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Relationship Between Crown Cover and Biometric Characteristics of Neem (*Azadirachta indica* Linn) in Majia Fuelwood Reserve, Dange-Shuni, Sokoto State Nigeria

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ABSTRACT

This research was conducted in order to examine the relationship between crown cover and biometric characteristics of Neem (*Azadirachta indica*) in Majia Fuelwood Reserve. Ten (10) sample plots ($30 \times 30m^2$) were marked and demarked at random covering both sides of the plantation. Plots were established 20m away from the boundary of the plantation avoiding edge effect. Data collected on individual trees include, DBH, DB, DM, DT and total height of each tree within the plot. The results of this study revealed, trees within 31-40 diameter class have the highest of crown yield metrics followed by 20-30, 51 above and 41- 50 having the lowest values, trees with 20-30m have the highest crown and yield metrics, followed by 11-20m, 31m above and the lowest was recorded among trees that are <10m in height. SLC results obtained show the majority of the trees have low (<70) and moderate (70<100) slenderness coefficient which shows that about (92%) of the trees are not likely to be overthrown by wind but few trees show high SLC which is about 8% of the total trees measured. Correlations among tree characteristics highlight consistent relationships where taller trees tend to exhibit longer crowns and larger crown projected areas. Diameter at Breast Height correlates positively with crown dimensions, indicating larger trunk diameters correspond to broader crowns. Additionally, slenderness coefficients increase with tree height and crown dimensions, potentially increasing vulnerability to wind damage. Basal area shows a strong positive association with tree and crown dimensions, reflecting larger trees having greater basal area. Finally, overall tree volume positively correlates with all measured variables, underscoring that larger dimensions contribute to greater stem volumes in trees. These patterns underscore the interconnected nature of tree morphology and its implications for forest dynamics and resilience

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Keywords: *Azadirachta indica*, Crown cover, Slenderness Coefficient, Height and DBH

1. INTRODUCTION

The crown of tree is the center of physiological activity, particularly gas exchange, which drives growth and development. The crown contains the foliage, the photosynthetic structure that provides carbohydrates for the growth and development of the whole tree (Leites and Robinson, 2004).

According to Dubravac et al. (2009) one of the most important elements of tree structure is the crown, where essential living processes like photosynthesis take place. The crown area also known as crown projection area, together with crown volume, also determines the amount of intercepted precipitation, and regulates the amount of precipitation that reaches the forest floor (Vrbek et al., 2008).

Many ecological and economic problems in forestry are approached using crown dimensional measures (Grote, 2003). According to Bella (1971) individual tree competition indices are derived from crown area estimates. This is because crown dimension is a result of past competition as well as an indicator of the current growth potential (Iwasa, 1984). Conversely, assessment of crown dimensions remains one of the most difficult and tedious tasks in forestry. Crown area can be estimated from stem dimensions (Dubrasich, 1997). The difficult measurements and the sensitivity of crown dimension on management makes it desirable to develop estimation procedures based on variables that are easier to measure than crown extension itself.

Thus, maximum crown diameters, which can be derived from stem diameter, has been used to estimate crown area (Goelz,1996). Measurement of crown dimension from either above the canopy or under the canopy are both subjected to a likely underestimation of crown width due to a limited visibility of crowns especially in a dense or mixed forest. The size of a tree crown is strongly correlated with the growth of the trees such as diameter at breast height, slenderness coefficient, tree height (Kazimierz et al., 2015). The crown displays the foliage for photosynthesis which is a key process in tree growth development. Thus, crown measurement is often done to help in the quantification of the growth of trees in the forest stand (Korhonen et al., 2006).

Tree slenderness coefficient often serves as an index of tree stability, or resistances to wind throw (Navratil, 1996). A low slenderness coefficient value usually indicates a longer crown, lower centre of gravity, and a better developed root system. Most of forest stands in Nigeria suffer considerable losses due to action of abiotic factors, such as wind. This brings about damages in the forest structures.

