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ASSESSMENT OF GROWTH VARIABLES AND REGRESSION MODELS FOR THE TREE VOLUME PREDICTION OF *Azardirachta indica* (A. Juss) AT WARWADE PLANTATION, DUTSE, JIGAWA STATE, NIGERIA

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ABSTRACT

Savannah is well known with less diverse ecosystem. Tree growth dynamics is a major technique in quantifying the forest composition. However, there is need to determine community structure and model which is suitable for Azadiractha indica in arid land. Therefore, the experiment was carried out to assess the tree growth variables and regression models for tree volume prediction of Azadiractha indica in Warwade plantation. Four (4) plots of 25m x 25m were using random sampling technique at interval of 100m from each other. Tree growth variables such as: diameter at breast height (DBH), diameter at the base (Db) middle (Dm), top (Dt) and height were taken with aid of Spiegel relascope. Frequency of occurrence of all tree with diameter at breast height (DBH) ≥10cm were measured. Three regression models were developed which are exponential, Quadratic and Vapour pressure. A total of eighty-one (81) stems ha^{-1} of the species were identified and counted. The tree growth variables measure showed that Azadiractha indica plantation had total volume of 14126.59m^3 per ha^{-1} and basal area was 339998.19m^2. The range of 61-70cm of diameter class had the highest number of terms per hectare (33.33%). The models developed showed that exponential model volume was found to be more suitable and good fit for tree volume prediction in the context of the data used. Therefore, exponential model generated in this study is recommended for volume prediction at Warwade Forest Reserve, Dutse, and Jigawa State.

Keywords: Growth Assessment, Regression Models, Tree Volume Prediction, *Azardirachta indica* and Warwade.

INTRODUCTION

The rainforest is well known with the most biologically diverse terrestrial ecosystem on earth (Gillespie *et al*., 2004; Onyekwelu *et al*., 2007*;* FAO, 2010; Salami and Akinyele, 2018). In terms of tree composition and species diversity, tropical rainforests are Earth's most complex ecosystems (Gebreselasse, 2011) with a vast area having savanna vegetation. This is a region that is itself diverse, necessitating a classification into derived savanna, southern Guinea savanna and northern Guinea savanna (Kumar *et al*., 2006; Salami, 2017). The resources abound in the High Forests, woodlands, bush lands, plantations and trees on farmlands. The forests occupy about 10 million hectares representing almost 10 percent of the total land area of 92, 377 hectares. This total is made up of about 445 gazetted Reserves, distributed over the five main ecological zones of Fresh water/mangrove, the lowland rainforest, the derived savanna and the sahel/sudan savanna. More than 5 percent of the total land area is devoted to wildlife conservation also distributed across the major ecological zones. Total area covered and the Volume of stands in national plantations are 382m^3 /ha and 165 million per cubic meter in 2010 (FAO, 2010). A plantation provides an extreme example of an even-aged structure. Two-aged stands are often, but not always, a result of human intervention and may be a temporary condition as management works towards developing an even-aged or uneven-aged stand (Salami *et al.,* 2020). Structure within these stands will often have patchy or partial over story canopies with a well-defined second story, or layer, of either pole timber or seedlings and saplings. Uneven-aged structure means a stand has three or more age classes. This type of structure is a result of increasing species, age- and size-class diversity within a stand. On the other hand, plantations are useful in silviculture, agro-forestry and all other industrial sectors that depend on the trees. It is also helpful in restoration of biodiversity, ecosystem structure and functioning. Plantations raised in fallow land, wastelands, mine spoils etc are helpful in reducing noise pollution, effective carbon sink supplier of vital oxygen and conserve soil and water (Sami and Jha, 2006). Tree plays a significant role in reducing erosion and moderating the climate. They remove carbon dioxide from the atmosphere and store large quantities of carbon in their tissues. Trees and forests provide a habitat for many species of animals and plants. Tropical rainforests are among the most bio diverse habitats in the world (Groulez and Wood, 2000). Forest influences people's health positively by preventing illnesses that are mediated by psychological processes such as stress and in curing diseases such as burn-out and depression. Green areas can also help in establishing personal and community identity, social activity, and social participation (Irvin *et al.*, 2002). Visiting the forests strengthens the human immune system and has a preventive effect on cancer generation and development (Morimoto *et al*., 2008). Forest regeneration, growth and mortality generate very specific structures Different rainfall also makes different kinds of forest. No forests exist in deserts, just a few trees in places where their roots can get at some underground water (Eagleman, 2014). Piotto (2007) proposed that the performance of planted native species of economic importance must be known to precisely prescribe appropriate species for enrichment planting for selecting potential species and predict their response. They are often less diverse and composed of fewer species than other structures. Most of the tree diameters come close to the average stand diameter. The aim of this growth assessment is to provide comprehensive information about the state and dynamics of forest for strategic and management planning.

