



Slenderness Coefficient Models in Forest Plantation and Natural Forest of *Khaya Senegalensis* in Shabu Community, Lafia, Nigeria

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Abstract

This study developed slenderness models for forest plantation and natural forest of *Khaya senegalensis* in Shaibu Community to foster planting of the tree species in urban and rural communities of Nasarawa State. The specific interest of the research is to develop height diameter models, slenderness coefficient model and examine relationships among the variables of *Khaya senegalensis* plantation in the Nasarawa State University and the natural forest of Shaibu Community Forests. Data were collected from randomly selected thirty (30) temporary plots of 0.01ha located in the plantation. Thirty (30) plots of 0.01ha were also selected from the Shabu community forest, Lafia. The data collected include total height and diameter at breast height. The results of height diameter model in the plantation showed that model one (1) with AIC (126.0709), BIC (130.2745) and RSE (1.853) has the lowest model selection indices when compared with the other three (3). The results of height diameter model in the *Khaya senegalensis* natural forest showed that model one (1) with AIC (158.456), BIC (162.6596) and RSE (3.179) has the lowest model selection indices when compared with the other three (3) also. The result of slenderness coefficient model in the *Khaya senegalensis* plantation showed that model one (1) with AIC (-17.61868), BIC (-13.41509) and RSE (0.169) has the lowest model selection indices when compared with the other two (2) models. The result of slenderness coefficient model in *Khaya senegalensis* of the natural forest showed that model one (1) with AIC (-12.91355), BIC (-8.709963) and RSE (0.1827) has the lowest model selection indices when compared with the other two (2) models applied. The correlation between diameter at breast height 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 diameter at breast height. The result also revealed that 76.7% (>80 high), 13.3% (70-80 moderate) and 10% (<70 low) in the *Khaya senegalensis* plantation. The result further unveiled that 23.3% (>80 high), 6.7% (70-80 moderate) and 70% (<70 low) in the *Khaya senegalensis* natural forest. *Khaya senegalensis* trees are very valuable for its attractive and durable wood properties. Therefore, effort should be made by the Federal and State Government including NGOs and individuals to managing its natural stands, urban and rural tree planting, particularly around Nasarawa State Communities with less planting density as the result in natural stand showed that less dense planting of *Khaya senegalensis* is resilient to wind throw which is the major threat in planting many tree species within rural and urban dwellings.

Key Words: Slenderness coefficient, height diameter model, wind throw, *Khaya senegalensis*.

Introduction

Khaya senegalensis (Desr.) is a multi-purpose tree species used in pharmacopoeia, urban forestry, shade and timber that is highly prized by rural populations (Sokpon and Ouinsavi, 2004). It occurs in riverine forests and scattered within the higher-rainfall savannah woodlands. In moister areas, the tree species is found on uplands, but it is restricted to riparian habitats or stream bottoms that extend into the savannah in the drier portions of the range. During the 1st year, the seedling develops a strong, deep taproot, which makes it the most drought hardy of all the *Khaya* species. In its natural habitat it is a medium-sized to large

tree (up to 30 m) with a wide crown while in cultivation as an exotic it could grow up to more than 35 m high and up to 1.5 m in diameter (Jøker and Gaméné, 2003). It is also very resistant to flooding and can be considered for planting on swampy soils. Except where selectively removed by logging, dry-zone mahogany remains a dominant species in most of its range. The tree species is subject to excessive and over-exploitation, exposing it to a loss of diversity that could eventually lead to its extinction (Mapongmetsem *et al.*, 2011). The supplies of its wood and other products from the native range in central Africa are diminishing, and there is little management of the limited

natural regeneration by plantations (Gary, 2007). Information on slenderness coefficient of most of our indigenous tree species like *Khaya senegalensis* among others are rarely available for urban and rural tree planting and management.

In the 1960s, forest cover was estimated at close to 10 million hectares. By 1978, it diminished to 4 million hectares (ha). (Kumar *et al.*, 2006) noted that many forests are under great human pressure and require urgent intervention to maintain the overall biodiversity, productivity and sustainability. The intricacy and rich diversity of life found in forests provides important services to human beings. Moreover, humans are destroying forest biodiversity at an alarming rate. Singh *et al.*, (2002) described biodiversity as the aggregate of genes, species and ecosystem in a particular location. It is useful for human survival and economic well-being and for the ecosystem productivity and balance. Purvis *et al.*, (2000) indicated that the concept of biodiversity is considered to be the integration of biological difference across all scales, from genetic level, through species and ecosystems, to the landscape that they present, or are part of, and the ecological processes that works with them. Therefore, it is important to compare the impacts of tree spacing on slenderness coefficient of the tree species in natural and plantation forest in order to avoid tree planting spacing leading to high slenderness coefficient, prone to wind throw and damage of tangible properties thereby encouraging tree planting in urban and rural communities of Nasarawa State.

