CROWN RATIO ASSESSMENT FOR *PROSOPIS AFRICANA* (GUILL.AND PERR.) TAUB SPECIES IN MAKURDI, NIGERIA

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ABSTRACT

Information on tree crown is prerequisite for sustainable utilization of forest tree resources, as it is the site for physiological activities that lead to tree growth and development. Crown ratio (CR) is an index of tree stability; it indicates tree vigour and is a useful parameter for assessing forest condition. This study aimed at assessing crown ratio for improved silvicultural management of naturally grown Prosopis africana species within the University of Agriculture Makurdi, Nigeria. Nine temporary sample plots (TSPs) of size 100 m x 100 m were established using simple random sampling method. Diameter at breast height (Dbh), total height (Ht) and crown diameter (Cd) and height to live crown base (HCB) were measured for all living P. africana trees with Dbh > 10 cm within the 9 TSPs. Data collected were subjected to descriptive and bivariate correlation analysis. The trees were further classified based on their Crown ratio as high vigour (CR>0.50), moderate vigour (CR= 0.30-0.50) and low vigour (CR<0.30). The result revealed that CR had strong negative correlation with Ht and HCB. Tree diameter attributes showed low positive correlation with CR. However, about 69% of the trees are within moderate CR class and only 3% areof the low CRclass. This implies that majority of the P. africana species in the study area are of moderate and high vigour. Hence, appropriate silvicultural Treatment such as thinning is recommended for trees with CR <0.3 to ensure moderate, better stand stability and sustainability of the species benefits.

Keywords: Correlation; Crown ratio; Economic trees; Tree growth characteristics; *Prosopis africana*

INTRODUCTION

Forests are large areas of land with varieties of tree, shrub and herb. Forest benefits to the environment and humankind, particularly the rural people who live close to the forest are enormous. These benefits include timber and non-timber products, such as fruits,pods, medicine, gum, resins, construction materials, nuts and seeds, tools, decorations, cosmetics, cultural artefacts and other needs (Oboho and Ogana, 2011). Hence, the vigour of these economic trees needs to be checked and known to ensure sustainability of its benefits.

Prosopis africana (Guill. and Perr.)Taub is one of the economic tree species that has both timber and non-timber benefits. *P. africana* belongs to the family Fabaceae, subfamily Mimosoideae. The common names include; Iron wood, Ubwa (Igbo), Kiriya (Hausa), Okpehe (Idoma), Kpaaye(Tiv) and Ayan in Yoruba language (Agboola, 2004). *P. africana*is one of the only known species of its genus found in Africa;the species occurring from Senegal to Ethiopia inthe zone between the Sahel and savannah forests. Abah*et al.* (2015), reported that almost all partsof the tree are medicinal and of high economic value to rural communities. The leaves and pods of *P. africana* are used for fodder and the seeds as seasoning for food (Laouali, 2016).It is used for the planks, mortars and pestles due to it resistant to wood borers and high wood density (SoteloMontes and Weber, 2009; Dau and Chenge, 2016).The tree species is highly valued for charcoal by blacksmiths due to the high calorific value of its wood (SoteloMontes*et al.*,2011).Furthermore, the leaves, roots and especially thebark are used in traditional medicine. According to Laouali (2016), *P. africana* is over exploited due to its numerous values, to ensure its sustainability, management practices that will aid its natural regeneration andpromoting their domestication is required to reduce the pressureon natural populations.

Often times, the impact of most natural or anthropogenic stress on tress, are evident on the crown as signs of deterioration may first be observed in the tree crowns. Thus, measurement of a tree crown is often used to assist in the quantification of tree growth (Popoola and Adesoye, 2012). However, tree crown is a significant feature of stand structure; it is the centre of physiological activity, particularly gas exchange, which drives essential living processes such as photosynthesis, growth and development (Leites and Robinson, 2004).Tree crown contains the foliage, network of branches and the anchor of fruits which are source of food for animals and man. Hence, understanding crown characteristics and status, will aid sustainable utilization of its benefits.

Previous studies have identified crown ratio as an indicator of tree'svigour, wood quality and an indicator of a tree's competitiveness in a stand (Sprinz and Burkhart 1987;Temesgen*et al.,* 2005). Crown ratio is the ratio of live crown length to tree height. In other word, the percentage of crown length from the base of the live crown to the tree tip to total tree height. It is often used as an important predictor variable for tree growth and yield equation. Hence, an important input variable to estimate the mortality of individual trees and also display changes in appearance of stand over-time (Adesoye and Oluwadare, 2008).

However, despite its aforementioned importance, assessment of crown ratio is one of the most difficult and mostly imprecisely measured tasks in forestry; as it is a function of tree height and crown diameter. Furthermore, the use of crown as an index of tree vigour is highly important, as larger ratios are indicative of healthier, faster growingtrees (Schomaker et al., 2007). Hence, this will aidproper decision-making. Therefore, this study was aimed at assessing crown [illegible] *Prosopis africana* species found in a natur[illegible] within the University of Agriculture, Makurdi, for sustainable and silvicultural management of the species and as baseline information for risk management.