Fig 1: *Azarditchrata indica* (Neem) plantation in Warwade, Dutse, Jigawa State.

MATERIALS AND METHODS

Study area

This study was carried out at Warwade Forest Reserve, Dutse Local Government about 6km away from capital city of Jigawa State. Study area was established during administration of former military governor Audu Bako in the 1970's (Ringim and Shafiu, 2019). Reserve is located between latitude 11^0.43' 30''N - $11^0$46'30''N and longitude $9^0$11'30''E - 9^0 16'30''E. The relief is flat with little undulation (Tasi'u, 2018). The geology of the area is sedimentary formation of the Chad basin (Olofin, 1987). The soil type is sand-loam, loamy and clay-loam soil respectively (Jigawa Agricultural Rural Development Agency, 2016). In terms ground water the area is characterized by low surface water and high ground water. The water table of the area is from 25m to 50m (Tasi'u, 2014). It covers the surface area of 526.0 ha (Ita *et al.*, 1985), height and Reservoir of 10m and 12.3m^3 (FGN, 2004). The optimum day temperature at day time is 29-33^0c and declined to 19-23^0C at night, annual rainfall per year is 1200 to 1500mm. Fishing activities takes place regularly day and night by local fishermen's. Also, some agricultural activities are carried out by local farmers both in raining and dry season.

Warwade Plantation

Warwade plantation was established for the purposes to reduce water evaporation from the dam. It serves as habitat to many bird species and reptiles within the dam. They also act as a giant filters clearing the air we breathe. Warwade Dam plantation was established in the 1970's to support diverse vegetation of plant species including shrubs, herbs, and tree. Some important plant species are Neem (*Azadirachta indica*), which are dominants species and some shrubs species include, Kharroub (*Piliostigma reticulum*), Kapok tree (*Calotropis procera*) and grass species: Coco grass (*Cyperus rotundus*), Sickle pod (*Cassia tora*) and Cane grass (*Eragrostis tremula*). The reserve is also used for propagating arable crops (rice, sorghum) during raining season. The area is comfortable and so attractive. Different plant species and shrubs dominated are: *Acacia species*, *Adansonia digitata*, *Azadirachta indica and Mangifera indica a*re found there.