Tree slenderness coefficient has been described as the ratio of tree diameter at breast height and tree total height (Magruder *et al.*, 2012). Also, James (2010) noted that slenderness coefficients above 100 generally indicate low stability and the affected tree is likely to buckle under its own weight. For forest trees, slenderness coefficient below 80 indicates excellent stability (Novak, 2006). Greater values indicate taller and narrower trees, and trees with values over a threshold of 80 are prone to wind-throw as well as wind-induced breakage (Rudnicki *et al.*, 2004). It indicates the shape of trees and together with tree vitality provides insight into the general stability of planted forests (Dodan and Peric, 2019). Wind throw occurs when the applied force during a storm overcomes the anchorage of a tree or the strength of its stem. Failure of the stem occurs through a variety of modes and height of failure varies substantially, reflecting points of particular structural

weakness, for instance, branch nodes, wounds, rotor points of localized stress as a consequence of the sway/vertical wind profile. Failure of root anchorage results in overturning and, in contrast to stem breakage, generally occurs over a period during the storm as different parts of the root/soil structure are damaged and the system ultimately fails. However, these challenges could be resolved through modeling, estimating and adopting appropriate measures in addressing tree slenderness coefficients as the knowledge of the tree slenderness coefficients would help forest and wildlife managers in understanding the structure and stability status of a stand. In addition, it is important to compare the impacts of tree spacing on slenderness coefficient of the tree species in natural and plantation forest in order to avoid tree spacing leading to high slenderness coefficient, prone to wind throw and damage of tangible properties in urban forestry thereby encouraging tree planting in urban and rural communities of Nasarawa State. Therefore, the main objective of this study is to assess slenderness coefficient models in forest plantation and natural forest in shabu community with specific interest in developing a height-diameter model, slenderness coefficient model and compare *Khaya senegalensis* slenderness coefficients in Nasarawa State University Khaya Plantation and natural trees of *Khaya senegalensis* in Shabu community, Lafia, Nasarawa State.

Methodology

The Study Area

This study was carried out at the Departmental of Forestry and Wildlife *Khaya senegalensis* Plantation, Faculty of Agriculture, Shabu-Lafia Campus, Nasarawa State University, Keffi and Shabu community forest in Lafia, Nasarawa State. It has longitude and latitude of (8°33' N and 8°32' E), located in the Guinea Savannah zone of North Central Nigeria with an altitude of about 177m above sea level. The mean monthly maximum temperature range is between 35.06°C to 36.40°C and 20.16°C to 20.50°C while the mean monthly relative Humidity and rainfall are 74.67% and 168.90mm respectively. Tropical ferruginous soils make up the major soil units found in Lafia Local Government Area. The parent material for the soils are from basement complex and sedimentary formations in the area (Lyam, 2000).

