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Tree Growth Analysis as a Panacea for Sustainable Forest Management in Northeast Nigeria: Study of Lannea Kerstingii (Anacardiaceae)

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Abstract: Lannea kerstingii (Anacardiaceae) is found mainly in the Guinean and Sudanese savannas with health benefits and also used as timber, firewood and charcoal. Growth analysis of Lannea kerstingii was carried out to fill existing data gaps and enhance the practice of forestry for sustainable forest and environmental management. Twenty sample trees were assessed for different growth parameters yielding a coefficient of determination (r^2) and Pearson's correlation coefficient (r). The analysis showed the relationship between DBH and tree height, crown diameter, crown area, basal area, crown ratio and volume as 0.617, 0.264, 0.103, 0.907, 0.009, 0.864, 0.79, 0.051, 0.32, 0.95, 0.94, and 0.93 respectively. In addition to generating data for tree growth analysis, forestry extension and capacity should be deepened with provision of adequate funding to relevant agencies to promote biodiversity conservation.

Keywords: *Anacardiaceae, Bagale, Environment, Forest, Management, Sustainability*

Conflicts of interest: None
supporting agencies: None

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1. Introduction

Lannea kerstingii (Anacardiaceae) is a tree which grows up to 12 meters high and 40 cm in diameter. It is found mainly in the Guinean and Sudanese savannas. The plant is used for wounds, vermifuge, pains, gastritis, diarrhea, oedema and childhood convulsions. It is also useful as material for timber construction, firewood and charcoal (Arbonnier, 2004).

Diameter at breast (DBH) is one of the important variables used in forestry practices to estimate the volume of standing trees. Total height, crown ratio and crown diameter could be estimated by means of stem diameter which is easy to measure for the studies in ground-based forest inventory and stand structure determination (Turan, 2009). Forest planning for wood resource management depends on precise evaluation of stand volume and trees. Data obtained from such study can guide forest managers for wood evaluation in a specific location for purposes of consumption (Akindele and Lemay, 2006). Therefore, accurate evaluation of stand volume in addition to appropriate utilization management are considered important. The application of allometric models to estimate above – ground biomass in tropical forests is required for studying carbon storage and exchange (Vieira et al., 2008). The use of different allometric models will result in variations in the calculation of the amount of biomass. Tree biomass is described as wood volume which is influenced by tree diameter and height, physiognomy and wood density (Vieira et al., 2008).In addition, tree biomass varies from region to region where its content varies according to species density, climatic factors and soil properties (Agevi et al., 2017).

The assessment of forest volume and associated biomass provides important baseline information that is needed to quantify above-ground carbon stocks which is especially important because forests account for 80% of terrestrial carbon globally (Dixon et al., 1994). National Forestry Programmes aim to provide consistent and robust information for monitoring and reporting of forest resources (Kangas and Maltamo, 2006). Developing equation models help forest managers to practice sustainable forest management (Paula et al., 2010), hence the relevance of modeling growth dimensions of Lannea kerstingii is vital.

Some of the most pressing risks to human health associated with a changing climate are the increases in heat-related deaths & infectious diseases (Patz, Campbell, Lendrum, Holloway & Foley, 2005). Trees perform a keystone role in terrestrial ecosystems (Manning, Fisher & Lindenmayer, 2006) and green infrastructure (Berland et.al., 2017). The objective of this study was to analyse the growth of Lannea kerstingii and use the results as a template for assessing trees in other forest ecosystems towards achieving sustainable forest management in Northeast Nigeria.

2. Materials and methods

The study area, Bagale Forest Reserve, is an old ecosystem which lies within latitude 9 11"and 9 N and longitude 12 20" and 1230"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 (Figure 1) (Adamawa state government, 2020).

A total of 15 sample plots were laid (randomized and replicated) in the reserve from which 20 individuals of Lannea kerstingii measuring ≥ 10cm and above were assessed. This species were identified in the herbarium of the Biological Science 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. Different variables for each tree were measured.

