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Assessment of Tree Slenderness Coefficients of Tree Species in J1 Forest Reserve

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Abstract:

Tree slenderness coefficient influences the susceptibility of a tree stand to wind-induced damage. The aim of this study is to evaluate the tree growth and tree slenderness coefficients of the tree species in the Owode division of J1 Forest Reserve to assess the health status of the forest plantation. Data collected include total height (m) and diameter at breast height (dbh) while data derived include basal area (BA), volume estimation (V), crown projection area (CPA) and crown ratio (CR). The result revealed that the trees in the diameter in the diameter 10-19 cm is dominant with 74 individuals followed by the trees in the diameter class 20-29 cm with 60 individuals. It was observed that 37 trees had low slenderness coefficients (SC>70) while 44 had high slenderness coefficients (SC<99). There was a positive but weak correlation between the tree height and tree slenderness coefficient as well as tree basal area. Most of the trees in the study area are stable due to the low and moderate slenderness coefficient recorded.

Keywords-**Tree slenderness coefficient, tree height, basal area, volume estimation**

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I. INTRODUCTION

Forests are Earth's the most abundant terrestrial habitat, found all throughout the world. Forests produce 75 percent of the biosphere's gross primary output and hold 80 percent of the planet's plant biomass. The annual net primary output of tropical forests is estimated to be 21.9 gigatonnes carbon, 8.1 gigatonnes carbon for temperate forests, and 2.6 gigatonnes carbon for boreal forests [1].

Different ecozones are formed by forests at different latitudes and elevations: boreal forests in the poles, tropical forests near the equator, and temperate forests in the middle latitudes. Higher elevations support forests that are similar to those found at higher latitudes, and precipitation has an impact on forest composition. Human society and woodlands have both beneficial and adverse effects on each other. Humans benefit from forest ecological services, and they also serve as tourist attractions. Forests can also have a significant impact on people's health. Human actions, such as forest resource harvesting, can have a negative impact on forest ecosystems [2].

The tree slenderness coefficient has been characterized as a dimensionless number based on the ratio of tree diameter at breast height (dbh) to total height and computed as the entire height of the tree divided by the dbh[3]. Greater values indicate taller and narrower trees, while trees with values exceeding 80 are more susceptible to wind-throw and wind-induced breakage [4]. The slenderness ratio of trees has been found to be a good indication of their long-term exposure to the wind before harvesting [5].[6] employed the approximation of a very tall, slender, plantation-grown tree responding dynamically like a pole or chimney when modeling tree behavior with a slenderness ratio of 75.

The simplest empirical stability indicator for a single tree or stand dimensions has been the tree slenderness coefficient (SC) [7]. According to [8], the tree slenderness coefficient has a significant impact on a stand's vulnerability to wind-induced damage. Mechanical stability is influenced by tree size, form, and structure, according to [9]. As a result, accurate information on a stand's SC becomes critical for predicting its stability and susceptibility to damage.Furthermore, because tree crown condition affects tree primary productivity and provides home for a variety of species, it is an excellent predictor of a tree's health [10].

Slenderness coefficients exceeding 100 often indicate low stability, according to [11] and [12], and the damaged tree is likely to buckle under its own weight. A slenderness coefficient of less than 80 indicates great stability in forest trees [13]. [14] proposed lower slenderness ratios of 50:1 for trees in metropolitan settings.

The crown, according to [15], is one of the most significant aspects of the tree structure, as it supports vital living processes such as photosynthesis. Together with crown volume, the crown projection area affects the quantity of precipitation intercepted and regulates the amount of precipitation that reaches the forest floor [16]. It is feasible to calculate the percentage of canopy cover and canopy closure using crown projection data [17].

The size, form, growth, and development of tree crowns, their distribution in time and place, and the proportions of the crown compared to other parts of the tree determine the crown structure of a forest stand. The crown size and shape of a tree are the consequence of a complex interplay between its internal genetic content and the influence of biotic and abiotic factors in the environment. The range of changes in crown size and form, according to [15], is dependent on tree species, site quality, age, tree position in the canopy, and management interventions over the life of the forest stand.