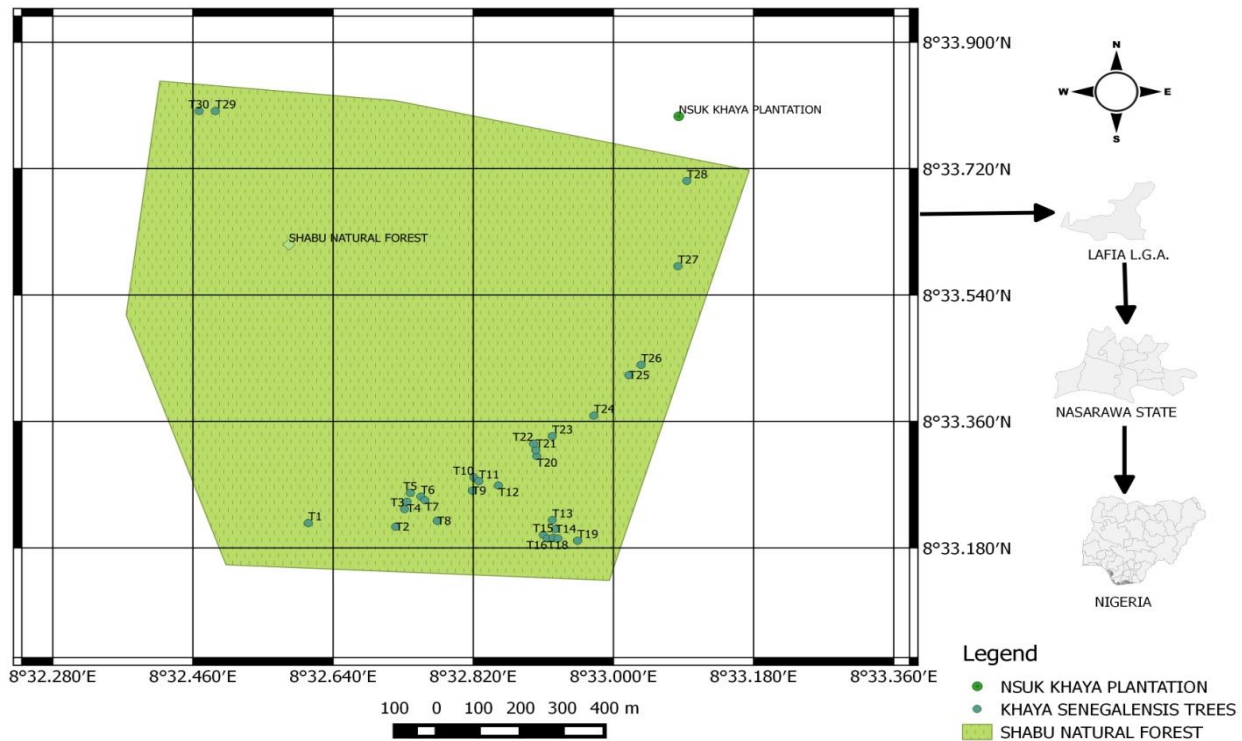


Fig. 1: Map of Nasarawa State University Khaya Plantation and Shabu Natural Forest Lafia.

Data Collection

Data were collected from thirty (30) temporary plots of 0.01ha located in the plantation of the species at the Nasarawa State University *Khaya senegalensis* and the natural forest located around Shabu community forest, Lafia. The data collected include total height and diameter at breast height. The instrument used are haga altimeter, diameter tape, ranging poles, survey tape and global positioning system (GPS).

Data Analysis

Tree Slenderness Coefficient

The individual tree slenderness coefficient was computed using:

$$SC = \frac{THT}{DBH}$$

Where

SC= slenderness coefficient of ith tree; THT= total height of the tree (m); Dbh= corresponding tree diameter at breast height (m).

The individual trees was grouped into slenderness coefficient classes as high (with SC > 80); moderate (with SC: 70-80) and low (with SC < 70) slenderness coefficients. The height - diameter and slenderness coefficient models for the species from the plantation and natural forest are presented in tables 1 and two respectively.

Table 1. Height - Diameter Model for Plantation and Natural Forest of the species

Model Code	models for forest plantation	models for natural forest
1	$H = DH + \frac{aDBH}{(b + DBH)} + \varepsilon$	1. $H = DH + \frac{aDBH}{(b + DBH)} + \varepsilon$
2	$H = DH + \left(\frac{DBH}{a + bDBH}\right)^2 + \varepsilon$	2. $H = DH + \left(\frac{DBH}{a + bDBH}\right)^2 + \varepsilon$
3	$H = DH + \frac{\exp(a + b)}{(DBH + 1)} + \varepsilon$	3. $H = DH + \frac{\exp(a + b)}{(DBH + 1)} + \varepsilon$
4	$H = DH + a * \exp\left(\frac{b}{DBH}\right) + \varepsilon$	4. $H = DH + a * \exp\left(\frac{b}{DBH}\right) + \varepsilon$

Table 2. Slenderness – Coefficient Models for Plantation and Natural Forest of the species

Model Code	models for forest plantation	models for natural forest
1	$LnSC = a + b Ln DBH + \varepsilon$	1. $LnSC = a + b Ln DBH + \varepsilon$
2	$SC = \frac{1}{a + b Ln DBH} + \varepsilon$	2. $SC = \frac{1}{a + b Ln DBH} + \varepsilon$
3	$a + b Ln DBH + \varepsilon$	3. $a + b Ln DBH + \varepsilon$

The crown projection area was computed for individual trees using:

$$CPA = \frac{\pi CD^2}{4}$$

Where:

CPA = crown projection area (m²); CD = crown diameter (m).

Percentage Canopy Cover

The percentage canopy cover was computed as follows:

$$C = 100(\varepsilon P * PCA)^{A^{-1}}$$

To correct for crown overlap, the equation suggested by Satterlund in Moeur (1986) was used:

$$C = 100[1 - \exp(-0.01C')]$$

Where:

C' = percent canopy cover without accounting for overlap; P= trees/ha for the ith sample plot; CPA= crown projection area/ha for the ith tree; A = total area (m²/ha); C = percent canopy cover that accounts for overlap.