Tree slenderness coefficients which is defined as the ratio of total height to diameter at 1.3 m above ground, have been widely used as an index of the resistance of trees to wind throw. In earlier studies (Eguakun and Oyebade, 2015; Ola-Adams, 1999) slenderness was usually one of the factors analyzed or it was investigated in respect of trees of a single species or it concerned several species growing in different regions. However, the suitability and effect of slenderness coefficient in predicting CA in Tectona grandis in Omo Forest Reserve has rarely been investigated. This study was aimed at investigating the effect of slenderness coefficient in crown area

2. METHODOLOGY

2. 1. Study Area

Majiya is a Fuelwood Reserve located along the side ways (west and east) of the road (Sokoto-Gusau) precisely at Inya area. It lies between the latitudes 12°52'53'' and 12°54'16''N and longitudes 5°18'19'' and 5°19'40''E. The plantation covers an area of 252ha. The area falls within the Sudan savannah zone. It has about 70 - 125 days of rainy season (Ibrahim *et al.*, 2018). Temperatures are variable during the dry and rainy seasons with minimum temperature between 10 and 23 °C and the maximum between 33 and 45°C. The mean maximum ranges from 35 – 37 °C.

Relative humidity is between 52 - 56% (SERC 2014; Ibrahim et al., 2018)). It is characterized by alternating rainy and dry seasons. The mean annual rainfall is 700 mm per annum. Rainfall is short and erratic, falling between the months of June and September with an altitude of 350 m above sea level (SERC 2014; Ibrahim *et al.,* 2018). Sokoto has two main seasons; the dry season which lasts from October to May/June, and the rainy season that lasts from June to September/ October. The harmattan season stretches from November to March, which is dry and dust laden wind (SERC 2014; *Ibrahim et al.*, 2018).

2. 2. Sampling Design and Data Collection

Simple Random Sampling was employed in this research. Ten (10) sample plots ($30\times30m^2$) were marked and demarked at random covering both sides of the plantation, coordinates of every plot were also recorded. Plots were established 20m away from the boundary of the plantation avoiding edge effect. Information on standing trees and stump were also recorded.

2. 3. Data Collection

The data obtained include

i. Counting and recording of individual all trees within each plot
ii. Measuring the total height all selected plots using Haga Altimeter
iii. Diameter at the breast height (DBH) of all individual trees were measured at 1.3m, flexible measuring tape was used to determine the circumference of the boles.
iv. Diameter at three different points (Base, middle, Top) were determined with the aid of Spiegel Relascope.

2. 4. Computations and Data Analysis

2. 4. 1. Crown diameter

This was measured for each tree using the formula as adopted by (Oyebade and Onyeoguzoro, 2017; Omijeh, 2022)

$$CD = \frac{\sum ri}{2}$$

where, CD = crown diameter; ri = projected crown radii measured on four axes

2. 4. 2. Crown Projection Area Computation

The crown projection area for individual tree in the study area was estimated as:

$$\text{CPA}=\frac{(CD^2)}{4}$$

where: CPA = crown projection area; CD = crown diameter

2. 4. 3. Crown ratio computation

Individual tree crown ratio was computed using:

$$\text{CR} = \frac{CLi}{Hi}$$

where: CLi = individual tree crown length; Hi = tree total height Adopted by Adeyemi and Ugo-Mbonu, (2017)

2. 4. 4. Basal area computation

The basal area for each sampled tree was determined using the formula suggested by Husch *et al.*, (2003).

$$BA = \frac{\pi \mathrm{D}^2}{4}$$

where: BA = Basal area in m^2; D = Diameter at breast height (m); π = Pi (3.142)

Basal area per plot were obtained by adding the basal area of all individual trees within the plot. Basal area per hectare for each age series was determined by first summing the basal areas of the 30 sample plots selected from the age series and finding their mean, then multiplying the mean basal area per plot by the number of sample plots per hectare which is 10

2. 4. 5. Volume estimation

The stem volume of each mean tree was estimated using the Newton's formula (Husch *et al.*, 2003; Dantani et al., 2019). The formula is expressed as:

$$V = \frac{\pi H}{24}(D_b^2 + 4D_m^2 + D_t^2)$$

where: V = Tree Volume (m^3); H = Tree height (m); and Db, Dm, and Dt are tree diameters at base middle and top positions.