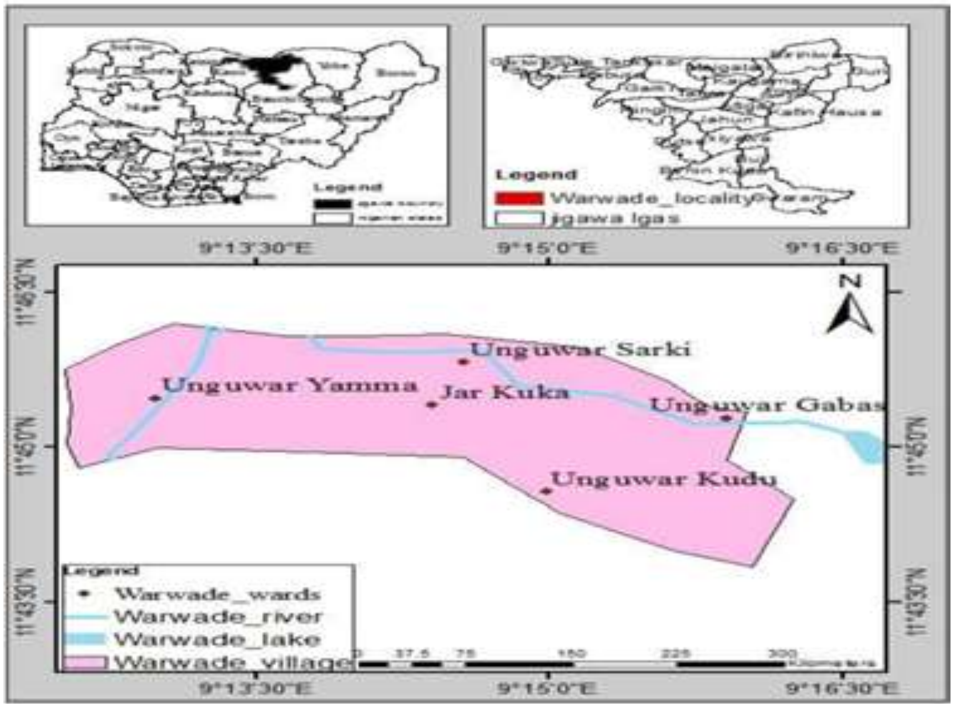

Fig 2: Map of Warwade Forest Reserve
Adopted by: Tasi'u, (2018)

Sampling design and data collection

Simple Random Sampling design was used during this study. Four (4) sample plots of equal size (25m ×25m) were laid and assessed. The plantation has the total area of 3.4ha and 2,500m^2 was surveyed which equivalent to 8.2% sampling intensity. Within each plot, growth data on total number of species, diameter at breast height (dbh), Diameter at the three points (base, middle and top) of the trees and total height of all living trees above 10 cm was recorded according to (Onyekwelu *et al*., 2007; Salami, 2017) using Spiegel relascope. The tree variables measured were used to extrapolate volume and basal area for the trees.

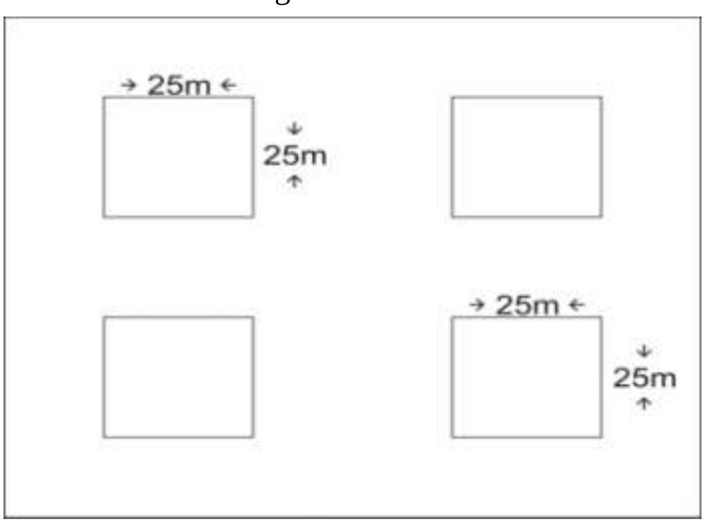

Figure 3: A Four (4) sample Plot layout of Random Sampling Technique

Data Analysis: Estimation of Variables

Basal area estimation

The Basal Area (BA) of individual trees were estimated using the formula according to Husch *et al*., (2003)

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

Where BA = Basal area (m^2), D = dbh (cm) and π = 3.142 (constant)

Volume over bark estimation

The volume over bark of individual trees was estimated using Newton equation developed for stem volume estimation (Husch *et al*., 2003):

$$V = \pi H \left[\frac{Db^2 + 4\mathrm{Dm}^2 + \mathrm{Dt}^2}{24} \right] \quad \ldots\ldots[2]$$

Where V = Volume over bark (m^3), H = stem height (m), Db = Diameter at the base, Dm = Diameter at the middle, Dt = Diameter at the top and π = 3.142 (constant)

Percentage Bias Estimation

The absolute percentage difference (% bias) was determined by dividing the difference between volumes obtained with Newton's formula (observed volume) and models output by the same observed volume and multiplied by 100.