Correlation Analysis

The cross tabulated Correlations of Tree Characteristics in *Khaya senegalensis* plantation and natural forest was computed as followed

$$\text{Correlation (r)} = \frac{Exy - \frac{(Ex)(Ey)/n}{\sqrt{(Ex^2 - \frac{(Ex)^2}{n})(Ey^2 - \frac{(Ey)^2}{n})}}}{\sqrt{(Ex^2 - \frac{(Ex)^2}{n})(Ey^2 - \frac{(Ey)^2}{n})}}$$

Statistic and model evaluation

Regression analysis was applied on *Khaya asenegalensis* trees in the plantation and natural forest in order to estimate its coefficients. The association among the measured tree growth variables was evaluated using Karl Pearson's product correlation coefficient at $\alpha = 0.05$. Also, AIC, BIC and RSE were used to evaluate the performance of the models.

Results

The performance indices of the height–diameter models in *Khaya senegalensis* plantation with constants a and b as the model parameters was indicated in table 3. From the table, model one (1) has the lowest model selection indices of AIC (126.07), BIC (130.27) and RSE (1.85), followed by model two (2) with AIC (126.22), BIC (130.43) and RSE (1.86), model four (4) with AIC (126.47), BIC (130.67) and RSE (1.87) and Model three (3) with AIC (126.22), BIC (130.43) and RSE (1.86). In figure 2, the total height was plotted against diameter at breast height to show the distribution of trees in the plantation with lines of best fit. The four lines of best showed increasing trends with many

data points on and around them. Model one's (1) line of best fit showed a better increasing trend with predicting

power on the data when compared to other three models' lines of best fit.

Table 3: H-D model Performance Indices of the *Khaya senegalensis* Plantation

Models	Coefficients	AIC	BIC	RSE	Pr (> t)
1	a = 13.73062	126.0709	130.2745	1.853	5.89e-07***
	b = 0.04688				0.0618
2	a = 2.424e-05	126.2218	130.4254	1.858	0.1662
	b = 1.364e-03				0.0022**
3	a = 12.456265	126.468	130.6716	1.865	2.79e-11***
	b = -0.027756				0.00632**
4	a = 2.424e-05	126.2218	130.4254	1.858	0.1662
	b = 1.364e-03				0.0022**