2. 4. 6. Tree slenderness coefficient estimation

Tree Slenderness Coefficient was estimated for all trees using:

$$SLC = \frac{Hi}{DBHi}$$

where: Hi = total height of the ith tree; Dbhi = corresponding Dbh.

The measured trees were classified according to the SC as follows: SC < 70: low slenderness coefficient; SC: 70 - 99: moderate slenderness coefficient; SC >99: high slenderness coefficient. The number of trees/ha and percentage of trees in each of the SC categories was computed for the area as adopted by Oladoye et al. (2020)

2. 4. 7 Data Analysis

The data collected were organized and screened for analysis. Descriptive statistics was used to summarize and group data into different diameter and height classes, basal area computation and volume estimation were achieved using excel. Model development and evaluation were achieved using R Statistical Package

3. RESULTS AND DISCUSSIONS

3. 1. Summary of Tree Growth Characteristics

Summary statistics providing a comprehensive overview of the variability and central tendencies of the tree growth characteristics in the dataset which is very important in understanding the distribution and range of each variable in the population of trees under consideration viz; Minimum, Maximum, Mean, standard error and standard deviation were obtained. Total Height (m) Ranges from 8.50- 46.00, mean 22.8683 with a standard error of 0.68213 and standard deviation of 7.56520. Diameter at Base (cm): Ranges from 24.76 to 61.11 centimeters. The average diameter at the base is 41.4360 centimeters, with an SE of 0.68746. The SD is 7.62429. Diameter at Breast Height (cm): Ranges from 20.05-52.04, mean=33.6451, SE= 0.62572. and SD=6.93953. Diameter at Middle (cm): Ranges from 15.00- 40.00, mean= 26.5650, SE= 0.43146 and SD=4.78512. Diameter at Top (cm): Ranges from 10.00-30.00, mean= 21.2967, SE=35342 and SD= 3.91962. Crown Diameter (m): Ranges from 3.30-10.45, mean=5.9512, SE=0.11965 and SD =1.32702. Crown Length (m) Ranges from 4.40-38.50, mean=15.2341 SE=0.60153, SD= 6.67130. Crown Ratio (m): Ranges from 0.34-0.84, mean= 0.6478 SE= 0.01013 and SD=0.11238. Crown Projection Area (m): Ranges from 2.72 to 27.30, mean= 9.2909, SE=0.40164, SD=4.45439. Slenderness Coefficients: Ranges from 23.74-125.30, mean=69.1483, SE=2.00544, SD =22.24142. Basal Area (m^2) Ranges from 0.03-0.21, mean=0.0927 SE=0.00360 and SD= 0.03992. Volume (m^3): Ranges from 1.88-48.88, mean=13.7245, SE= 0.71118 and SD=7.88732.

Table 1. Summary of Tree Growth Characteristics

Tree Variables	**Min**	**Max**	**Mean** ± SE	**SD**
Total Height(m)	8.50	46.00	22.8683±0.68213	7.56520
Dimeter at Base (cm	24.76	61.11	41.4360±0.68746	7.62429
Diameter at Breast Height (cm)	20.05	52.04	33.6451±0.62572	6.93953
Diameter at Middle (cm)	15.00	40.00	26.5650±0.43146	4.78512
Diameter at Top (cm)	10.00	30.00	21.2967±0.35342	3.91962
Crown Diameter (m)	3.30	10.45	5.9512±0.11965	1.32702
Crown Length (m)	4.40	38.50	15.2341±0.60153	6.67130
Crown Ratio (m)	0.34	0.84	0.6478±0.01013	0.11238
Crown Projection (m)	2.72	27.30	9.2909±0.40164	4.45439

