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GROWTH AND YIELD MODELS FOR TEAK IN SHANGEV-TIEV PLANTATION, KONSHISHA LOCAL GOVERNMENT AREA BENUE STATE, NIGERIA

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ABSTRACT

Growth and yield models can estimate future yields and explore silvicultural options. Models enable an effective process to prepare resource forecasts, the most significant aspect is its potentials to explore management options and silvicultural alternatives. Growth and yield models give a mathematical and statistical way to quantifying the quantity of wood in a tree without felling the tree in order to manage wood resources, take economic choices and promote sustainable forest management. The increasing wave of errant and unmanaged exploitation of forests causes high rate of deforestation therefore the reservation of forest estates has to be created. The aim of this study was to assess the growth and yield models of Shangev-tiev teak plantation in Konshisha Local Government Area of Benue State. Twenty-five sample plot size of 20m x 20m were randomly selected. Growth variable measured were total height, diameter at breast height and diameter at the base. A total of twelve volume models was selected to estimate tree volume. Tree volume had a mean of 1.27m^3 with 2.68m^3 as the maximum volume. All the models generated have positive intercepts. Models 3, 7, 11 and 12 had a R^2 value of 0.99 and standard error estimate of 0.01. $\ln V = 0.30 + 0.01 \ln (D)$ had the highest F-Ratio value of 4385 with a R^2 value of 0.90 and standard error estimate of 0.25. Model 5 is recommended for use in the study area because it is simpler and practical because it needs only one explanatory variable (diameter at breast height) to be measured and by pass the height measurements that is time-consuming and costlier. It also by passes the errors inherent in height measurements of standing trees. It is recommended that beating up should be carried out because of the shortage of trees as a result of deforestation, expansion and associated erection of buildings to avoid extinction of trees in the study area.

Keywords: Coefficient of determination, diameter at breast height, Growth, *Tectona grandis*, volume models

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INTRODUCTION

Teak (*Tectona grandis* Linn f.) is a subtropical deciduous tree of the Verbenaceae family and a significant as well as precious multipurpose tropical hardwood (Koirala *et al*., 2017). *Tectona grandis* is one of the prominent tree species planted in tropical African countries such as Nigeria, Ivory Coast and Ghana, South and Central American countries like Brazil, Costa Rica, Panama and others, Indonesia (Tewari and Mariswamy, 2013). It occurs naturally in Myanmar (formerly Burma), India, Thailand, and Lao People's Democratic Republic (Hansen *et al*., 2017).

Nigeria is known to have the largest teak plantation in Africa, with approximately 70,000 ha, that covers 52.7% of the total area under teak plantation in the continent (Dantani *et al*., 2019). *Tectona grandis* was introduced in Nigeria in

1902 through planting the seeds which was gotten from India and thereafter from either Thailand or Myanmar (Hansen *et al*., 2017).
Forests have vital roles in reclamation of marginal lands, soil regeneration and preventing soil erosion. Other roles of forests are shelter and weather amelioration, food and medicinal products all of which are important to the sustenance of life. The forests, is more than any other biotic aspect of the ecosystem, is crucial to environmental stability and the quality of life. The ecosystem roles provided by forests sustain human society and the surrounding environments (Iizuka *et al*., 2022). Carbon sequestration is now a discussion of intrigue for mitigating the global impacts of climate change (Iizuka and Tateishi, 2015).

While government is ensuring conservation of the forest resources, the stability of the economy, employment opportunities, the communities and private stakeholders make sure they benefit from the same resources without ensuring the sustainability of the resources. In Nigeria the rural dwellers quest to expand agricultural lands at the expense of forest resources has continuously risen. The increasing wave of errant and unmanaged exploitation of forests causes high rate of deforestation therefore the reservation of forest estates has to be created. In some vicinities, forest management often locked out the local communities who are important in having long-term sustainability (Azeez *et al*., 2013). In forest management strategies, the association between government and the local communities has been noted to be hostile (Akindele, 2003), because of the failures of government to adequately merge the communities into forest management processes.