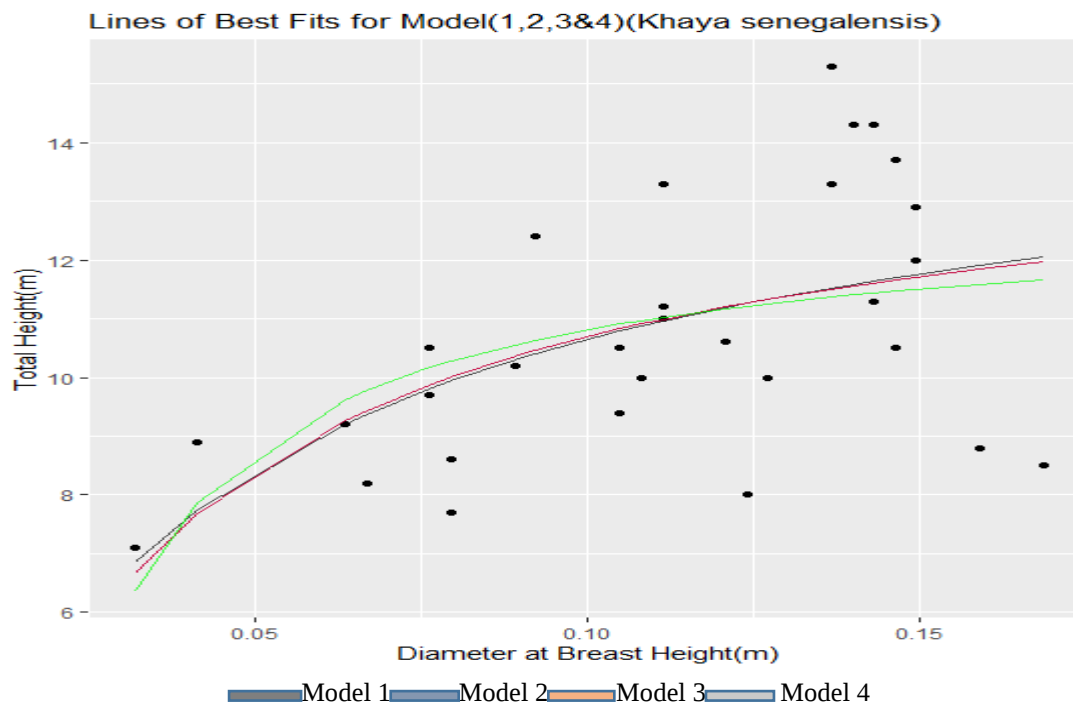


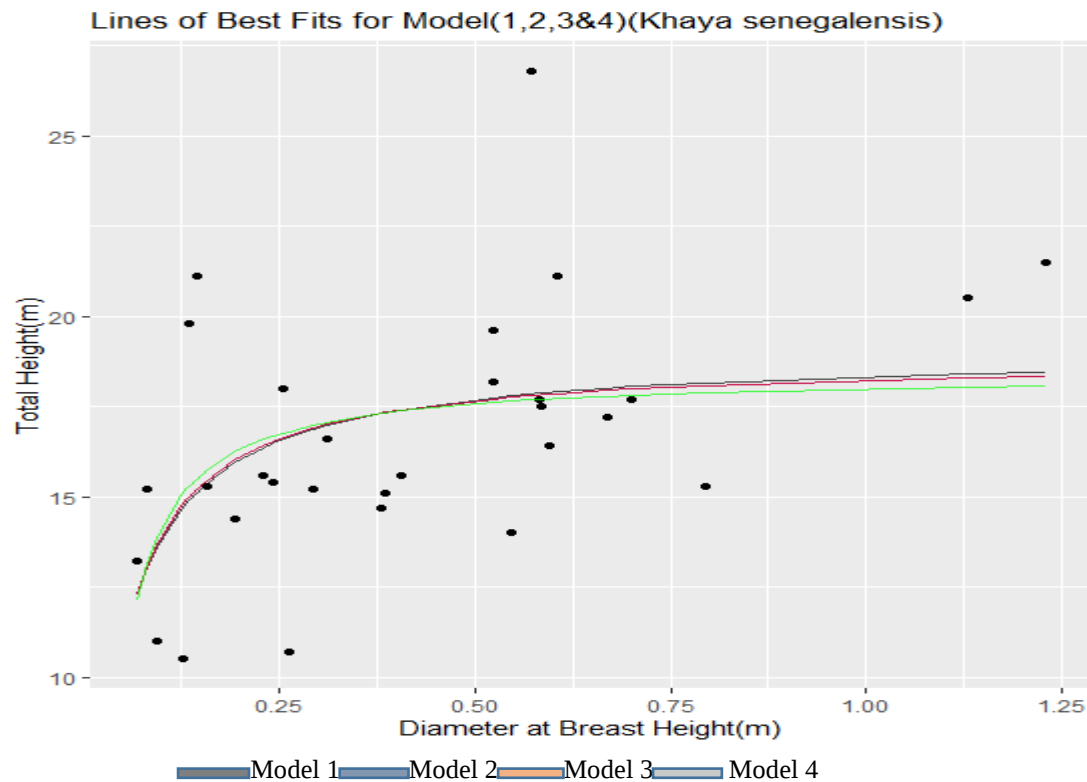
Fig. 2: Lines of best fit for model (1, 2, 3 and 4) of the *Khaya Senegalensis* Plantation

The result of height diameter (H-D) model Performance indices of the *Khaya senegalensis* in natural forest is shown in table 4. Model one (1) has the lowest model selection indices of AIC (158.46), BIC (162.66) and RSE (3.18), followed by model two (2) with AIC (158.62), BIC (162.82) and RSE (3.19), model four (4) with AIC (158.62), BIC (162.8238) and RSE (3.187) and model three (3) with AIC (159.09), BIC (163.30) and RSE (3). In figure 3, the total height was plotted against diameter at breast

height of *Khaya Senegalensis* from the natural forest in the study area. The graph shows the distribution of trees within the plantation. The four (4) models also depicted increasing trends with deterministic and residuals of the lines of best fit. Model one (1) showed a better increasing trend of line of best fit with many data points on and around it when compared to other three lines of best fit applied. It also indicates the line of best fits suitable for predicting tree growth of different stands within the plantation

Table 4: H-D Model Performance Indices of the *Khaya senegalensis* Natural Forest

Models	Coefficients	AIC	BIC	RSE	Pr(> t)
1	a = 17.72140 b = 0.04061	158.456	162.6596	3.179	5.67e-15*** 0.0163
2	a = 1.779e-05 b = 1.007e-03	158.6202	162.8238	3.187	0.2449 0.0179*
3	a = 17.1124 b = -0.4189	159.0946	163.2982	3.213	18.99<2e-16*** 0.0182*
4	a = 1.779e-05 b = 1.007e-03	158.6202	162.8238	3.187	0.2449 0.0179*

Fig. 3: Lines of best fits for model (1,2,3,4) of *Khaya Senegalensis* trees in Natural Forest