MATERIAL AND METHODS

Study Area

The study was carried out in at the northern part of University of Agriculture Makurdi, Benue State, Nigeria. It is located on longitude 8° 21ˈE to 8°39ˈE and latitude 7° 33ˈNto7°52ˈNin Benue State, within the southern guinea savannah ecological zone of Nigeria and covers a total land area of 7,978 km^2. The topography of the study area is characterized by gentle hills. The soil is mainly sandy-loamy; the climate is characterized by distinct rainy and dry seasons. The annual rainfall ranges between 1016 mm to 1524 mm spreading over May to October. The climate of the area is tropical sub-humid with high temperatures and high humidity; the average maximum and minimum daily temperature of 35°C and 21°C in wet season, and 38°C and 16°C in dry season. The study area is bounded at the North-East by Guma Local Government Area and by River Benue in the South (Dau and Chenge, 2016).

Sampling Procedure

Data used for this study was collected from nine (9) randomly selected Temporary Sample Plots (TSPs) of size 100 m × 100 m within the study area. Within each TSP, total enumeration living *Prosopis africana*trees with Dbh ≥10.0 cm in the selected plots were made. Diameter at the base (Db), middle (Dm), top (Dt) and at breast (Dbh), total (Ht) and merchantable height (Mt), height to live crown base (HCB), crown diameter (Cd), crown length (CL), basal area (BA) were measured from a total number of three hundred and twenty-three (323) *P. africana* trees found in all the nine selected plots.

Measurement of Tree Growth Variables

Tree diameter

Stem diameter for all tree individuals with Dbh ≥ 10.0 cm were measured. The point of the measurement was recorded from the uphill sides of the trees and on the inside of the lean for leaning trees. Furthermore, trees with deformations at 1.3 m (Dbh) and 0.3 m (stump diameter), measurements were made at the sound points on the stem above the abnormality. Also, for buttressed trees, a point of measurement was selected approximately 0.5 m above the convergence of the buttress (Husch*et al*., 1982). Diameter measurements of trees were recorded using diameter tape graduated in centimeters. During the measurement, loose bark, climbers and epiphytes were lifted above the measuring tape. Spiegel relaskop was used to measure diameters at the top and middle of the trees.

Crown diameter

The tree crown diameter measurements were based on the assumption that the vertical projection of a tree crown is circular. Four radii were measured and, in the direction, forming equal angles (Zuhaidi, 2009).

The average crown diameter (Cd) was then calculated as such:

$$Cd = \sum \frac{r_i}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where; Cd = average crown diameter, r_i = projected crown radii measured on four axis and i=1, 2, 3 and 4.

Height measurement

Total height and height to base of the live crown (HCB) was measured using Spiegel relaskop. HCB was determined by identifying the point along the stem where the lowest live branch is attached to the main stem as indicated by Jiang *et al.,* (2007). Hence, height from the ground to the tip of the tree was measured as the total height.

Data Analysis

Individual tree derived variables were computed from the measured growth variables

Basal area

Basal Area for each tree was computed using:

$$BA = \frac{\pi(\mathrm{Dbh})^2}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where: BA = Basal Area (m^2), π = Pi is constant (3.143) and Dbh = Diameter at breast height (cm)

Volume

Tree volume was estimated using the Newton-Simpson's formula (Akindele, 2005) expressed as:

$$V = \pi\frac{H}{24}(\mathrm{Db}^2 + 4\mathrm{Dm}^2 + \mathrm{Dt}^2) \ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where; V = Total volume (m^3), H = total height (m), π = Pi is constant (3.143) Db = Diameter at the base (cm), Dm= Diameter at mid-point (cm) and Dt = Diameter at the top (cm).

Descriptive statistics

Descriptive and inferential statistics were used in this study. The tree growth variables were described using measures of central tendency and measures of dispersion.

Bivariate correlation analysis

Pearson's product-moment correlation coefficient was used to examine the linear relationship between crown ratio and other tree variables

The correlation coefficient was computed as:

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{N}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{N}\right]}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(4)}$$

Where, r= correlation coefficient, X = variable (1) to be compared, Y =variable (2) to be compared, N = total numbers of observations or trees measured.

Crown ratio

Crown ratios of individual trees were computed using the mathematical expression below:

$$\mathrm{CR} = \frac{CL}{Ht} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Where CL= crown length (m) and Ht= total height (m)

Crown ratio classification

Crown ratio of *P. africana* species found in the study area was computed and classified into three vigour classes modified from Schütz, (2001):

i. Low vigour (CR<0.3)
ii. Moderate vigour (CR 0.3-0.5)
iii. High vigour (CR> 0.5)

Frequencies of the observed numbers of tree in each class was calculated

RESULTS

The entire data obtained from the field inventory were carefully collated and analysed to detect and represent fundamental growth patterns. The dataset comprises of tree growth variables measured from *Prosopis africana* species found within the study area. A total of 323 trees measured and summary statistics of the dataset used in this study are presented in Table 1. The diameter at breast height ranged from 17.27- 63.82 cm, total height ranged from 4.0 to 13 m, crown length ranged from 1.2 to 6.4m from and crown ratio ranged from 0.2 to 0.8 m.