Rapid degradation of natural resources worldwide has been a concern among researchers. Since the beginning of this current century the speed of forest destruction has increased greatly. There is no significant difference in the rate of forest loss at the global level compared to Nigeria. The conservation of natural resources can be facilitated through the use of existing knowledge of rural communities on the sustainable use and management of forest resources. In recent decades, conservation regimes have not been able to manage resources in a sustainable route due to its rigidity which has deprived the local communities of the desire to manage and utilise resources in a way that is sustainable. This could be attributed to the non-recognition and participation of indigenous communities of Shangev-tiev in Konshisha Local Government Area in all cases of pre- and post-harvest assessment and difficulties in stock assessment and planning whose livelihood depends on such resources, and are the custodians of the natural landscapes.

The economic benefits of Teak plantations are undeniable, local information on the growth and yield characteristics of teak, that can pave way for the exploitation of its potential benefits and taking crucial management decisions, is scare in various locations (Álvaro, *et al*., 2018). Creation of wood-based industries needs detailed and up-to-date information on the source, the rate of supply of raw materials and quantity available, this needs elaborate information of the forest resources available as well as the rate of development and depletion. The significance of monitoring of growth and yield dynamics of trees is important to ensure sufficient management responses (Amusa and Adedapo, 2020).

Growth and yield models for quantifying the volume of trees are beneficial tools in forest management (Kershaw *et al*., 2017; Burkhart *et al*., 2018). Growth and yield models can estimate future yields and to explore silvicultural options. Models enable an effective process to prepare resource forecasts, the most significant aspect is its potentials to explore management options and silvicultural alternatives. For instance, foresters need the information on long-term effect on both the forest and on future harvests, of a particular silvicultural decision, like changing the cutting limits for harvesting. A growth model, can examine the likely outcomes, for the intended and alternative cutting limits, and therefore decision is objective. Tree volume models that can estimate the volume of trees is important if the trees are cut down for commercial uses (Mugasha *et al*., 2016). Predicting tree volume is one of the primary objectives for sustainable management of forest resources and a number of statistical models is applied in forestry to get this goal (Dende *et al*., 2023).

Growth and yield models give a mathematical and statistical way to quantifying the quantity of wood in a tree without felling the tree in order to manage wood resources, take economic choices and promote sustainable forest management. Researches carried out on exotic plantation species in West Africa has displayed that volume models are important for forest owners and managers in undertaking critical decisions and also planning for wood felling (Goussanou, 2016). This study was carried out to assess the growth and yield models of Shangev-tiev Teak plantation in Konshisha Local Government Area Benue State.

MATERIALS AND METHODS

Study Area

The area of the study is Shangev-tiev teak plantation in Konshisha Local Government Area, Benue State, of Nigeria as shown in Figure 1. The total size of the plantation is 284.77 hectares. Shangev-tiev teak plantation is located between Gaav/ Shangev-tiev close to Agberagba town in Konshisha Local Government of Benue State, Nigeria which lies between latitude 7^0 00'N to $7^0$30'N and Longitude 8^0 30'0E to 9^0 0'0E of Benue State North- Central Nigeria. The relief of the study area range from 84-90m above the sea level. Topography is a fairly level or gently sloped. There is only one drainage system in the study area, these is the semi-permanent streams. It drains into River Konshisha where they are all carried to the sea. There is an abundance and even distribution of water (H_2O) point in the area.

The study area usually comprises of two seasons, the wet and dry (Harmattan) seasons. The vegetation of the study area is described as guinea savannah. The soil of the study area is a good sandy loam underlying rocks are of the cretaceous series It is very high in organic matter giving it dark color appearance.