Bias Percentage

$$\frac{\mathrm{Vo}-VP}{\mathrm{Vo}} \; x \; 100\,\% \ldots\ldots\ldots[3]$$

Where: Vo =The observe volume
Vp =The predicted volume (models output)

The value must be relatively small for the model to be acceptable for management purpose

Volume Models Assessment and Selection

The volume models were assessed with the view of recommending those with good fit for further uses. Different criteria were used in model selection. The model tested in this study was selected based on the following statistics: Akaike information criterion (AIC) Coefficient of determination (R^2), as well as Standard Error (SE).

Three different models were developed and assessed based on some statistical performance. The equations were ranked and selected on the basis of highest coefficient of determination (R^2), highest correlation coefficient (R), smallest standard error of estimate (SEE), as the best models.

Coefficient of Determination (R^2): This is the measure of the proportion of variation in the dependent variable that is explained by the behavior of the independent variable (Thomas, 1977). For the model to be accepted, the R^2 value must be high (>50%).

Standard Error (SE)

This is also referred to as the standard deviation or residual of the error variance of the estimate. It measures the spread of data and is a good indicator of precision. The value must be small.

RESULTS

Study conducted on the assessment of growth variables and regression models for the tree volume prediction of *Azardirachta indica* at Warwade plantation, Dutse, Jigawa State, Nigeria. The total and mean Dbh were 1802.91cm and 22.26cm respectively while the total and mean Basal area 339996.19m and 411226m. Also, the total and mean volume was 14126.60m^3ha^{-1} and 174.40m^3ha^{-1} (Table 1). The highest percentage height distribution was found with range of 6-10m (79%) while the lowest (12.35%) with range between 11-15m (Table 2). Furthermore, percentage diameter class distribution was assessed. The range between 61 -70cm with 33% had the highest percentage followed by the range of 71-80cm with 22.22% (Table 3).

Table 1: Descriptive statistics for Tree Growth Variables Obtained at the Study Area

	Minimum	Maximum	Total	Mean	Std. Deviation
Dbh (cm)	9.87	34.70	1802.91	22.26	5.55
Dm (cm)	7.64	35.33	1761.53	21.75	5.81
BA (m)	754.87	9332.53	339998.19	4197.51	1972.43
Height (m)	4.00	12.30	632.51	7.81	2.25
Volume (m^3)	34.377	408.710	14126.60	174.40	78.87

Dbh= Diameter at breast height, Dm= diameter at the middle, BA= basal area.

Source: Field survey, (2019)

Table 2: Percentage Height distribution for *Azardirachta indica* in Warwade Plantation

Height (m)	Frequency	Percentage (%)
0-5	7	8.64
6-10	64	79.0
11-15	10	12.35
Total	**81**	**100**

Table 3: Percentage (%) frequency distribution into diameter classes

Diameter classes (cm)	Frequency	Percentage (%)
10-20	0	0
21-30	1	1.24
31-40	4	4.93
41-50	3	3.70
51-60	6	7.40
61-70	27	33.33
71-80	18	22.22
81-90	15	18.52
91-100	2	2.47
>100	5	6.17
Total	**81**	**100**