The result of S-C model performance indices of *Khaya senegalensis* in the plantation forest showed that model one (1) had the lowest model selection indices of AIC (-17.62), BIC (-13.42) and RSE (0.17), followed by Model two (2) with AIC (257.98), BIC (262.18) and RSE (16.7), and Model three (3) with AIC (258.41), BIC ((262.62) and RSE (16.82). The result of S-C model performance indices of *Khaya senegalensis* in the natural forest shows that model one (1) had the lowest model selection indices of AIC (-12.91), BIC (-8.71) and RSE (0.18), followed by Model two (2) with AIC (269.45), BIC (273.65) and RSE (20.21), and Model three (3) with AIC (274.11), BIC (278.32) and

RSE (21.85). The result in table 7 showed the cross tabulated correlation values among the variables of *Khaya senegalensis* in plantation in the study area with probability levels of 0.01 and 0.05. The paired correlation between slenderness coefficient (SC) and Diameter at Breast Height (DBH), Total Height (TH), Crown Diameter (CD), Crown Projection Area (CPA) are negatively correlated. But correlation among other variables are positively correlated. The highest positively paired correlated variables is between CPA and CD (97%) while negatively paired correlated variables is between SC and DBH (-84%).

Table 5: S-C Model Performance Indices of *Khaya senegalensis* in the Plantation Forest

Models	Coefficients	AIC	BIC	RSE	Pr (> t)
1	a = 3.00992 b = -0.70861	-17.61868	-13.41509	0.169	5.55e-16*** 1.12e-09***
2	a = 0.0209058 b = 0.0048614	257.9795	262.1831	16.7	19.71<2e-16** 4.94e-14***
3	a = -90.739 b = -87.128	258.4126	262.6162	16.82	2.71e-05*** 1.07e-11***

Table 6: S-C Model Performance Indices of *Khaya senegalensis* in the natural Forest

Models	Coefficients	AIC	BIC	RSE	Pr(> t)
1	a = 2.94896 b = -0.86004	-12.91355	-8.709963	0.1827	50.07<2e-16*** -19.60<2e-16***
2	a = 0.0285821 b = 0.0088762	269.4451	273.6487	20.21	9.74e-13*** 1.94e-10***
3	a = -1.304 b = -58.337	274.1118	278.3154	21.85	0.854 8.79e-12***

Table 7: Correlations of Tree Characteristics (Plantation Forest)

	DBH	TH	SC	CD	CPA
DBH(m)	1				
TH(m)	.526**	1			
SC	-.841**	-.174	1		
CD(m)	.480**	.556**	-.468**	1	
CPA(m ²)	.422*	.476**	-.374*	.965**	1

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

The result in table 8 showed the cross tabulated correlation values among the variables of *Khaya senegalensis* in the natural forest in the study area with probability levels of 0.01 and 0.05. The paired correlation between slenderness coefficient (SC) and Diameter at Breast Height (DBH), Total Height (TH), Crown Diameter (CD), Crown

Projection Area (CPA) are negatively correlated. But the correlation among other variables is positively correlated. The highest positively paired correlated variables is between CPA and CD (98%) while negatively paired correlated variables is between SC and DBH, CD (-74%).

Table 8: Correlations of Tree Characteristics (Natural Forest)

	DBH	TH	SC	CD	CPA
DBH(m)	1				
TH(m)	.503**	1			
SC	-.728**	-.200	1		
CD(m)	.719**	.238	-.734**	1	
CPA(m ²)	.744**	.272	-.668**	.983**	1

** . Correlation is significant at the 0.01 level (2-tailed). * . Correlation is significant at the 0.05 level (2-tailed).

The result showed the statistical test of significant between tree slenderness coefficients of the species in the plantation and natural forest using the T-test (Table 9). The result revealed a high significant difference of 0.0004339*** at 0.5 probability level between tree slenderness coefficients

in the plantation and natural forest in the study area. The result of tree canopy area showed that *khaya senegalensis* in the plantation had canopy projected area cover of 57.1 % while *khaya senegalensis* in the natural forest had a canopy projected area cover of 55.8 % (table 10).

Table 9: Statistical test for the difference between Slenderness coefficients of the Plantation and Natural Forest

Source of variation	Df	T-value	Pr(>T)
Slenderness Coefficients	58	3.7325	0.0004339***

Table 10: Canopy Projected Area for *Khaya senegalensis* Plantation and Natural Forest

Forest	CPA/Ha (%)	Corrected CPA/Ha (%)
Khaya senegalensis Plantation	84.62399	57.09749
Khaya senegalensis Natural Forest	81.75265	55.84776

The results in Figure 4 showed the classified trees based on slenderness coefficients as >80 (high), 70-80 (moderate) and < 70 (low) in the plantation. The < 70 represents trees are not prone to wind thrown, 70-80 moderate presents trees with 0.5 probability of withstanding wind thrown and >80 high represents trees prone to wind thrown in the study area. The result revealed that 76.7% (> 80 - high), 13.3% (70-80 - moderate) and 10% (< 70 - low) in the plantation. The results in Fig. 5 showed the classification of trees

based on slenderness coefficients as >80 (high), 70-80 moderate and <70 low in the natural forest. The <70 (low) represents trees not prone to wind thrown, 70-80 (moderate) presents trees with 0.5 probability of withstanding wind thrown and > 80 (high) represents trees prone to wind thrown in the study area. The results revealed that 23.3% (>80 - high), 6.7% (70-80 - moderate) and 70% (<70 - low) in the plantation.