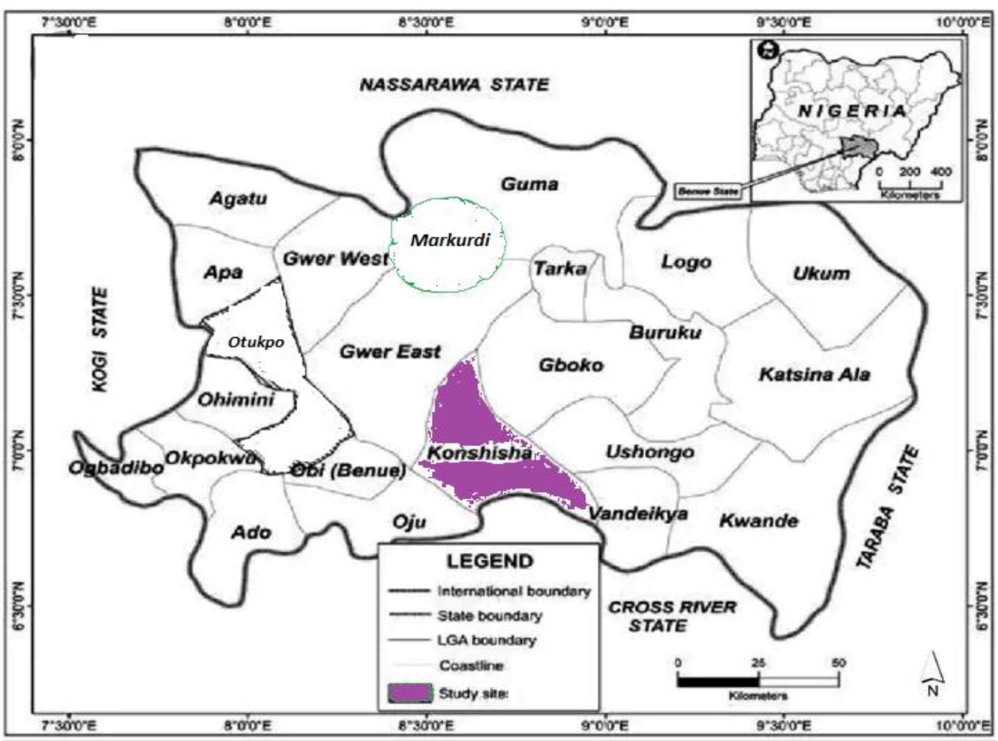

Figure 1: Map of the study area

Sample plot
The stand of *Tectona grandis* (teak) plantation was investigated. The total size of the plantation was two hundred and eight four (284.77hectares). Twenty-five (25) plots of sample plot size of 20m x 20m were randomly selected. A total number of four hundred and sixty-nine (469) tress was examined in the entire stand of *Tectona grandis* plantation.

Data collection
Haga altimeter was used in measuring tree height and diameter tape was used in measuring diameter at breast and at the base.
Growth variable measured were
i Total height (in meters)–vertical distance from the base of the tree to the tip of the crown.
ii The Diameter at breast height –Diameter measurement taken at point 1.30m along the stem from ground
iii Diameter at the base –Diameter measurement taken at 0.3m along the stem from ground.

Volume Models
A total of twelve (12) volume models that consisted of simple linear and multiple linear regression models and their logarithmic transformation was used for tree volume estimation. The tree volume is dependent variable while the independent variables are stump diameter, diameter at breast height and total height. Simple and multiple regression analysis was used for the volume prediction equations (Akindele and LeMay, 2006; Tewari *et al*., 2013).

The simple linear model uses one variable (D), (DB), and combined variable (D^2H), and (DH) to estimate tree volume.
The simple linear models are:
$V = b_0 + b_1(D)$ ……. (1)
$V = b_0 + b_1(DB)$ ……. (2)
$V = b_0 + b_1(D^2H)$ ……. (3)
$V = b_0 + b_1(DH)$ ……. (4)
The logarithmic transformation of equation (1, 2, 3 and 4) was used to predict the parameters:
$lnV = b_0 + b_1 \ln(D)$ ……. (5)
$lnV = b_0 + b_1 \ln(DB)$ ……. (6)
$lnV = b_0 + b_1 \ln(D^2H)$ ……. (7)
$lnV = b_0 + b_1 \ln(DH)$ ……. (8)
The multiple linear models are:
$V = b_0 + b_1(D) + b_2(H)$ ……. (9)
$V = b_0 + b_1(D) + b_2(D^2)$ ……. (10)
$V = b_0 + b_1(D) + b_2(D^2H)$ ……. (11)
$V = b_0 + b_1(D) + b_2(H) + b_3(D^2H)$ ……. (12)
Where V = volume, b_0, b_1, b_2 and b_3 are the regression parameters, DB = diameter at base, D = diameter at breast height, ln = natural log and H = total height.

Model Assessment
The models were assessed to know their validity and recommend the best model to be used. The statistical metrics used are:

Coefficient of Determination (R^2)
The (R^2) measures the proportion of variation in the tree volume which can be explained by the independent variables in the volume equations. For the equation to be accepted, R^2 value should be > 0.5 (Thomas, 1977). The formula below was used to compute coefficient of determination.

$$\boldsymbol{R^2} = 1 - \frac{\sum (y-\hat{y})^2}{\sum (y-\bar{y})^2} \text{ ……. (13)}$$

Where R^2 = Coefficient of determination, y is the reference value, $\hat{y}$ is the predicted value, $\bar{y}$ is the mean of the reference values and 1= regression line.

