotechnology (NACGRAB)	07º 23.315´	003º 50.465´
Institute of Agricultural Research and Training (IAR & T)	07º 22.471´	003º 50.771´
National Horticultural Research Institute (NIHORT), Idi-ishin	07º 24.468´	003º 50.836´

Preliminary Data Analysis

The first task in this study was to calculate tree basal area and volume of all the sampled Iroko trees. Basal area was computed using the formula:

$$BA = \frac{\pi D^2}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where *BA* = Basal area (m^2); D = Diameter at breast height (1.3m above the ground level).

Volume may be estimated for some specific merchantable portion of the stem only or for the total stem. In this study, volume was estimated for merchantable portion of the stem. Merchantable height is defined as the usable portion of the tree stem, that is, the part for which volume is computed or the section expected to be utilized in a commercial logging operation (Avery and Burkhart, 2002). Based on the data collected for this study, merchantable volume was estimated using the Newton's formula (FAO, 1980) expressed as:

$V = h/6 (A_b + 4A_m + A_t)$……........ 2

Where V = tree volume (in m^3), A_b, A_m and A_t = tree cross-sectional area at the base, middle and top of merchantable height, respectively (in m^2) and h = total height (in meter).

Developing the Regression Equations

Several equations were considered and tried for the species. However, the logarithmic equations were the most appropriate for the species in the study area. The model was therefore selected for this study.

Adequacy of the models

The major fit statistics calculated for each volume equation were the co-efficient of determination (R^2) and the standard error of estimate (SEE).

$$R^2 = 1 - \frac{SSE}{SST} \text{..........................} 3$$

$$SEE = \sqrt{\frac{\sum_{i=1}^{n} \hat{e}_i^{\,2}}{n-k}} \text{ .... } 4$$

Coefficient of determination (R^2)

Standard Error of Estimate (SEE)

Where, $\hat{e}$ is the difference between the observed (y_i) and the estimated volume values $(\hat{y})$; SSE is the error sum of squares, SST is the total sum of squares, n is the number of trees in the model–fitting data set, and k is the number of coefficients in the fitted equation.

t-test and Correlation Analysis

Paired sample t-test was used to compare the observed and predicted stem volume. However, correlation analysis was used to determine the relationship between the growth variables from the study locations.

RESULTS AND DISCUSSION

Diameter distribution of sampled Iroko trees

Table 2 shows the distribution of the studied trees into diameter at breast height (*dbh*) classes. A total number of sixty one (61) trees were measured in the study area. Out of this 61 trees, 26.2% were in the diameter class 105.1-130cm, 24.6% in the class 130.1-155cm while 23% trees were in 155.1-180cm diameter class. However, few trees were discovered in the extreme diameter classes. It therefore implies that majority of the trees in the study area were distributed in the diameter class ranging from 105.1 to 180cm. This is relatively high compared to the diameter distribution of some exotic trees reported by Akindele (2003) to be in the range of 10 and 70cm in Akure forest reserve sharing almost the same climate as Ibadan.

Table 2: Distribution of the trees into diameter at breast height (dbh) classes

dbh Classes (cm)	Frequency	Percentage
≤30	1	1.6
30.1-55	3	4.9
55.1-80	1	1.6
80.1-105	5	8.2
105.1-130	16	26.2
130.1-155	15	24.6
155.1-180	14	23
180.1-205	4	6.6
205.1 &above	2	3.3
Total	61	100

Other variables of the Iroko trees

The values obtained for the tree growth variables are summarized and presented in Table 3. This shows that *M. excelsa* trees exhibited very wide variation in their growth attributes. This could be due to the differences in their age, site in tandem with the inadequacy of silvicultural treatment since the time of their emergence. This result could be supported with the finding of Maltamo *et al.* (2007) that variation in tree growth variables is subjected to stand density, stand silvicultural history, genetic factors of tree seed, tree position in the stand, site fertility and mineral soil.