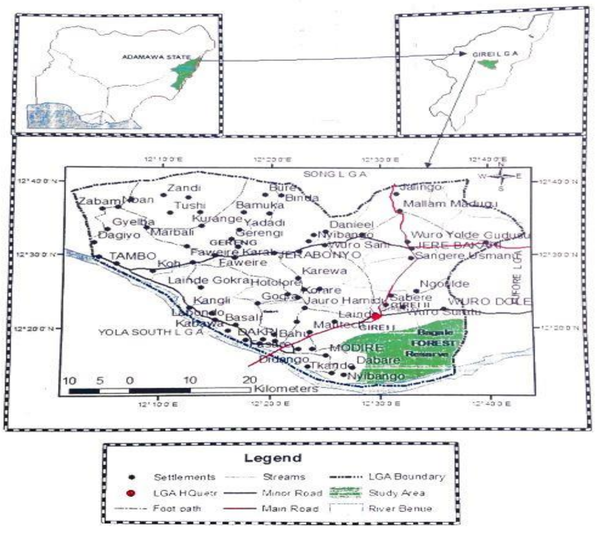

Figure 1: Map of the study area

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

$X = Y \tan A + Z$ (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 haga altimeter following the procedure of Pearson et al. (2013).

2.2. Crown ratio

This was computed for each of the species in the sample plots using the formula

$CR = Cli/THTi$ (2)

Where, Cli=individual tree crown length

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

2.3. Crown diameter

This was measured for each tree using the formula

$CD = \sum ri/2$ (3)

Where, CD=crown diameter

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

2.4. 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

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

Where C=circumference, D=Diameter

$\pi = 22/7 = 3.14$

2.5. 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).

Basal area $= C2/4\pi r$ (5)

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

$\pi = 22/7 = 3.14$

2.6. Volume

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

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

Where,

V=Actual tree volume (over bark in m^3)

H= Tree height (m)

Ab=Cross-sectional area at the base of the tree (m^2)

Am=Cross- sectional area at the middle of the tree (m^2)

An=Cross=sectional area at the top of the tree (m^2) (Akindele, 1987)

3. Results and discussion

Graphically, with stem diameter as predictor variable there were positive correlations with tree height, crown diameter, basal area and volume. Correlations with crown area and crown ratio were weak. The presence of outliers could be due to the practice of agroforestry resulting in microhabitat variations of the individual trees in the sample plots (Figures 1, 3, 5, 7).

The coefficient of determination (r^2) in the correlation between dbh and tree height was 62% (Table 2). This means that 62% of the variations in tree height in the 20 samples were accounted for by variations in their stems. The r^2 value between dbh and crown diameter was 26%. Notably, greater correlations existed with dbh as predictor variables against basal area and volume. The r^2 values were 90.7% and 86.4% respectively. These results do not agree with those of Buba (2013) who obtained Pearson’s correlation coefficients (r) between the stem diameter, tree height, crown height and crown length for *Daniella oliverii* as 0.693, 0.693 and 0.733 respectively. For the same species, he obtained coefficients of determination (r^2) as 0.480, 0.617 and 0.537 respectively all in the Nigerian Guinea Savanna.

The regression models are also presented in Table 2. DBH is used as predictor because it is easy and cost effective to measure compared to using other growth parameters. The tree crown ratio and crown area could not be estimated using dbh because both the correlation and the F-value are not significant (Table 2).

The minimum and maximum stem diameter recorded were 0.07 and 0.48 cm which did not agree with the findings of Buba (2013) who obtained 0.32 and 0.70 cm respectively for ten samples of Vitellaria paradoxa also in the Northern Guinea Savanna. The relationship between DBH and CR was extremely weak. There were also positive correlations between DBH, crown diameter and BA. Stronger correlations were found by using crown diameter as independent variable than by using crown diameter, crown area or crown ratio. These positive correlations were also found by Troxela et.al. (2013) and El-Mamoun et al. (2013).However, Ige et al. (2013) found DBH to be a weak estimator of growth dimensions in *Gmelina arborea.*

Regression models were derived for the growth parameters in the study area. The models can be used to estimate tree height which is expensive and difficult to estimate in the forest (Tanka,2006).The relationship between DBH and total height is fundamental for developing growth and yield models for forest stands (Troxela et al., 2013; El-Mamoun et al., 2013). Troxela et al. (2013) and Zhang et al. (2013) observed that pattern of growth for individuals of some tree species is not always constant as it can be affected by the biophysical factors in different localities. It is also suggested that a successful predictor model for a given species might not be fitted for other species growing even in the same locality under similar conditions (Urban et al., 2010). El-Mamoun et al. (2013) also suggested that different tree species that are growing in the same locality may not be fitted to one allometric model, so each species should have its unique model.

