

Tree stem diameter (DBH) as predictor variable in assessing other growth parameters of *Sclerocarya birrea* (Anacardiaceae) in a Nigerian Guinea Savanna.

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Abstract: From 15 sample plots each measuring 100m by 100m randomised and replicated within Bagale Forest Reserve, thirteen *Sclerocarya birrea* trees were assessed for height, crown ratio, crown diameter, crown area, basal area and volume. Tree stem DBH was used as predictor variable for these growth parameters. Results showed that the coefficient of determination (r^2) and Pearson's correlation (r) between DBH and height, crown diameter, basal area, crown ratio and volume were 0.50, 0.55, 0.14, 0.97, 0.38, 0.94, 0.25, 0.31, 0.02, 0.94, 0.14 and 0.89 respectively. The minimum and maximum stem diameter were 0.13 and 0.89 while the mean crown diameter, maximum and minimum heights were 8.5 and 18.7 meters respectively.

Developing equation models help forest managers to practice sustainable forest management, arrive at cost-benefit ratios and to determine best management practices for sustainable forests.

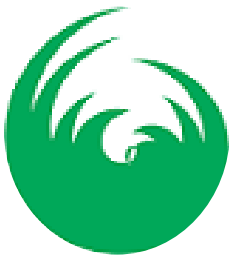
Keywords: DBH, Predictor variables, Bagale Forest Reserve, Coefficient of determination, Pearson's correlation coefficient.

INTRODUCTION

The common variables measured in forest inventories are diameter at breast height (DBH), height, crown measures and these variables are used to derive other variables such as form factor, volume, biomass, carbon, productivity, diversity and importance value index (Baral *et al.*, 2020; Bhandari *et al.*, 2021a, Bhandari *et al.*, 2021b)

Height-diameter models are used to calculate measurable quantities needed to characterise forest growth and yield (Tewari *et al.*, 2014) especially volume, weight and biomass. For inventory purposes, it is common to measure DBH on all trees in a plot

while limiting the measurement of height to a subsample of trees because measurements of height are more difficult and time consuming (Ahmadi *et al.*, 2013). There are many height-diameter equations for different tree species in various regions that can be fitted to linear or non-linear functions. In most of these models DBH is a predictor variable for estimating total tree height. Additional stand variables are often included to improve prediction for a wide range of stand conditions and management practices. Therefore, a single height-diameter relationship may not be useful in all the possible situations that can be found in different stands (Lappi, 1997; Eerikainen, 2003). Developing equation models help forest



managers to practice sustainable forest management, arrive at cost-benefit ratios and to determine best management practices for sustainable forests (Paula *et al.*, 2010). Hence the modelling of growth dimensions of *Sclerocarya birrea* is important.

Diameter at breast height and the total height of the individual trees are the commonly used predictor variables along with wood density, crown measures, stand density and some other measures of competition (Shrestha *et al.*, 2018a). However, using DBH only is one of the most usual practices because the measurement of DBH is easier, accurate and cost effective compared to height and other variables. DBH alone described more than 95% variation in stem volume of *Shorea robusta*. (Subedi, 2017). Addition of height together with DBH as predictor variable improved the model predictability (1.05% increase in R^2 , 8.33% decrease in RMSE and 15.57% decrease in AIC). Models with DBH only as predictor variable can also be used with acceptable accuracy in the absence of height data.

Sclerocarya birrea in the family of anacardiaceae is a tree up to 12 metres high with trunk to 80cm in diameter with relatively dense rounded crown. It occupies North of the 9° parallel in West Africa from Senegal to Cameroon and as far as Uganda and Ethiopia (Arbonnier, 2004).

Gouwakinnou *et al.*, (2011) attest to the more than 20 different uses of this plant including its commercial and agroforestry potentials. According to these authors, socio-economic relevance of this plant highlights how gender, local availability, ethnicity

and community location interact to influence its utilization value.