Table 3: Summary of Statistics of growth variables

Variable	Mean	Minimum	Maximum	Std. Dev.	Std. Error
SV	16.59	0.14	66.36	11.54	1.47
BA	1.68	0.05	11.46	1.47	0.18
dbh (cm)	137.95	24.00	382.00	49.84	6.38
db (cm)	168.22	27.00	430.00	60.81	7.78
THT	27.22	9.00	41.00	6.56	0.84
MHT	14.94	4.00	22.00	4.52	0.57
dm (cm)	96.59	20.00	180.00	26.65	3.41
dt (cm)	79.08	10.00	160.00	24.65	3.15

Volume and growth variables of the Iroko trees

Result showed the volume of all the sampled *M. excelsa* trees in the selected institutions in Ibadan was 1012.27m^{3}-- (Table 4). University of Ibadan (UI) accounted for 754.63m^3 amounting to approximately 75% of the entire volume. This was followed by the University College Hospital (UCH), having a volume of about159.60m^3. The reason for the high percentage of the tree volume in the University of Ibadan is connected with the protection of trees on the campus and this is among the mandate of the Campus Tree Management Committee (CTMC). The Campus Tree Management Committee (CTMC) is the only body that is set up by the University of Ibadan Senate Council to manage trees on the campus. The main objective of the committee is to manage trees on the campus as well as protect life and property from tree damage (Babalola, 2010). The committee occasionally carries out some silvicultural treatments such as pruning of tree branches, and after due inspection and confirmation of tree status, give approval for felling of the weak trees on campus (Onefeli, 2010; Babalola, 2010). However, it was observed that management of indigenous trees, including *M. excelsa,* in most of the sampled institutions is still not up to the required standard. For instance, some of the institutions limit their management to the mandate tree crops.

The relationships between the tree volume and the predictors (i.e. *db* and *dbh*) are depicted graphically in Figure 1 & 2. As could be observed from the figures, there is positive relationship between tree volume and diameter at the base and at breast height. This indicates that an increase in the value of one variable is associated with an increase in the value of the other variable.

Table 4: Distribution of the stem volume (SV) in the study area

Institutions	SV (m3)	Percentage (%)
NACGRAB	1.57	0.15
FCF	70.80	6.99
UCH	159.60	15.76
IAR & T	7.68	0.75
NIHORT	17.99	1.77
UI	754.63	74.54
Total	**1012.27**	**100.00**

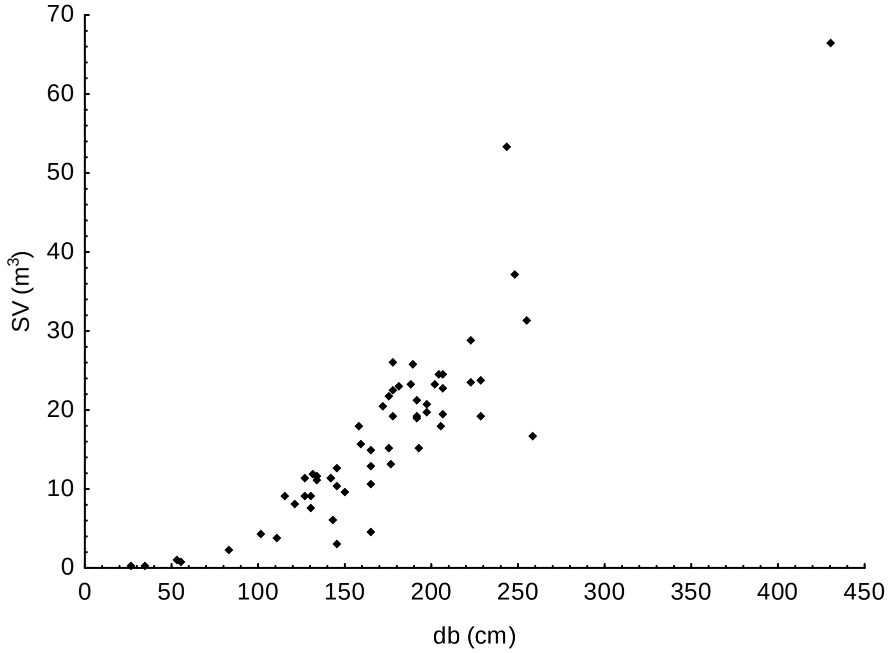


Figure 1: Scatter plot showing relationship between the stem volume (SV) and the diameter at base (*db*)