Forestry, like any other industry, necessitates efficient resource management. However, one of Nigeria's forest management issues is a lack of timely information on stand conditions. Only current and trustworthy information on the growth status of the stand, which can be used by forest managers/management to offer correct and timely information on current growing stock, may enable sustainable management of forest stands.Though various studies on slenderness coefficient and stand stability potential have been conducted in many regions of the world, the relationship between tree slenderness coefficient and tree growth characteristics has not been investigated in Nigeria. However, due to climate change, environmental degradation, and desert encroachment in the tropics, including Nigeria, a critical assessment of tree slenderness coefficient and tree growth characteristics in Nigeria as it relates to the evaluation of stand stability in Nigeria is essential.

According to [18], little attention has been paid to the growth characteristics of many tree species in Nigeria, and where silvicultural intervention has been implemented without a thorough understanding of growth characteristics, poor management decisions are always made, resulting in lower stand productivity. As a result, the health of the forest plantation in the Owode division of J1 Forest Reserve was assessed using tree growth and tree slenderness coefficients.

II. MATERIALS AND METHODS

A. Location of the Study

The study was carried out at Owode division of J1 Forest Reserve, situated in Oluyole Local Government Area Ibadan Oyo state, Nigeria. Its original name (with diacritics) is Idi-Ayunre. It is located between latitude 07^{o} 10`N and longitude 03$^{o}$52`E lying at an altitude 122 meters above sea level (CRIN, 2016).

B. Data Collection

Growth variables such as total height (m) and diameter at breast height (dbh) were measured. Basal area and volume were estimated from measured growth characteristics of height and basal area. The species were identified by a taxonomist. Data from the quantitative measurement were subjected to ecological analysis using indices such as relative dominance, species diversity and evenness.

C. Data Analysis

The data collected from tree measurement was processed into a suitable form for statistical analysis while the non-measurable tree growth characteristics (TGC) were estimated for further analysis procedures. The estimated TGCs include basal area (BA), volume estimation (V), crown projection area (CPA) and crown ratio (CR) as shown in the expressions below.

Basal Area Estimation

The basal area for each tree in each sample plot was estimated using the formula:

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

Where BA = Basal Area (m²);

D = dbh, $\pi = 3.143$.

In each plot, the total basal area of all the trees was computed and used to estimate the basal area per hectare using the formula of [19].

Tree volume estimation

The tree volume for each tree within the study area was estimated using Newton' equation

$$V = BA \times HT$$

Where BA= Basal Area;

HT= Tree Height;

Tree Slenderness Estimation

Tree slenderness was estimated for all trees using this formula

$$TSC = \frac{THT}{D}$$

Where TS = tree slenderness;

THT =Total height and;

D = diameter at breast height

III. RESULTS AND DISCUSSION

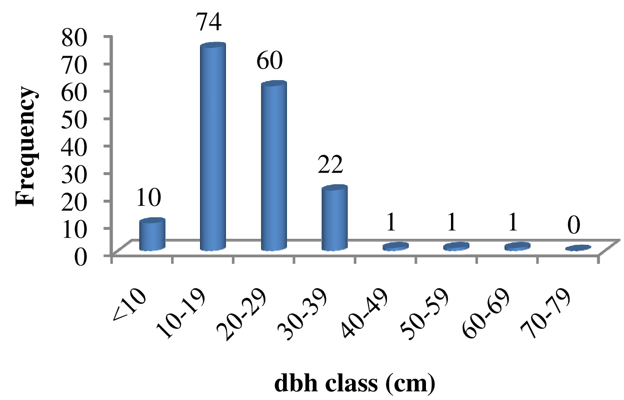

Fig. 1: Diameter Class Distribution of Trees in the Study Area

The result presented above revealed that the trees in the diameter in the diameter 10-19 cm is dominant with 74 individuals followed by the trees in the diameter class 20-29 cm with 60 individuals, while the least was found in diameter classes 40-49, 50-50 and 60-69 cm with one individual each (Figure 1). This reveals that there are fewer big trees in the study area.