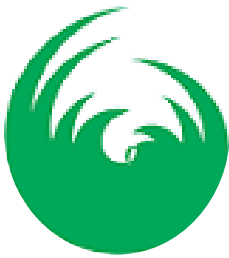
Arbonnier (2004) also recorded the presence of medicinally important chemical constituents in *Sclerocarya birrea* notably polyphenols, tannins, coumarins flavonoids, triterpenoids, phytosterols *et.c.*

The objective of this study is to derive growth and yield data including prediction models of this tree which can be helpful in forest management, planning and policy development especially considering the socio-economic and agroforestry potentials of this plant.

MATERIALS AND METHODS

The study area, Bagale Forest Reserve is an old forest ecosystem which lies within latitude 9° 11' and 9° N and longitude 12° 20' and 12° 30' E in North-East Nigeria in the Northern Guinea Savanna zone. The reserve has an area of 69.4 square miles, about 18,000 hectares (Adamawa state government, 2020).

A total of 15 sample plots were laid (randomized and replicated) in the reserve from which 13 individuals of *Sclerocarya birrea* measuring ≥ 10 cm and above were assessed. This species was identified in the herbarium of the Biological sciences department, Ahmadu Bello University, Zaria, Nigeria. In order to eliminate bias, the selected trees were numbered with red paint to avoid double counting. The biggest, smallest and medium-sized trees were all captured in



the sample plots. There was no sign of pruning on the trees in the area of study.

The following variables for each tree were measured; tree height, crown diameter, crown area, basal area, crown ratio and volume.

Tree height

This is the total height minus the distance from the ground level to the base of live crown, that is the lowest green leaves. To measure total height, the peak of the tree was pointed with the clinometers at certain distance from the tree and then the reading of the This was computed for each of the species in the sample plots using the formula:-

$$CR = Cli / THT_i \quad (2)$$

Where, Cli=individual tree crown length

THT_i=total height of the ith tree (Oyebade and Onyeoguzoro, 2017).

diameter

This was measured for each tree using the formula:-

$$CD = \sum r_i / 2 \quad (3)$$

Where, CD=crown diameter

r_i= projected crown radii measured on four axes (Oyebade and Onyeoguzoro, 2017)

angle on clinometers and the distance of the tree angle to the operator were recorded (Gareth, 1991).

$$X = Y \tan A + Z \quad (1)$$

Where X=tree height, Y=distance from tree to the observer, A=angle of elevation, Z=height of the observer at eye level. The height of each tree was measured using a clinometer and an altimeter following the procedure of Pearson *et al.*, 2013.

Crown ratio

Crown Tree girth

This is the measurement of the circumference of the tree taken at 1.3m above ground level (Eyre *et al.*, 2000). The stem DBH was calculated as follows

$$C = D \times \pi \quad (4)$$

Where C=circumference, D=Diameter

$$\pi = 22/7 = 3.14$$

Basal area

This involved determining the cross-sectional area of each tree trunk at 1.35m above the ground measured in square meters. This parameter was determined based on the formula by Wratten and Fry (1980).

$$\text{Basal area} = C^2 / 4\pi r \quad (5)$$



Where, C=girth size (diameter at breast height)

$$\pi=22/7=3.14$$

Volume

The volume of each tree was established using the Newton's formula (Husch *et al.*,1982) which is expressed as:

$$V=H (Ab+4Am+An)/6 \quad (6)$$

Where,

V=Actual tree volume (over bark in m³)

H= Tree height (m)

Ab=Cross-sectional area at the base of the tree (m²)

Am=Cross- sectional area at the middle of the tree (m²)

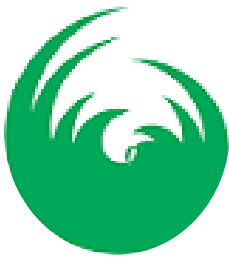
An=Cross=sectional area at the top of the tree (m²) (Akindele,1987).