Standard Error of Estimate
The value should be small for the model to be accepted.

$$\text{SEE} = \sqrt{\frac{\sum_{i=1}^{n}(V_i-\hat{V}_i)^2}{n-k}} \quad \text{……. (14)}$$

V_i is the observed volume for the ith tree; $\hat{V}_i$ is the predicted volume for the ith tree; k is the number of model parameters; n is the number of observations.

Significance of Regression (F-ratio)
It was used for testing overall significance of the regression models. F-tabulated at $p < 0.05$ level of significance was compared with the F-ratio (F-calculated). When F-calculated is greater than F-tabulated the model is significant and is used in predicting tree volume.

RESULTS
Growth Variables
The result of the descriptive statistics (i.e., the mean, standard deviation, standard error, co-efficient of variation, minimum and maximum of

each growth variable (characteristics) for the tree species is shown in Table 1. Volume has a mean of 1.27m^3 with 0.05 m^3 as minimum and 2.68m^3 as the maximum volume. Diameter at breast height has a variable mean of 0.18m with 0.08m as minimum and 0.38m as maximum. Diameter at base has a mean of 0.24m and 0.59m maximum. Height has a mean of 3.61m with the minimum of 2.00m and maximum of 6.3m.

Table 1: Descriptive Statistics of Tree Variables for Shangev-Tiev teak plantation

Tree variable	Num.	Minimum	Maximum	Mean	SE	STDV	C.V %
Vol	469	0.05	2.68	1.27	0.02	0.38	53.5
H	469	2.00	6.3	3.61	0.04	0.88	24.3
DH	469	0.18	2.22	0.69	0.02	0.37	53.0
D	469	0.08	0.38	0.18	0.00	0.05	28.4
D@B	469	0.12	0.59	0.24	0.00	0.07	30.2
D^2H	469	0.06	28.97	2.72	0.19	4.05	148.8
LnVol	469	-3.05	0.99	-0.48	0.03	0.53	-110.3
LnD	469	-2.49	-0.96	-1.75	0.01	0.29	-16.7
LnD@B	469	-3.97	-0.53	-1.20	0.02	0.33	-22.2
LnD^2H	469	-2.76	3.37	0.26	0.06	1.26	474.6
LnDH	469	-1.72	0.80	-0.49	0.02	0.51	-103.2

Where H = Total height (m), D = Diameter at breast height (m), D@B = Diameter at base (m), ln = natural log and Vol =Volume (m^3).

Diameter and Height Distribution

Figure 1 show a height class distribution for the year 2021, class 6-7m had the least frequency. Diameter at breast height distribution is shown in Figure 2 the class distribution of trees at 14-19 cm had the highest frequency. Figure 3 shows the Diameter at the base distribution the class 20-29cm had a frequency of 250 trees.

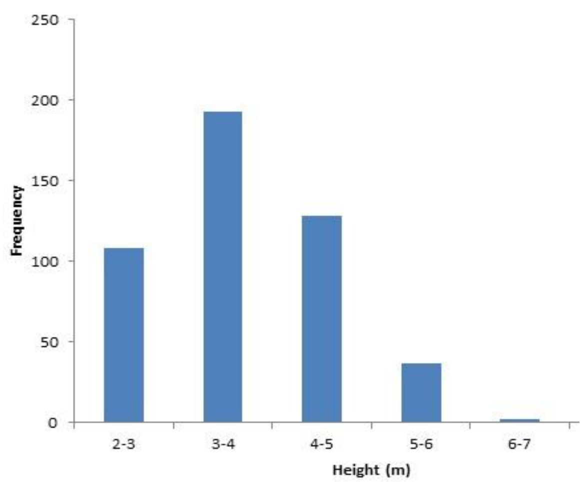

Figure 1: Height class distributions for (*Tectona grandis*) in Shangev-tiev teak plantation