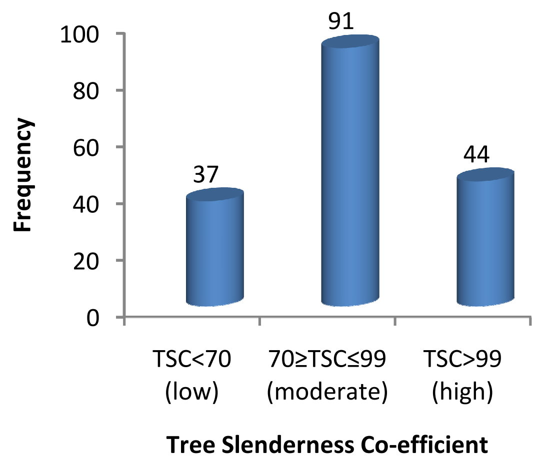

Fig 2: Slenderness coefficient of trees in the study area

The figure above showed the tree slenderness coefficients (SC) category for the pooled data in the study area. It was observed that 37 trees had low slenderness coefficients (SC>70). 91 trees were moderately slender (SC: 70-99), while 44 had high slenderness coefficients (SC<99) (Figure 2). This reveals that most of the trees in the study can withstand high wind velocity. [4] noted that trees with values over a threshold of 80 are prone to wind-induced breakage. For forest trees, a slenderness coefficient below 80 indicates excellent stability [13].

TABLE 1: SUMMARY OF THE GROWTH CHARACTERISTICS IN THE STUDY AREA

Parameters	Minimum	Maximum	Mean
Height	5.2	45	18.51±0.53
DBH	6.46	60.82	21.42±0.66
TSC	30.09	381.7	93.14±3.05
B.A	0.001	0.29	0.04±0.003
Vol.	0.02	8.04	0.91±0.85

The table above presented the summary of the growth characteristics of the trees in the study area. The mean height and Dbh in the area were 18.51±0.53 m and 21.42±0.66 cm respectively. The mean B.A. and Vol. were 0.04±0.003 m^2 and 0.91±0.85 m^3 respectively. Tree slenderness coefficient (TSC) values were between 0.02 and 8.04 with a mean of 0.91±0.85 (Table 1). It was revealed that there wasa steady growth of the trees in the study area. The dbh was able to explain the relationship that existed within the growth variables. Basal area and volume among others throughout assessment followed the same trend with the tree dbh. According to [20], basal area per hectare is computed from standing trees.

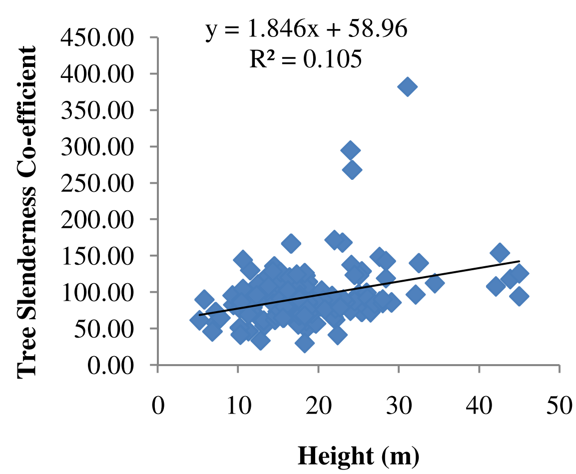

Fig 3: Relationship between Tree Height and TSC

The figure above shows that there is a positive but weak correlation between the tree height and tree slenderness coefficient. The results of this study are similar to the report of [21] where the relationship of tree slenderness coefficients and tree height for major species in the forests were evaluated using empirical models.