RESULTS AND DISCUSSION

Table1 Descriptive statistics for *Sclerocarya birrea*

Statistics

	Diameter at Breast Height	Tree Height	Crown Diameter	Crown Area	Base Area	Crown Ratio	Volume
N	13	13	13	13	13	13	13
Mean	.4446	15.3308	2.9308	31.1615	.1823	.1931	3.0062
Std. Error of Mean	.05444	.84219	.40070	4.64476	.04462	.02437	.83335
Median	.4400	16.3000	2.7000	30.4000	.1500	.1600	2.1500
Std. Deviation	.19628	3.03655	1.44475	16.74692	.16089	.08788	3.00470
Range	.76	10.20	5.50	46.80	.61	.32	11.14
Minimum	.13	8.50	1.70	8.60	.01	.10	.16
Maximum	.89	18.70	7.20	55.40	.62	.42	11.30
Sum	5.78	199.30	38.10	405.10	2.37	2.51	39.08



	25	.3350	13.2500	1.9500	15.4000	.0900	.1400	1.2000
Percentiles	50	.4400	16.3000	2.7000	30.4000	.1500	.1600	2.1500
	75	.5250	17.8500	3.3500	45.4500	.2200	.2150	3.8500

DBH=Diameter at breast height (cm)

TH=Total height (m)

CD=Crown diameter (m)

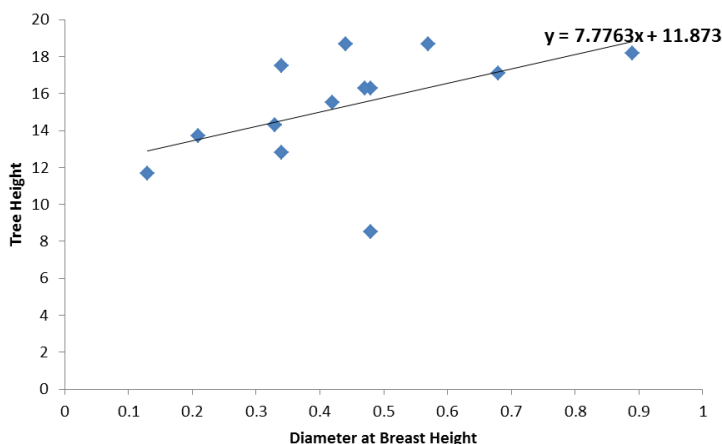
CA=Crown area (m²)

BA=Basal area (m²)

CR=Crown ratio

VOL.=Volume(m³)