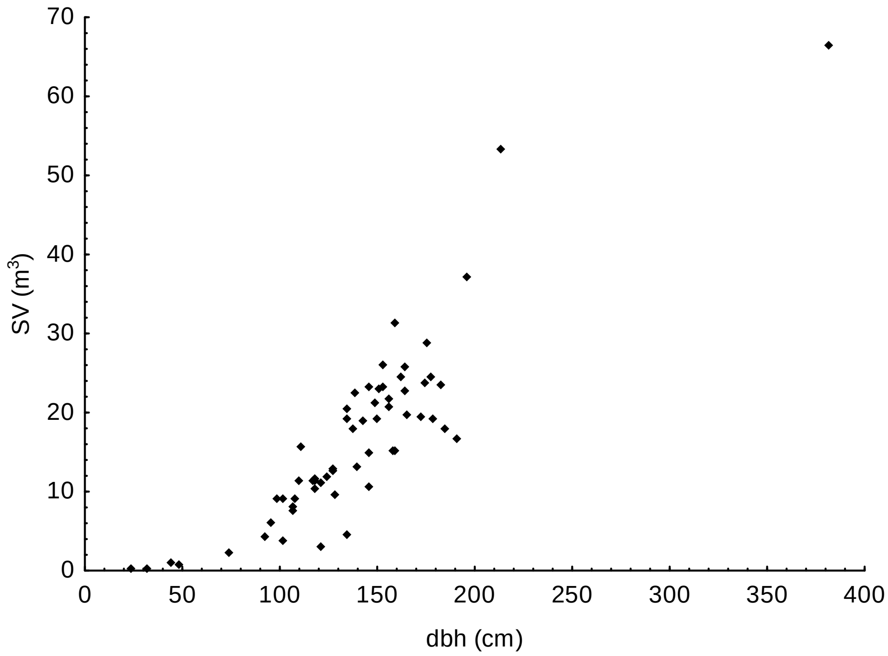


Figure 2: Scatter plot showing relationship between the stem volume (SV) and the diameter at breast height (*dbh*)

Correlation of the growth variables

The correlation coefficients between the *M. excelsa* tree growth variables are presented in Table 5. The Table shows that there is a very significant (p<0.05) correlation among all the variables. Additionally, there is a strong linear relationship (at p = 0.01) between *db* and THT, db and MHT, *db* and *dm, db* and *dt*, *dbh* and THT, *dbh* and MHT, *dbh* and *dm* and *dbh* and *dt*. This suggests that *db* and *dbh* could serve as a substitute to *dm* and *dt* in tree volume estimation for *M. excelsa*. Similar results have been reported for pines (*Pinus* spp) and oaks (*Quercus* spp) (Bylin, 1982), teak (*Tectona grandis*) (Osho, 1983) and bald cypress (*Taxodium distichum*) (Parresol, 1998).

Although, the linear correlation coefficient between *db* & SV and between *dbh* & SV is quite high (0.88), an examination of the scatter diagram indicates that the relationship is somehow curvilinear (Figure 1 & 2). This is very informative in selecting the regression equations to be used for estimating tree volume from diameter at base and at breast height.

Table 5: Correlation Matrix for the Tree Growth Variables

	SV	BA	Db	dbh	THT	MHT	dm	dt
SV	1.00							
BA	0.84**	1.00						
Db	0.88**	0.87**	1.00					
Dbh	0.88**	0.92**	0.97**	1.00				
THT	0.58**	0.41*	0.64**	0.59**	1.00			
MHT	0.65**	0.32*	0.53**	0.51**	0.72**	1.00		
Dm	0.82**	0.65**	0.82**	0.83**	0.52**	0.50**	1.00	
Dt	0.78**	0.59**	0.79**	0.79**	0.53**	0.51**	0.98**	1.00