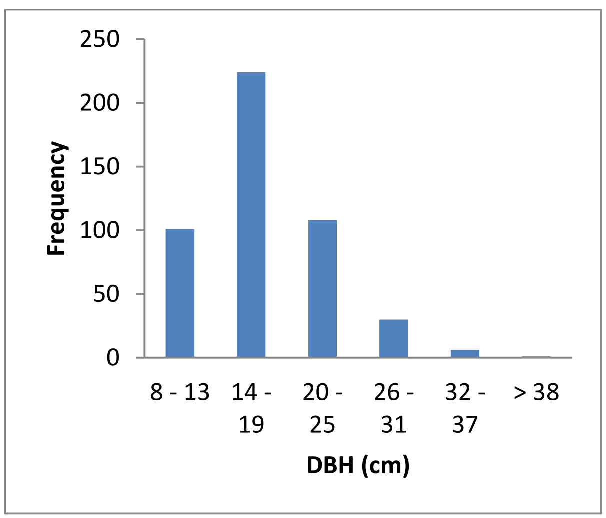

Figure 2: Diameter at breast height distribution for (*Tectona grandis*) in Shangev-tiev plantation

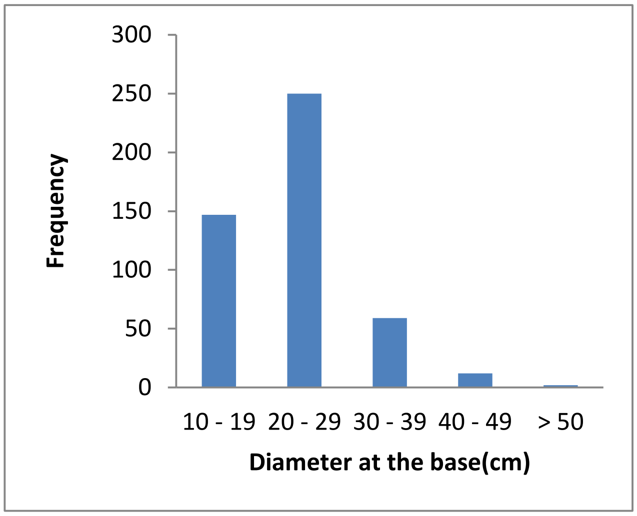

Figure 3: Diameter at the base distribution for (*Tectona grandis*) in Shiengev-tiev plantation

Volume Equations

The regression parameter for *Tectona grandis* in the study area is presented in Table 2. Coefficients of determination (R^2) ranged from 0.06 to 0.99. All the models were significant at p<0.05 level. In this study, all the models generated have positive intercepts (table 2). The standard error estimate ranged between 0.01 to 3.31.

Models 1, 2 and 10 are not suitable for tree volume estimation in the study area except for models 3, 7, 11 and 12 that had a R^2 value of 0.99 and standard error estimate of 0.01 while model 9 had a R^2 value of 0.99 and standard error estimate of 0.32 an alternative is $lnV = 0.99 + 1.47(DH)$ with a R^2 value of 0.97 and standard error estimate of 0.13. $lnV = 0.30 + 0.01 \ln (D)$ had the highest F-Ratio value of 4385 with a R^2 value of 0.90 and standard error estimate of 0.25.

The coefficients indicate the predicted change in the volume of the tree associated with a one-unit change in each predictor variable while the other variables are constant. $V = 0.30 + 0.00(D) + 1.20(H)$, a coefficient of 1.20 for height signifies that, a one-unit increase in height is linked with a 1.20 increase in tree volume, provided the diameter at breast height remain constant.

Table 2:Model Summary for teak plantation in Shangev-Tiev Plantation in Benue state, Nigeria.

Model No.	Models	R^2	SEE	F-Ratio	Sig. F
1	V = 0.30 + 0.00(D)	0.072	3.28	36	0.00
2	V = 0.27 + 0.05(DB)	0.06	3.31	27	0.00
3	$V = 1.00 + 7.86(D^2H)$	0.99	0.01	24	0.00
4	$V = 0.99 + 0.00(DH)$	0.98	0.51	2	0.00
5	$lnV = 0.30 + 0.01 \ln (D)$	0.90	0.25	4385	0.00
6	$lnV = 0.95 + 2.68\ln (DB)$	0.61	0.51	728	0.00
7	$lnV = 1.00 + 1.00\ln (D^2H)$	0.99	0.01	3	0.00
8	$lnV = 0.99 + 1.47\ln(DH)$	0.97	0.13	2	0.00
9	$V = 0.30 + 0.00(D) + 1.20(H)$	0.99	0.32	3	0.00
10	$V = 0.30 + 0.00(D) + 0.30(D^2)$	0.08	3.28	19	0.00
11	$V = 0.30 + 0.00(D) + 8.86(D^2H)$	0.99	0.01	14	0.00
12	$V = 0.30 + 0.00(D) + 1.2 (H) + 8.86(D^2H)$	0.99	0.01	1	0.00