Relationship between Diameter at Breast Height and Tree Height



Relationship between Diameter at Breast Height and Crown Diameter

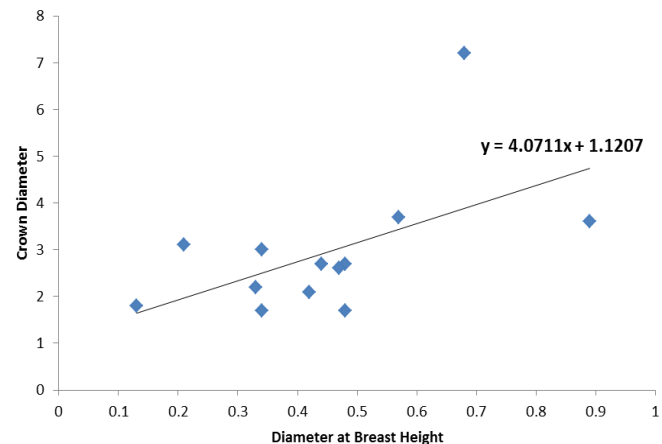




Fig 1

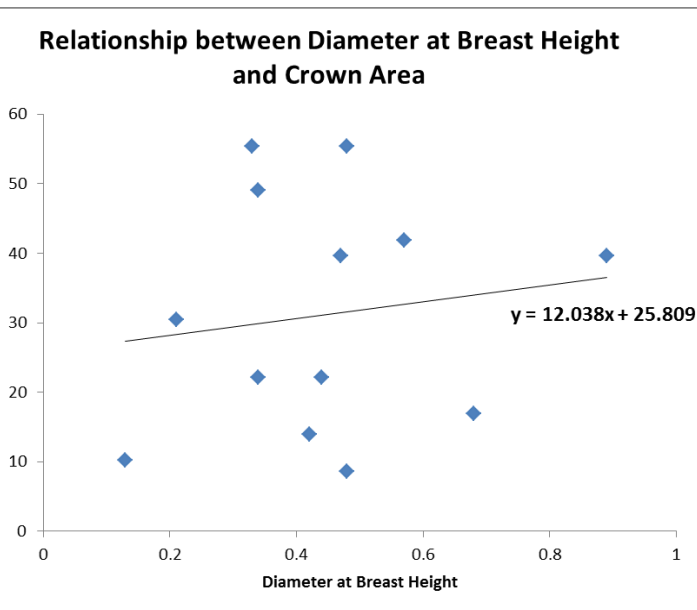


Fig 2

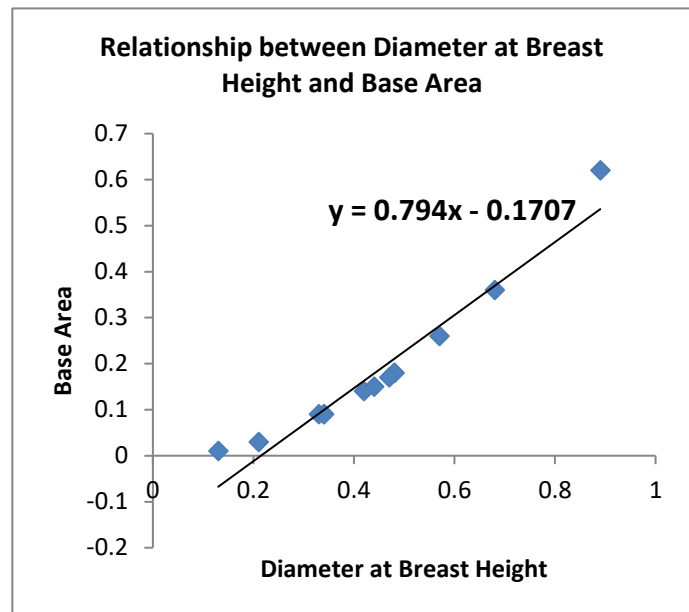


Fig 3

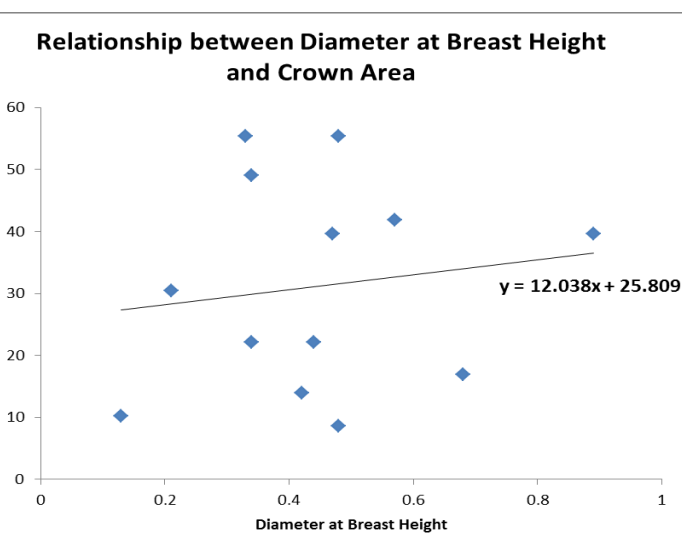
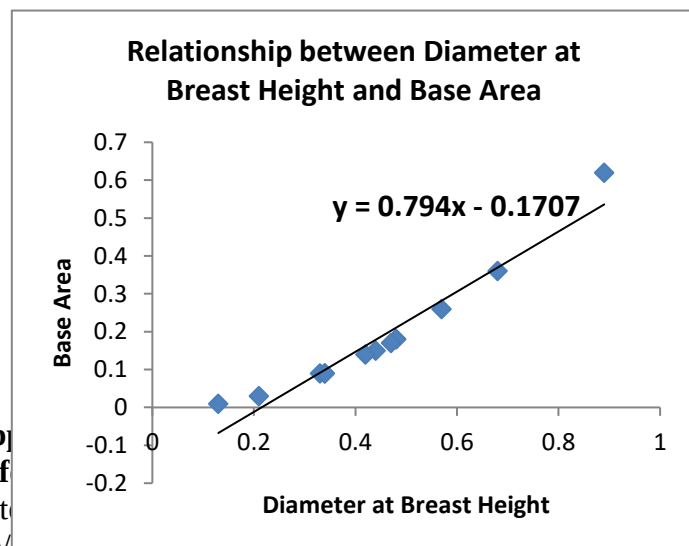