Slenderness Coefficients	23.74	125.30	69.1483±2.00544	22.24142
Basal Area(m^2)	0.03	0.21	0.0927±0.00360	0.03992
Volume(m^3)	1.88	48.88	13.7245±0.71118	7.88732

Min=Minimum, Max=Maximum, *Mean ± Standard Error, SD=Standard Deviation

3. 2. Diameter Class Distribution

The table (2) below provides a breakdown of different tree diameter classes and their corresponding crown characteristics, basal area (BA), and stem volume (V). Trees within 31-40 diameter class have the highest of crown yield metrics followed by 20-30, 51 above and 41-50 having the lowest values.

Table 2. Diameter Class with Corresponding Growth and Yield Characteristics

DBH(cm)	CD(m)	CR(m)	CPA(m)	BA(m^2)	SV (m^2)
20-30	198.6	23.62	277.5	2.01	331.82
31-40	413.4	43.83	637.0	6.47	962.31
41-50	58.8	7.17	87.4	1.45	168.91
51 Above	61.3	5.06	140.9	1.47	225.07
Grand Total	732.0	79.68	1142.8	11.40	1688.11

DBH=Diameter at Breast Height, CD=Crown Diameter, Crown Ration, CPA=Crown projection Area, BA=Basal Area and V=Stem Volume

3. 3. Slenderness Coefficient

This table (3) below represent slenderness coefficient classes and their corresponding crown characteristics, basal area and stem volume of the sampled trees. SLC represent the stability of trees, from the result obtained the majority of the trees have low (<70) and moderate (70<100) slenderness coefficient which shows that about (92%) of the trees are not likely to be overthrown by wind but few trees show high SLC which is about 8% of the total trees measured

Table 3. Slenderness Coefficient with corresponding Growth and Yield Characteristics

SLC (%)	CD(m)	CR(m)	CPA(m)	BA(m^2)	V(m^3)
1-69 (Low)	399.5	43.01	609.1	6.67	734.57
70-99 (Moderate)	274.2	29.73	447.7	4.04	761.91
100 (High)	58.3	6.94	86.0	0.68	191.63
Grand Total	732.0	79.68	1142.8	11.40	1688.11

DBH=Diameter at Breast Height, CD=Crown Diameter, Crown Ration, CPA=Crown projection Area, BA=Basal Area and V=Stem Volume

3. 4. Height Class Distribution

The table below (4) provides information on height classes and their corresponding crown characteristics, basal area, and stem volume. Trees with 20-30m have the highest crown and yield metrics, followed by 11-20m, 31m above and the lowest was recorded among trees that are <10m in height.

Table 4. Height Class with corresponding Growth and Yield Characteristics

TH(m)	CD(m)	CR	CPA	BA(m^2)	V(m^3)
<10	39.9	4.36	53.6	0.57	32.84
11-20	234.8	24.44	348.7	3.64	422.19
21-30	353.7	40.21	543.6	5.41	859.21
31 Above	103.7	10.67	196.8	1.78	373.87
Grand Total	732.0	79.68	1142.8	11.40	1688.11

TH=Total Height, CD=Crown Diameter, Crown Ration, CPA=Crown projection Area, BA=Basal Area and V=Stem Volume