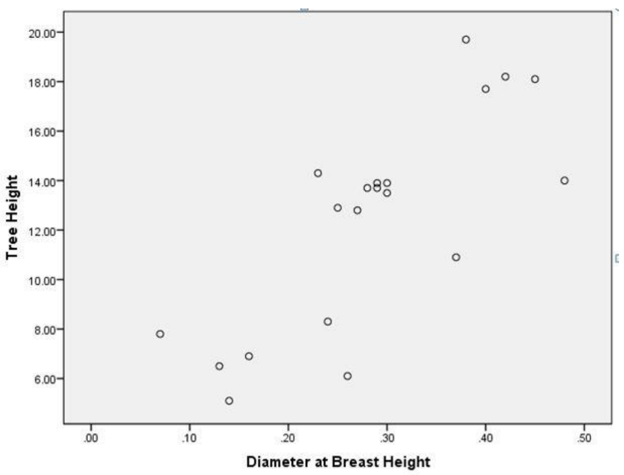

Figure 2: Relationship between DBH and TH

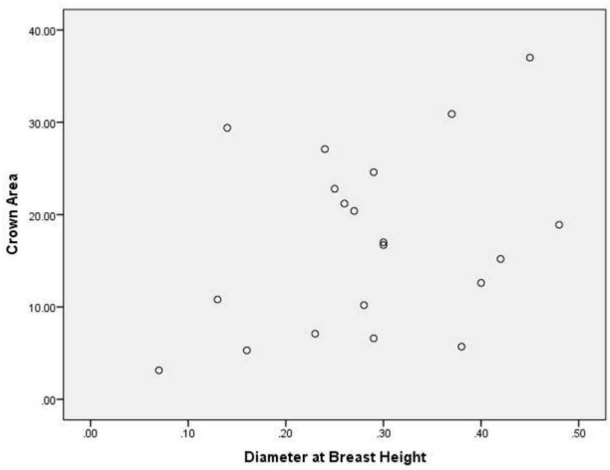

Figure 3: Relationship between DBH and CA

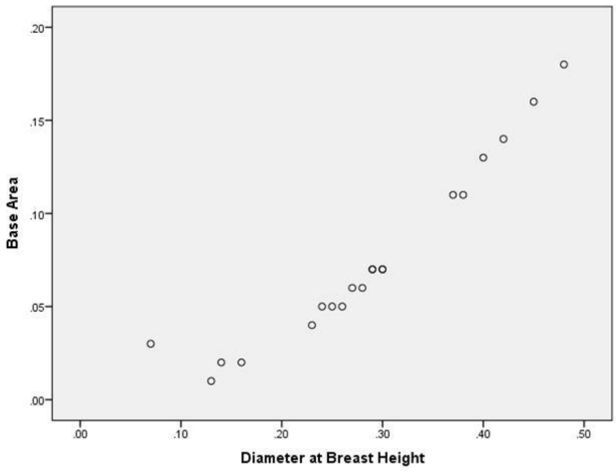

Figure 4: Relationship between DBH and BA

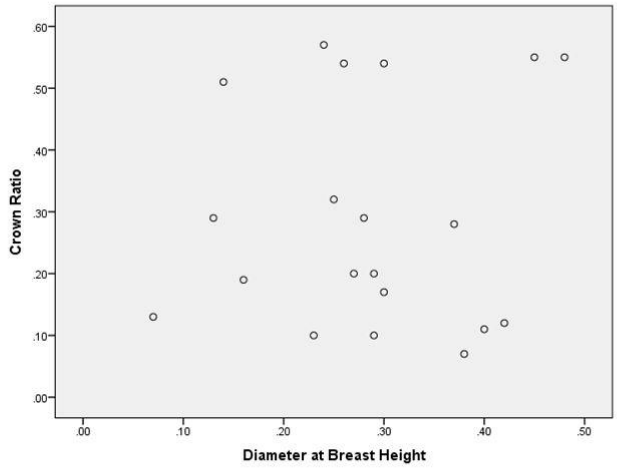

Figure 5: Relationship between DBH and CR

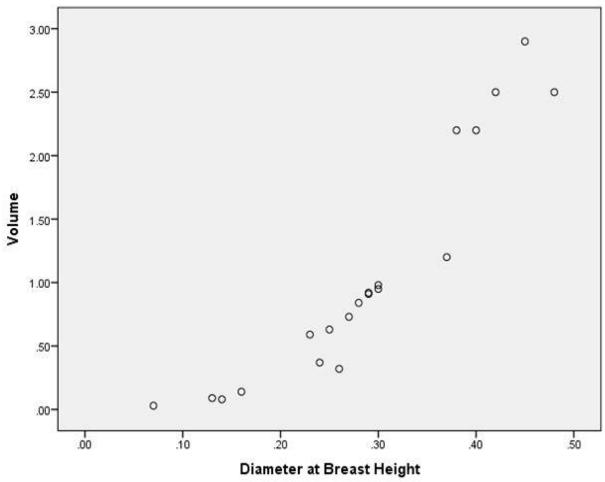

Figure 6: Relationship between DBH and Volume

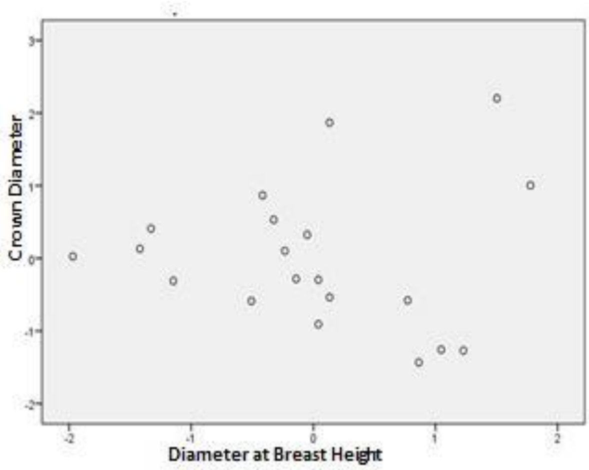

Figure 7: Relationship between DBH and CD

Table 1: Details of *Lannea kerstingii*

		Diameter at Breast Height	Tree Height	Crown Diameter	Crown Area	Base Area	Crown Ratio	Volume
N		20	20	20	20	20	20	20
Mean		.2855	12.4000	3.3750	17.1320	.0750	.2915	1.0540
Std. Error of Mean		.02447	.97527	.53768	2.14173	.01075	.04091	.20266
Median		.2850	13.6000	2.6000	16.8500	.0650	.2400	.8750
Std. Deviation		.10942	4.36155	2.40457	9.57810	.04807	.18297	.90632
Range		.41	14.60	8.90	33.86	.17	.50	2.87
Minimum		.07	5.10	1.00	3.14	.01	.07	.03
Maximum		.48	19.70	9.90	37.00	.18	.57	2.90
Sum		5.71	248.00	67.50	342.64	1.50	5.83	21.08
	25	.2325	7.9250	1.6000	7.8750	.0425	.1225	.3325
Percentiles	50	.2850	13.6000	2.6000	16.8500	.0650	.2400	.8750
	75	.3775	14.2250	4.0750	24.1500	.1100	.5325	1.9500