* = Significant at 0.05 p-level
** = Significant at 0.01 p-level

Tree Volume Prediction

The nine (9) volume prediction equations tried in this study are as follows:

$$SV = -11.6730 + 16.8030db \qquad \text{.........5}$$

($R^2 = 0.7829; SEE = 5.4262; p<0.05$)

$SV = -11.7831 + 20.5709dbh$ 6

($R^2 = 0.7883$; SEE = 5.3571; $p<0.05$)

$SV = -12.1483 + 7.5324db + 11.6499dbh$ 7

($R^2 = 0.7975$; SEE = 5.2863; $p<0.05$)

$SV = 11.5809 + 1.0921dbh2db$ 8

($R^2 = 0.5666$; SEE = 7.6667; $p<0.05$)

$SV = 5.4465 + 5.1926dbh^2$ ……….9

($R^2 = 0.7103$; SEE = 6.2680; $p<0.05$)

$SV = -9.5437 + 17.6403dbh + 0.8399dbh^2$ ……….10

($R^2 = 0.7910$; SEE = 5.3700; $p<0.05$)

$lnSV = 1.4530 + 2.2930lndb$ ……….11

($R^2 = 0.8974$; SEE = 0.3518; $p<0.05$)

$lnSV = 1.8647 + 2.4093lndbh$ ……….12

($R^2 = 0.8888$; SEE = 0.3661; $p<0.05$)

$lnSV = 1.5924 + 1.4915lndb + 0.8600lndbh$ ……….13

($R^2 = 0.9011$; SEE = 0.3485; $p<0.05$)

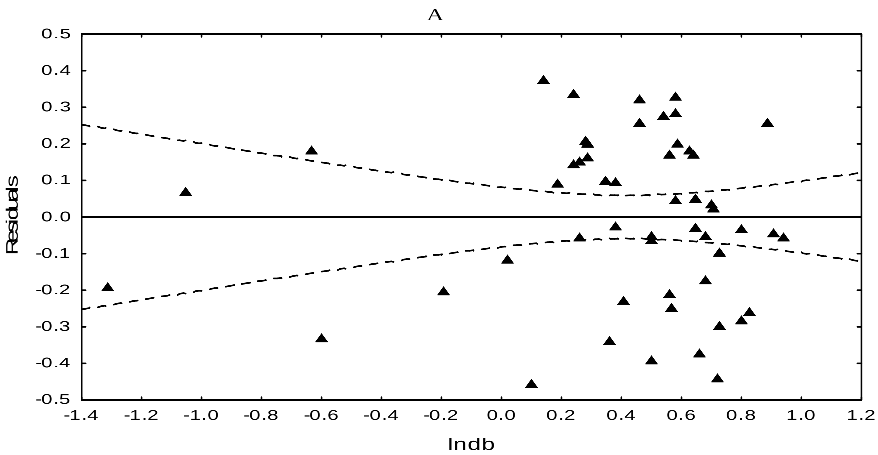
All the volume prediction equations (Equation 5-13) seem statistically sound ($p<0.05$) to predict the volume taking diameter at base and at breast height as the independent variable. By comparing the regression statistics of the nine equations, equation 13 was considered the best, as a result of its highest coefficient of determination (0.9011) and smallest standard error of estimate (0.3485). Consequently, it was further examined to determine its effectiveness. The equation was one of the logarithmic equations, which involves transformation of both the dependent and independent variables. Such transformation of data having curvilinear relationships permits the usual application of the ordinary least squares method of regression analysis. In a related study on baldcypress in South Delta region of Louisiana, USA, Parresol (1998) reported that the logarithmic equation was the most appropriate for predicting volume from tree diameter. Although, his equation had a negative intercept and a positive slope, while the best equation from this study had a positive intercept as well as the slope. This difference in the sign of intercept may have been due to difference in tree species involved.