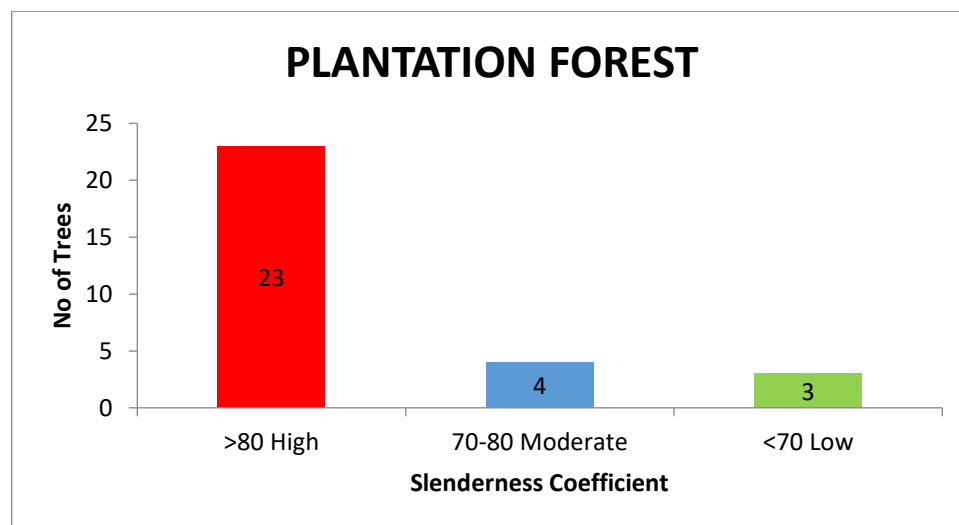


Fig 4: Classification of Tree Slenderness Coefficients in the Plantation

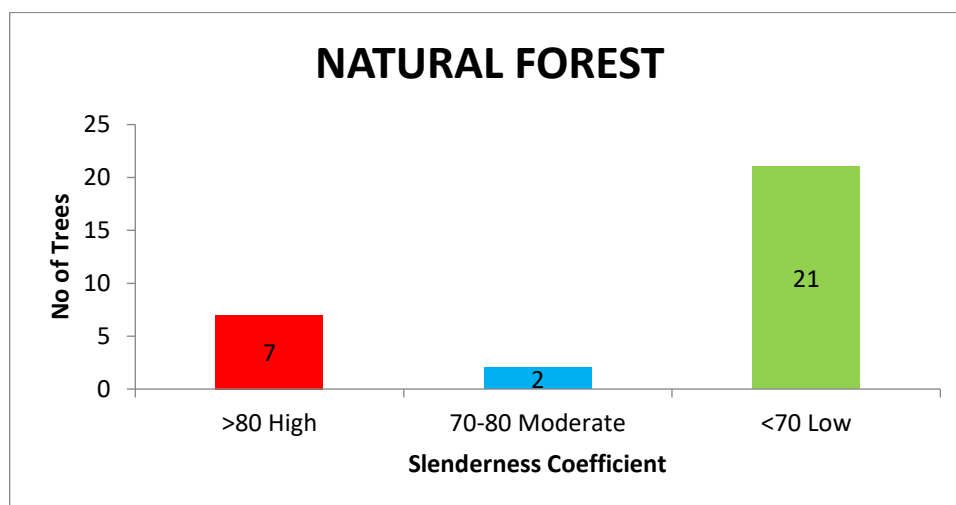


Fig.5: Classification of Tree Slenderness Coefficients in the Natural Forest

Discussion

Height-diameter model was developed to access the tree total heights of *Khaya senegalensis* in both the plantation and natural forest. It is abysmal to engage in measuring total height of all trees in a given plantation in the course of carrying out a project due to the difficulties in visibility and fatigue posed by canopy cover (Clement, 2023). The result of height diameter (H-D) model in both forest plantation and natural forest showed an increasing deterministic trend with minimum residuals. This implies that the trees are in competition zones where they strive for growth resources such as water, sun light, soil nutrients and space for maximum productivity. Competition is an important driver of community structure and dynamics in forests worldwide (Kunstler *et al.*, 2016). Unlike natural forest, forest plantation had a smoother and steeper increasing slope which indicates that they are at medium zone of completion while an increasing rate with almost constant slope of the natural forest indicates that they are approaching maximum competition zone. It is vital to understand the characteristic of the growth variables in order visualize the relationship among them, especially, heights, diameters, crown covers and slenderness coefficients. As this would unveil the species structural growth behaviour and stability.