Fig 4



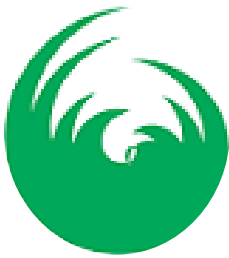


Fig 5

The minimum and maximum stem diameters were 0.13 and 0.89 respectively while the mean stem diameter was 0.44. The mean crown diameter was 2.93 with maximum and minimum heights at 8, 5 and 18.7 respectively.

(Table1). Buba (2013) recorded 0.54,0.95,0.32, and 0.70 as minimum and maximum stem dbh for *Daniella oliverii* and *Vitellaria paradoxum* respectively in the Nigerian Guinea Savanna. He also observed that using stem dbh as predictor variable a significant relationship existed against it and tree height and crown length ($F_{0.05}$), but not significant against crown height and crown ratio for the same species.

The graphs (Figs. 1-6) revealed the relationship among the growth parameters. The presence of outliers in the graphs could be due to the practice of agroforestry and other anthropogenic activities by the inhabitants within and outside the forest reserve to make way for farming. DBH had moderate and positive correlations with total height and crown diameter but extremely weak and positive correlation

Fig 6

with crown area. Very strong and positive correlation between DBH and Basal area and volume are revealed by the graph. The correlation between DBH and crown area was weak. The mean of crown length tends to be lower than that of tree height, therefore there is a measure of consistency with predicted values for crown ratio (Temesgen *et al.*,2005).To corroborate this, Casell &Berger (2002), stated that the prediction intervals for crown ratio modelling are always between 0 and 1.

The results of regression and correlation analysis of the growth and yield of the species are produced in (Table 2).The values of Pearson's correlation coefficient R between DBH and height, Crown diameter (CD),Crown area (CA), Basal area (BA), Crown ratio (CR) and Volume (VOL).were 0.50,0.55,0.14,0.97,0.38 and 0.94 while corresponding values of the coefficients of determination (r^2) were 0.25,0.31,0.02,0.94,0.14 and 0.89 respectively. This implied that 25, 31, 2, 94, 14 and 89 percent of tree height, crown diameter, crown area, basal area crown ratio and volume respectively were accounted for by stem diameter.



The corresponding F-values from the ANOVA were significant and ranged between 0.22 for the relationship between DBH and CA to 166.94 for DBH and BA. Stronger correlations were observed in the relationships between DBH vs BA and DBH vs VOL. Prediction growth models were also presented in Table 2. Ige *et al.*, (2013) found DBH to be a weak estimator of other growth dimensions of *Gmelina arborea*.