3. 5. Correlation Coefficients

The table below (5) shows relationship between crown cover and biometric characteristics measured. Tree Height (TH) shows a strong positive correlation with Crown Length (CL) and Crown Projected Area (CPA), indicating that taller trees tend to have longer crowns and larger crown projected areas. Diameter at Breast Height (DBH) demonstrates a moderate positive correlation with Crown Diameter (CD) and Crown Projected Area (CPA) suggesting that trees with larger diameters tend to have larger crown diameters and projected areas. Crown Length (CL) exhibits a strong positive correlation with Tree Height (TH) and Crown Diameter (CD), indicating that taller trees tend to have longer crowns and larger crown diameters. Crown Ratio (CR) shows a moderate positive correlation with Crown Length (CL) and Crown Projected Area (CPA), this suggests that trees with longer crowns and larger crown projected areas tend to have larger crown radii. Crown Projected Area (CPA) demonstrates a strong positive correlation with Tree Height (TH) and Crown Diameter (CD) indicating that taller trees and those with larger diameters tend to have larger crown projected areas. Slenderness Coefficient (SLC) displays a strong positive correlation with Tree Height (TH), Crown Length (CL), and Crown Radius (CR), suggesting that taller trees with longer and wider crowns tend to have higher slenderness coefficients making the vulnerable to wind throw and destruction. SLC shows a weak negative correlation with DBH signifying slight tendency for trees with larger diameters to have lower slenderness coefficients and less vulnerable to windthrow. BA displays a weak negative correlation with SLC suggesting that trees with higher slenderness coefficients may have slightly smaller basal areas, although the correlation is not significant. BA shows a strong positive correlation with Diameter at Breast Height (DBH), Crown Diameter (CD), and Crown Projected Area (CPA), this indicates that trees with larger diameters and crown diameters tend to have larger basal areas. Volume (V) demonstrates a strong positive correlation with all other variables, indicating that trees with greater heights, diameters, crown dimensions, and basal areas tend to have larger stem volumes.

The correlation between tree basal area and slenderness coefficient was negative. This implies that the proportion of trees prone to wind-throw or damage in the area decreases with increase in tree basal area. This agrees with the finding of Martin-Alcon *et al.* (2006) and Ezenwenyi and Chuku (2017) that the proportion of wind-throw and damaged trees in a stand decreases strongly at higher stand basal area for a given slenderness ratio. Slenderness coefficient is negatively and significantly correlated with diameter variables and positively correlated with crown metrics (CD, CR, CPA) which is tin total disagreement with what was obtained by Ezenwenyi and Chuku 2017, his variation may be as a result of difference in the area, tree species, soil and environmental conditions on which tree grows. As the basal area of trees increases, the slenderness coefficient decreases, higher basal area indicates larger, more mature trees with a larger cross-sectional area, lower slenderness coefficient suggests that these trees are less slender or more robust in relation to their height, this implies that larger, more mature trees in the study area are less prone to wind-throw or damage compared to smaller, slender trees. The negative correlation aligns with the findings of Martin-Alcon *et al*. (2006) and Ezenwenyi and Chuku (2017), who observed a decrease in the proportion of wind-throw and damaged trees with higher stand basal area.

Table 5. Correlation Matrix for the estimated parameters

	TH(m)	DBH(cm)	CD(m)	CL(m)	CR(m)	CPA(m)	SLC	BA(m^2)	V(m^3)
TH(m)	1								
DBH(cm)	0.331**	1							
CD(m)	0.354**	0.525**	1						
CL(m)	0.943**	0.348**	0.343**	1					
CR(m)	0.499**	0.152	0.073	0.734**	1				
CPA(m)	0.374**	0.538**	0.984**	0.381**	0.111	1			
SLC	0.808**	-0.259**	0.029	0.723**	0.387**	0.026	1		
BA(m^2)	0.321**	0.990**	0.534**	0.350**	0.171	0.560**	-0.260**	1	
V(m^3)	0.771**	0.628**	0.621**	0.765**	0.382**	0.664**	0.380**	0.640**	1

4. CONCLUSION

In conclusion, the correlations among tree characteristics highlight consistent relationships where taller trees tend to exhibit longer crowns and larger crown projected areas. Diameter at Breast Height correlates positively with crown dimensions, indicating larger trunk diameters correspond to broader crowns. Additionally, slenderness coefficients increase with tree height and crown dimensions, potentially increasing vulnerability to wind damage. Basal area shows a strong positive association with tree and crown dimensions, reflecting larger trees having greater basal area. Finally, overall tree volume positively correlates with all measured variables, underscoring that larger dimensions contribute to greater stem volumes in trees. These patterns underscore the interconnected nature of tree morphology and its implications for forest dynamics and resilience

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