Scatter diagram of the residuals over the range of the independent variables are presented in Figure 3 (A & B). The graphs revealed that the assumption of independence of residuals is valid, and there is no evidence of an outlier. Equation 13 was used to generate predicted volume of the *M. excelsa* from the institutions. Mean of predicted stem volume (PSV) and observed stem volume (OSV) are shown in Table 5. However, validation of the equation was done by testing for significant difference between the PSV and OSV. The paired t-test showed that there was no significant difference ($p>0.05$) between them (Table 6). In addition, there was a very significant linear relationship between the PSV and OSV ($p<0.05$). Hence, these suggest that the best chosen volume prediction equation gave reasonable estimates of *M. excelsa* volume and that combination of diameter at base and at breast height as the independent variable was a good predictor. Even though the equation is a logarithmic equation, yet it is desirable to express the predicted values in arithmetic units. However, this cannot be done by just taking the antilogarithm of the unbiased logarithmic estimate. As emphasized by Parresol (1998), the antilogarithm of *In SV* yields the median of the skewed arithmetic distribution rather than the mean. Consequently, the correct method for converting the predicted logarithmic values into arithmetic units is to use the expression specified by Yandle and Wiant (1981) as follows:

$$v = \exp(Y + \sigma^2/2 \quad \text{..........} 14$$

Where, v = Predicted volume in arithmetic units,

σ^2 = error variance. For instance the predicted volume for a tree whose diameter at base and at breast is 53cm and 44cm respectively is 1.10m^3.



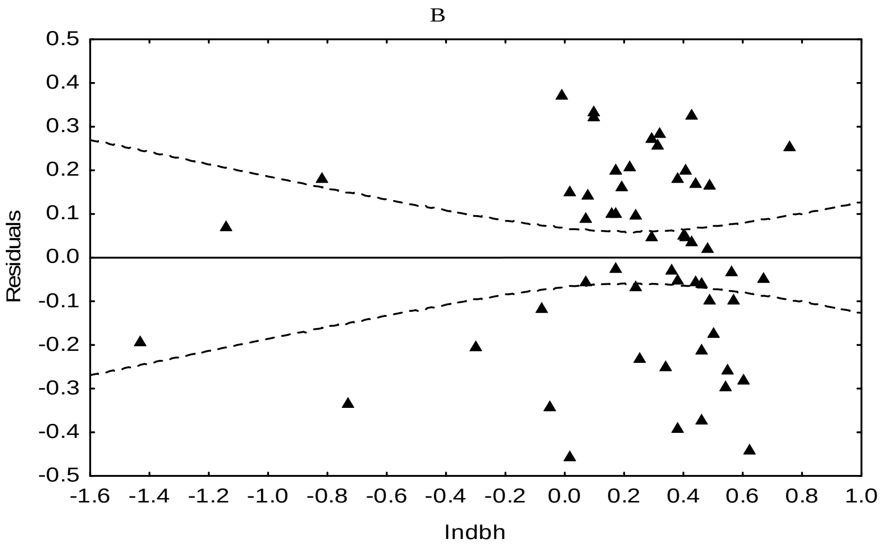


Figure 3: Residual Plots for the best volume equation

Table 6: Relationship between observed and predicted stem volume

Variable	Mean	t-value	p-level	r	p-level
OSV (m3)	16.59	0.714	0.478ns	0.828	0.000*
PSV (m3)	17.02				

OSV = observed stem volume, PSV = predicted stem volume
ns= not significant (p>0.05)
*= significant (p<0.05)

CONCLUSION

All the nine developed models in this study seem statistically sound to predict stem volume of *M. excelsa* trees. However, it was discovered that the logarithmic equation was the best of all the equations. Hence the stem volume of *M. excelsa* can be predicted from diameter at base and at breast height by employing this equation to give good precision. The prediction equation developed in this work would be very useful and applicable where tree dimensions such as diameter at middle and top as well as the height of *M. excelsa* is difficult to assess and there is need to reduce the cost of inventorying such species. Also, these diameter based *M. excelsa* equations presented in this paper provide a simple tool for volume estimation in field research and commercial calculation before harvest and valuation of the species where *db* and *dbh* fall within the range observed in this study.

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