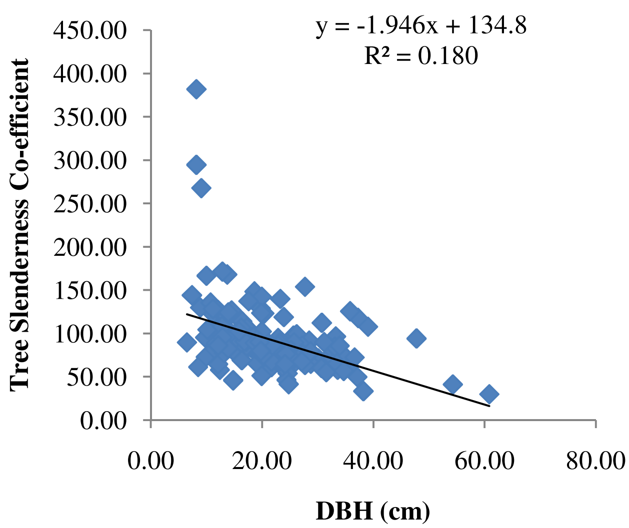

Fig 4: Relationship between diameter at breast height and TSC

The result presented in the figure above indicates that the tree slenderness coefficient values tend to decrease for larger trees, and the largest slenderness coefficient values occur for the trees with small dbh. This indicates that the dbh is a better predictor of the slenderness coefficient than the age and volume. The results confirm that the slenderness coefficient generally decreases with increasing stand dbh. This trend was in agreement with the reports of several authors on the growth attributes and management scenarios for some vegetations in Southwest, Nigeria [22].

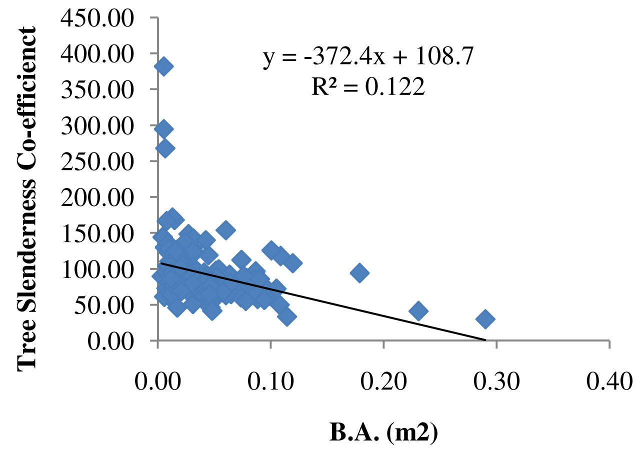

Fig5: Relationship between Basal Area and TSC

The result presented in the figure above indicates that there was a weak correlation between tree basal area and slenderness coefficient. This implies that the proportion of trees prone to wind-throw or damage in the area decreases with an increase in tree basal area per hectare. This agrees with the finding of [23], that the proportion of wind-throw and damaged trees in a stand decreases strongly at higher stand basal area for a given slenderness ratio.

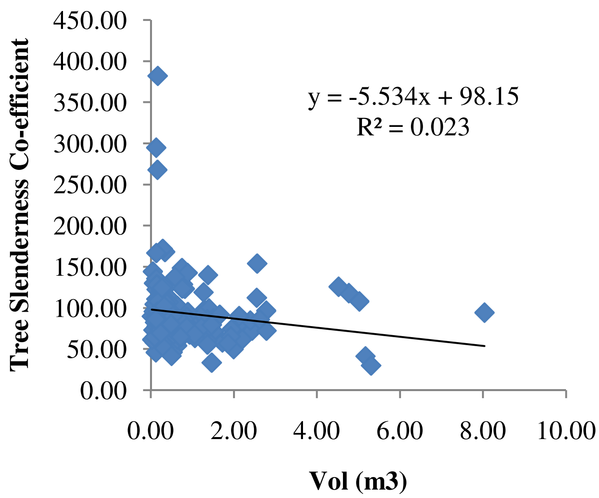

Fig6: Relationship between Volume and TSC

The result presented in the figure above indicates that the tree slenderness coefficient values tend to decrease as the volume increases but the rate at which it decreases is very low which makes it no significant factor for determining tree slenderness coefficient. This corroborates the finding of [24] and [25], who reported that trees in denser stands tend to be slender compared to the less-dense ones because of competition for light among trees is more in denser.

IV. CONCLUSION

The study revealed that most of the trees in the study area are stable because of the low and moderate slenderness coefficient recorded. Themean values of the DBH indicated that the study area consists mostly of trees that are between 10 – 15 years old. DBH showed a converse relationship with TSC while the height is directly related to TSC.

There should be the consistent establishment of trees in forest reserves with adequate spacing to reduce the level of slenderness coefficient.

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