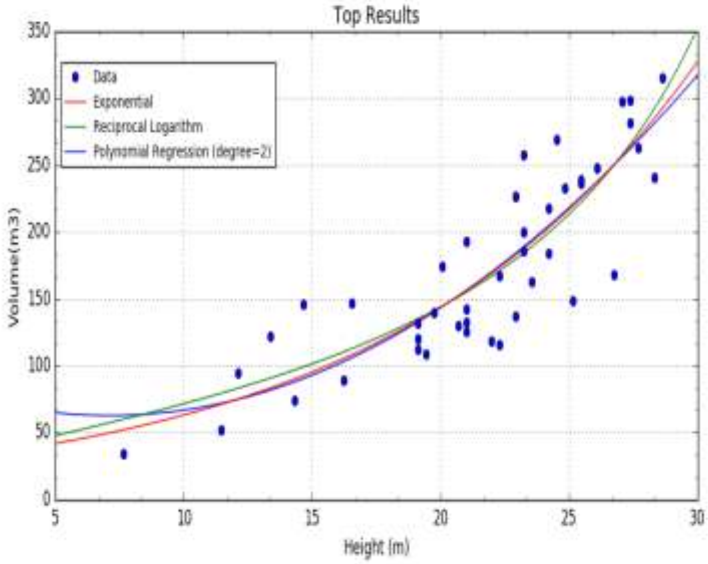

Fig 4. Graph for Estimation of Volume from Height

Table 4. Models selected for Volume estimation from Height and their assessment criteria

Models	Equation	R^2	SE	AIC
Reciprocal Logarithm	V=1/0.021-0.0075lnH	0.92	22.4	286.1
Exponential	V=43.16Exp0.179H	0.92	22.8	287.0
Quadratic	$V=104.79-14.79H+3.02H^2$	0.91	23.6	291.9

Table 5. Validation Result of the Models for Volume estimation from Height

Parameters	Reciprocal Logarithm	Exponential	Quadratic
Mean Observed Volume (m^3)	153.22	153.22	153.22
Mean Predicted Volume (m^3)	184.80	135.46	177.94
Percentage Bias (%)	-20.61	11.95	-23.43
Rank	2nd	1st	3rd

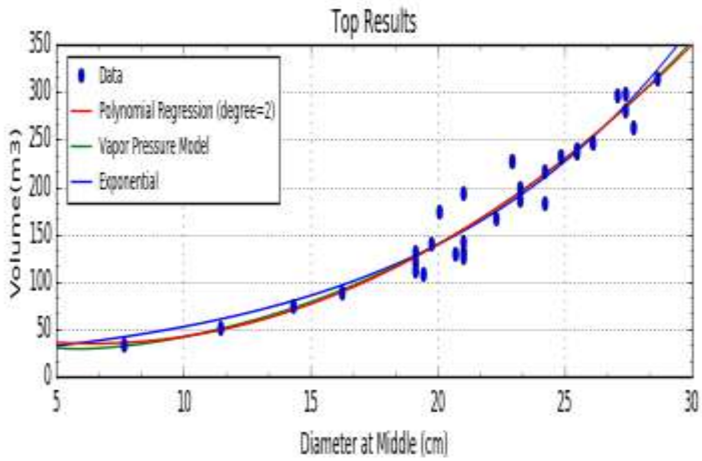

Figure 5: Graph for Estimation of Volume from Diameter at the Middle

Table 6: Models selected for Volume estimation from Diameter at middle and their assessment criteria

Models	Equation	R^2	SE	AIC
Vapor Pressure Model	V=Exp(-5.00+17.71Dm+3.02*lnDm)	0.94	19.48	191.3
Exponential	V=19.67Exp0.09Dm	0.93	19.74	191.0
Quadratic	$V=57.85-7.28Dm+0.57Dm^2$	0.94	19.41	191.1

Table 7: Validation Result of the Models for Volume estimation from Diameter at the middle

Parameters	Vapor Pressure Model	Exponential	Quadratic
Mean Observed Volume (m^3)	153.22	153.22	153.22
Mean Predicted Volume (m^3)	158.82	136.26	158.89
Percentage Bias (%)	-3.66	11.07	-3.57
Rank	3rd	1st	2nd