DISCUSSIONS

The mean DBH and height was (0.18m and 3.61m) this is an indication that most of the trees encountered in the study area are not above minimum merchantable size of 48cm stipulated by logging policy of south western Nigeria. This is not in line with the study of Nurudeen *et al.* (2014) who reported high mean values of 1.24m and 16.56m for DBH and height of trees. The mean DBH is in line with the study of Tewari and Singh (2018) who reported mean DBH of 18.07cm but had a mean total height of 14.27m for *Tectona grandis* Stands in Gujarat, India.

Selected volume equations should be because the tree parameters are easily and not expensive to measure (Phillips, 1995) as well as ease of operation is a significant criterion in the use of volume tables (Perez and Kanninen, 2003). The coefficients of determination differ among the models; it could be due to the fact that single variable of Diameter at the base or DBH had low R^2. The high R^2 results suggest that a very large portion of the variation in tree volume is explained by diameter at breast height and height for the plantation. This is in agreement with the result of Koirala (2017) that had an R^2 of 0.959 for volume of teak in Central Lowlands of Nepal. Dende *et al*. (2023) had an adjusted R-squared of 0.913 for a regression modelling approach for stem volume estimation of *Gmelina arborea* and *Tectona grandis* within Dogo-Kétou Forest Reserve, Benin Republic. The adjusted R-squared shows that 91.3% of the variable in the volume of the tree is due to the variation in the height, diameter and tree species (Alkharusi, 2012).

Logarithmic volume models have the merit of more closely fulfilling the homogeneity of variance assumption of ordinary regression but suffer from the demerit that a transformation bias is phase in (Avery and Burkhart, 1994). The logarithmic transformation of the models was very efficient. This is in line with the studies of Louis, (2005) in developing total volume model for teak in Tanzania. The combined variable equation, is well known in volume estimations of various tree species with R^2 usually above 95% (Avery and Burkhart, 1994). Aghimien *et al*. (2016) developed growth and yield models for uneven-aged secondary forest in IITA, Ibadan, Nigeria and stated that the logarithmic transformed model of the combined variable of diameter at breast height and height performed excellently having an R^2.value of 0.94 which is close to the value obtained in this study and a standard error of 0.4285.

Volume models with two independent variables (diameter at breast height and total height) performed better than those with only one (diameter at breast height or diameter at the base) based on the model evaluation. The model $V = 1.00 + 7.86(D^2H)$ is recommended for use in the study area.

Model 5 is simpler and practical because it needs only one explanatory variable (diameter at breast height) to be measured and by pass the height measurements that is time-consuming and costlier. It also by passes the errors inherent in height measurements of standing trees.

CONCLUSION

Growth and yield models were developed for teak in Shangev-Tiev plantation, Konshisha Local Government Area of Benue state, Nigeria. This study assessed tree species variables and also tested the efficacy of linear regression equations for tree volume estimation in Shangev-Tiev teak plantation.

Most of the trees were distributed in the middle diameter class and the percentage in the large diameter class is considerably small. This is because trees with very large diameters are usually the fortunate ones during the expansion drive of the study area. The small number of trees in the study area shows that the area has been disturbed in the recent past due to expansion and the associated erection of buildings to accommodate more area of buildings. Obviously, the study area is sparsely rich in trees.

The stand volume equations, which incorporated tree growth variables, will enhance future yield prediction of the study area since they provide quantitative basis for estimating stand growth. The volume prediction equations provide the means through which the production potential of the existing stands can be estimated in the study area. It is believed that the equations obtained in this study area will enhance sound and informed management decisions for the study area for management purposes.

RECOMMENDATIONS

i. The research recommends that beating up should be carried out because of the shortage of trees as a result of deforestation, expansion and associated erection of buildings to avoid extinction of trees in the study area.
ii. The volume equation developed in this study is very useful in all cases of pre- and post-harvest assessment and can be useful for stock assessment and management planning. The selected models can be applied in similar sites with little or no variation.
iii. The government should involve the local people in management practices to avoid deforestation of this forest for agricultural purposes and fuel wood consumption.

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