Ahmadi *et al.*, (2016) developed 39 generalized height-diameter prediction models for *Fagus orientalis*. The goodness of fit of the models showed that r^2 ranged from 0.62 to 0.78 and RMSE from 3.3 to 4.7 in the validation phase. Considering all the performance criteria, a model which uses DBH, dominant height, basal area per hectare and number of trees per hectare was found to be the best model to predict the height of *Fagus orientalis*.

Oyebade & Onyeoguzoro (2017) observed that for each of the species of *Hevea brasiliensis* plantation the mean values for the diameter at the base was the

highest in the stand while that for crown ratio was 0.494 with a standard deviation of 0.095. This is confirmed by Casella & Berger (2002) who stated that the prediction intervals for crown ratio models are always between 0 and 1. Temesgen *et al.*, (2005) observed that tree height influences crown ratio development.

From 420 *Azadirachta indica* (neem) trees measured in four states of Katsina, Kano, Zamfara and Sokoto, Shuaibu & Alao (2016) developed five multiple regression equations after measuring merchantable height, stump diameter, diameter at breast height and diameter at top of the stem before the crown and obtained the following results: $V=0.329-0.699(D)+0.436(DH)-0.035(H)$ and $V=1.109-2.227(D)+0.184(H)$. The R^2 , SEE, F-value and RMSE were 0.99, 99%, 0.01, 0.00004, 47149; and 0.00001, 0.96, 93%, 0.02, 0.0005, 4051 respectively.

Table 2. Regression prediction model, Pearson correlation coefficient (r) and correlation coefficient of determination (r^2) of the different tree dimensions

variable	F-value	Prediction model	r	R ²	Sig.level
DBH vs TH	3.72	$Y=7.77x+11.9$	0.50	0.25	0.04
DBH vs CD	4.84	$Y=4.07x+1.12$	0.55	0.31	0.03
DBH vs CA	0.22	$Y=12.04x+25.8$	0.14	0.02	0.32
DBH vs BA	166.94	$Y=0.79x+0.17$	0.97	0.94	0.0001



DBH vs CR	1.83	$Y=0.16x+0.12$	0.38	0.14	0.10
DBH vs VOL	86.01	$Y=14.4x+3.40$	0.94	0.89	0.0001

Interpretation of Results

DBH Vs TH Moderate +Positive correlation/relationship

DBH Vs CD Moderate +Positive correlation/relationship

DBH Vs CA Extremely weak +Positive correlation/relationship

DBH Vs BA Very strong + Positive correlation/relationship

DBH Vs CR Weak +Positive correlation/relationship

mDBH Vs VOL Very strong +Positive correlation/relationship.

The minimum and maximum stem diameter were 0.13 and 0.89 respectively while the mean stem diameter was 0.44. The mean crown diameter was 2.93

CONCLUSION

A study using DBH as predictor variable of other growth parameters of *Sclerocarya birrea* was carried out in Bagale Forest Reserve, North-East Nigeria. The minimum and maximum stem diameters, mean height and mean DBH were 0.13, 0.89, 15.3 and 0.44

respectively. DBH had moderate and positive correlation with total height and crown diameter while the relationship between DBH and BA on one hand and volume on the other were very strong and positive. The relationship between DBH and crown area though positive was extremely weak. The coefficient of determination (r^2) and Pearson's correlation coefficient (r) showing the relationship between DBH and tree height, crown diameter, crown area, basal area, crown ratio volume were 0.50, 0.55, 0.14, 0.97, 0.38, 0.94, 0.25, 0.31, 0.02, 0.94, 0.14 and 0.89 respectively. Results from growth and yield of trees and prediction models could be inconsistent because plants show plasticity due to climatic and soil variability, hence caution should be applied in using them.

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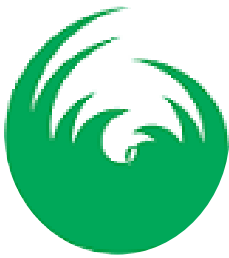
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