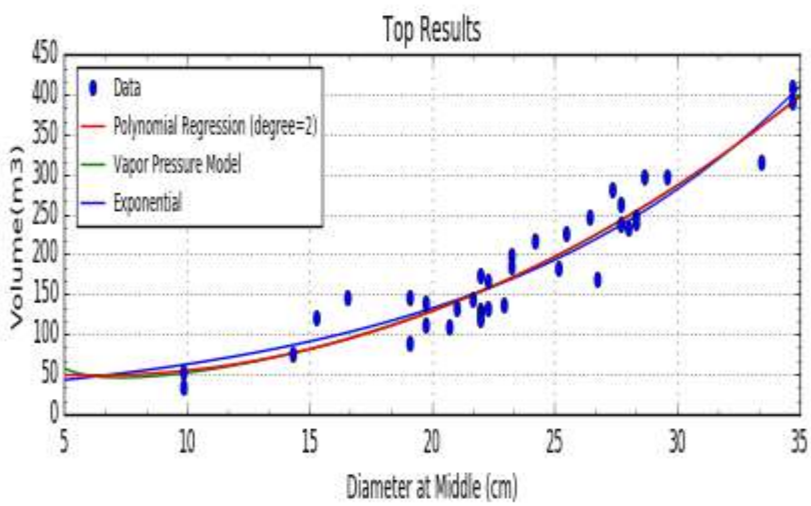

Figure 5: Graph for Estimation of Volume from Diameter at Breast Height

Table 8: Models selected for Volume estimation from Diameter at Breast Height and their assessment criteria

Models	Equation	R^2	SE	AIC
Vapor Pressure Model	V=Exp (-3.5+13.67Dbh+2.56*ln Dbh)	0.90	25.20	233.59
Exponential	V=28.68Exp0.076Dbh	0.90	26.33	235.56
Quadratic	V=46.75-4.96Dbh+0.406Dbh^2	0.92	25.09	233.23

Table 9: Validation Result of the Models for Volume estimation from Diameter at Breast Height

Parameters.	Vapor Pressure Model	Exponential	Quadratic
Mean Observed Volume (m^3)	153.22	153.22	153.22
Mean Predicted Volume (m^3)	158.82	136.26	158.89
Percentage Bias (%)	-14.29	-14.34	-14.31
Rank	1st	3rd	2nd

DISCUSSION

Floristic distribution

The results of this study showed that *Azadirachta indica* in Warwade Forest Reserve is a repository of standard mono-plantation. Eighty-one (81) stands of *Azadiratcha indica* were reported in Warwade Forest Reserve which is below the value of total enumeration of 123 *Nauclea diderrichii* in Forestry Research Institute of Nigeria in Ibadan, Nigeria, (Salami *et al*, 2020). The floristic distribution of this plantation was found to be relatively high. However, the genetic resources were relatively high compared with values obtained in a Gambari Forest Reserve in South western Nigeria (Nurudeen *et al.*, 2017; Salami and Akinyele, 2018). Aigbe *et al.*, (2014) reported 387 stems ha^{-1} in Strict Nature Reserve (SNR) of Akure Forest, Nigeria.

Height distribution

The result from table 2 showed that the height of all tree sampled in plantation ranged between 0 to 15m. Range of height of the tree between 6-10m had the highest percentage (79%) followed by 11-15m with the value of 12.35%. The least performance ranged was 0-5m with the value of 8.64%. This implied that the little differences in the height distribution is attributed to the improper management practices and competition with farmers within the reserve. The height of the tree measured showed that the plantation is still at the young age. Conversely, (Abubakar *et al.*, 2017) assessed height of the trees in Illo-Kaoje Forest Reserve was 0-30m.

Diameter distribution at breast height

There was higher number of stems per hectare in the diameter classes of 61-70cm with population sizes of 27 trees (33.33%) in Warwade Forest Reserve. Diameter ranges of 71-80 cm had 18 trees/ha (22.22%), while the diameter class of 81-90cm had 15 trees/ha (18.52%) in Reserve. Lesser number of stems per hectare was recorded in diameter classes of 91-100 cm in study area and the range of 0 to 20cm as shown in table 3 had population value. It implies that higher number of the trees was mature and they were merchantable. Salami and Akinyele (2017) and Salami and Akinyele, (2018) discovered highest number of trees for diameter class 10-19.9 cm (27.93%) at Gambari Forest. Also, Oduwaiye and Ajibode (2005) reported the highest number of trees for diameter class of 11-30 cm followed by those of between 0-10 cm at Onigambari Forest Reserve. Conversely, Oduwaiye *et al.*, (2002) revealed that all the plots accessed had the largest class of diameter below 10 cm at the Okomu Permanent Sample Plot.