Table 2: Regression prediction model, Pearson Correlation coefficient (r) and correlation coefficient determination (r^2) of the different tree parameters

Tree variable	F-value	Prediction model	r	r^2	Sig.
DBH vs tree ht	29.0	Y=31302x + 3.46	0.79	0.617	0.000^b
DBH vs CD	6.44	Y=11.283x+ 0.15	0.51	0.264	0.021^b
DBH vs CA	2.06	Y=28.045x+ 9.13	0.32	0.103	0.168^b
DBH Vs BA	174.6	Y=0.418x - 0.044	0.95	0.907	0.000^b
DBH vs CR	0.159	Y=0.157x +0.247	.094	0.009	0.694^b
DBH vs VOL	114.2	Y=7.70x - 1.144	0.930	0.864	0.000^b

4. Conclusion

Forest measurements are very crucial in the development of forest policies for sustainable forest management in the North-East sub region of Nigeria. The minimum and maximum stem diameter (DBH) were 0.07 and 0.48 cm respectively. Using DBH as predictor, strong positive relationships were recorded with basal area while weak relationships were observed with crown ratio and crown area. A moderate positive correlation was recorded with crown diameter among the 20 sample trees of Lannea kerstingii in the study area. The coefficient of determination (r^2) and pearson correlation (r) show the relationship between DBH and tree height, crown diameter, crown area, basal area, crown ratio and volume.

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