Tree slenderness coefficient unveils the relationship between diameter at breast heights and total heights of trees in a given area. This relationship reveals the impact of wind on trees in plantations and natural forests. As noted by Liu *et al.* (2003), when tree slenderness coefficient becomes very high, there is possibility of exposure of such trees to bending stress, leading to reaction wood, which may affect wood properties as well as the ultimate usage to which the

wood can be put. Jullien *et al.* (2013) observed that high slenderness coefficient is the best accurate predictor of tree growth stress. The result of slenderness coefficients showed that model one had a better predicting power for tree slenderness coefficients in both forest plantation and natural forest with minimum residuals. It also revealed that about 76.7% of the trees in the forest plantation had their slender coefficient >80 high but due to their planting arrangement and closed canopy of the plantation, the trees were able to withstand wind force, thereby avoiding stem snaps. Trees with high slenderness coefficient are more susceptible to breakage than those with low slenderness coefficients.

Unlike the forest plantation, about 70% of the trees in natural forest had their slenderness coefficient <70 low which indicate excellent stability of the trees. This agrees with the finding of Martin-Alcon *et al.* (2012), that the proportion of wind-throw and damaged trees in a stand decreases strongly at higher stand basal area for a given slenderness ratio. Trees with values over a threshold of 80 are prone to wind-induced breakage. For forest trees, slenderness coefficient below 80 indicate excellent stability (Smudla, 2004; Slodicak and Novak, 2006; Kontogianni *et al.*, 2011). It implies that the trees in open space were able to withstand the force of wind by building biomass across their stems. It also revealed a significant difference ($P < 0.05$) between slenderness coefficients of forest plantation and natural forest in the study area. The excellent stability of the species in natural forest suggest that it could be planted as urban tree in shabu-lafia community with less cluster of planting arrangement without any doubt of stem snapping.

The benefits of planting this tree species in urban areas are enormous as it ranges from curbing climate change, providing microclimate for populace, highly valued timber for roofing, furniture and encourage biodiversity. Planting of the tree species should be encouraged in shabu-lafia community to curb the ravaging impacts of climate change such as flooding, drought and excessive high temperature. The paired correlation between slenderness coefficient (SC) and Diameter at Breast Height (DBH), Total Height (TH), Crown Diameter (CD), and Crown Projection Area (CPA) were negatively correlated. But the correlation among other variables were positively correlated. The strongest positively paired correlated variables was between CPA and CD (98%) while the strongest negatively paired correlated variables was among SC and DBH, CD (-74%). This implies that the proportion of trees prone to wind-throw or damage in the area decreases with increase in tree diameter at breast height. This result agrees with the finding of Martin-Alcon *et al.* (2012), that the proportion of wind-throw or damaged trees in a stand decreases strongly at larger diameter at breast height for a given slenderness ratio.

The percent canopy cover in the *khaya senegalensis* plantation was about 57.1% per hectare on the whole. This implied that in a hectare (10,000 m²), only 5,710 m² of the land area were under canopy cover. On forest type basis, percentage canopy cover was higher in *khaya senegalensis* plantation than in *khaya senegalensis* natural forest. Canopy cover is an indicator of wildlife habitat, and they are a good descriptor of forest stand structure.

Conclusion

The result of height diameter models showed that model one (1) had a better predicting power for *Khaya senegalensis* tree heights in both forest plantation and natural forest in the study area. The result of slenderness coefficients also showed that model one (1) had a better predicting power for predicting *Khaya senegalensis* slenderness coefficient in both forest plantation and natural forest in the study area. The correlation between diameter at breast height 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 diameter at breast height. Unlike the forest plantation, about 70% of the trees in natural forest had their slenderness coefficient <70 low which indicate excellent stability of the trees. It implies that the trees in open space were able to withstand the force of wind by building biomass across their stems. It also revealed a significant

difference ($P < 0.05$) between slenderness coefficients of forest plantation and natural forest in the study area. *Khaya senegalensis* trees are very valuable for its attractive and durable wood properties. Therefore, effort should be made by the Federal and State Government including NGOs and individuals to managing its natural stands, urban and rural tree planting, particularly around Nasarawa State Communities with less planting density as the result in natural stand showed that less dense planting of *Khaya senegalensis* is resilient to wind throw which is the major threat in planting many tree species within rural and urban dwellings.

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