Community structure index

Consequently, the descriptive statistics of the tree growth variable obtained as shown in table indicated that total basal area and volume per hectare to be 339998.19m^2 and 14126.599m^3 ha^{-1} respectively. The mean Dbh and volume per hectare were found to be 22.2cm and 174.40m^3 ha^{-1} respectively. The value obtained for basal area is an indication of a well-stocked forest (Alder and Abayomi, 1994) and (Nurudeen *et al.*, 2014). The mean Dbh and height encountered (22.26cm and 7.80m) is an indication that most of the trees encountered in the study area are above minimum merchantable size of 48cm stipulated by logging policy of north western Nigeria

Model prediction

The models selected for estimation of Volume from Height (H) were the Reciprocal Logarithm, Exponential and Quadratic models. These models were selected because they had the lowest assessment criteria values. Exponential model was ranked as the best with the lowest AICC value of 286.1, lowest SE value of 22.4 and a high R^2 value of 0.92 when estimating volume from Height as shown in Table 4. Validation for the Volume-Height relationship was done using Percentage Bias estimator and Exponential model returned the best with the smallest value of 11.59 as shown in Table 5. Models selected for estimation of Volume from Diameter at the Middle (Dm), were Vapor Pressure model, Exponential and Quadratic models. On the whole, Exponential model was ranked as the best with the lowest AICC value of 191.0, very low SE value of 19.74 and a high R^2 value of 0.93 when estimating volume from Diameter at the Middle as shown in Table 6. Exponential model also ranked as the best after validation with a Percentage Bias of 11.07 as shown in Table 7. Models selected for estimation of Volume from Diameter at Breast Height (Dbh), were Vapor Pressure model, Exponential and Quadratic models. On the whole, Vapor Pressure model ranked as the best after validation with a negative. Percentage Bias evaluated to be -14.29 as shown in Table 9. The validation result for selected model's percentage bias showed that most of the models have a low percentage bias varying from -20.61 to 11.95 %. This was in agreement with the findings of Adekunle (2007) who reported that the percentage bias less than 30% is an indication of good fit models. However, (Nurudeen *et al.,* 2014) revealed that the range of 14.64 – 40.31% models of tree volume predictions in stands of *Tectona grandis* are in good fit.

CONCLUSION

Growth assessment and regression Models for Tree Volume Prediction of Neem Stands in Warwade Forest Reserve was investigated. Total of eighty-one (81) stems ha-1 were recorded at the reserve. The prominent tree sizes in the reserve were dbh sized class of 61-70cm, which tend to dominate. Also, the descriptive statistics of the tree growth variable obtained indicated that total basal area and volume per hectare to be 339998.19m^2 and 14126.599m^{3}ha^{-1} respectively. Dbh is easy to measure and often available from forest inventories. Both models account for a high proportion of variability in predictions and produce accurate predictions based on the results of statistical analyses. Exponential model was found to be more suitable and fit for volume prediction. Evans (1992) stated that many tropical countries afforestation programmes tend to emphasis plantation establishment and neglecting subsequent silvicultural management decision.

Recommendations

This study should help to promote the development of tree volume predictions for mono-species stand. It will also help to promote a basis for further investigations on the relationship between volume and other growth parameters. It is hoped that this study will be of value to forest managers, policy makers and growth modelers. It is believed that this study will provide a basis for further data collection management at Warwade Forest Reserve. Therefore, exponential model generated in this study with good fit is recommended for tree volume estimation in plantation of Neem at Warwade Forest Reserve, Dutse, Jigawa State.

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