Table 1: Summary statistics table for growth characteristics variables.

Variables	Descriptive Statistics		
	Minimum	Maximum	Mean ± SE
Ds (cm)	21.303	70.180	32.165 ±0.557
Dbh (cm)	17.271	63.820	29.241 ±0.506
Dm (cm)	12.108	51.167	24.367 ±0.422
Dt (cm)	10.678	33.478	25.427 ±0.440
Cd (m)	3.070	10.800	6.320 ±0.090
Ht (m)	4.050	13.400	7.327 ±0.092
BA (m^2)	0.019	0.320	0.074 ±0.003
V (m^3)	0.095	3.388	0.446 ±0.020
HCB (m)	1.060	9.433	4.081 ±0.081
CL (m)	1.237	6.408	3.246 ±0.031
CR	0.216	0.806	0.457 ±0.005
HDR	8.558	62.526	6.771±0.455

Where: Ds= stump diameter, Dbh= diameter at breast height, Dm= diameter at the middle, Dbh= diameter at the top, Ht= total height, HCB= height to live crown base, CD= crown diameter,HDR = height to diameter ratio, CL= crown length, CR= crown ratio, BA=Basal area, V = Total volume and SE = standard error. Number of trees = 323

The result of Pearson's product-moment correlation analysis between the crown ratio (CR) and other measured and derived tree growth variables was shown in Table 2. Crown ratio was significant and shows strong negatively correlation with HCB and Ht. However, the result revealed low and positive correlation with tree stem diameter (Ds and Dbh), Basal area, crown diameter, crown length and total volume (non-significant). The graphical relationships of CR versus Ht; HCB; HDR and CR versus Dbh were presented in Figures 1-4. It can be seen that crown ratio of *Prosopis africana* trees in the study area are essentially linearly (negative) related with total height, height to live crown base and height diameter ratio. Hence, crown ratio displayed a positively linear relationship with diameter at breast height.

Table 2: Results of correlation analysis of Tree Size Variables with CR

	Correlation								
Variables	Ds	Dbh	Cd	Ht	BA	V	HCB	CL	HDR
CR	0.27*	0.27*	0.05*	-0.63*	0.28*	0.04^{ns}	-0.84*	0.29*	-0.71*

* =Correlation is significant and ns=Correlation is not significant at 0.05 level (2-tailed).Ds= stump diameter (cm), Dbh= diameter at breast height (cm), Ht= total height (m), HCB= height to live crown base (m), Cd= crown diameter (m), HDR

= height diameter ratio, CL= crown length (m), CR= crown ratio, BA=Basal area (m^2), V = Total volume (m^3). I of trees = 323

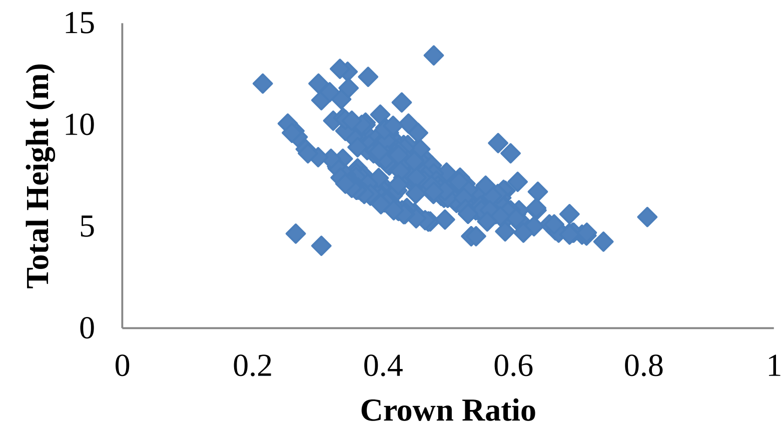

Figure 1: Relationship between crown ratio and total height

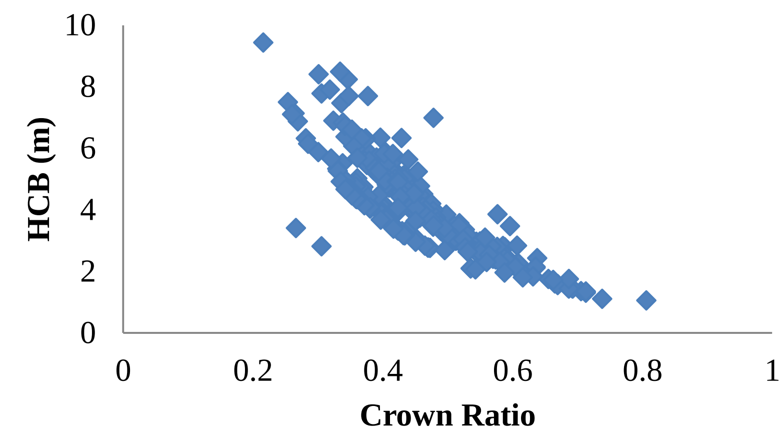

Figure 2: Relationship between crown ratio and height to live crown base

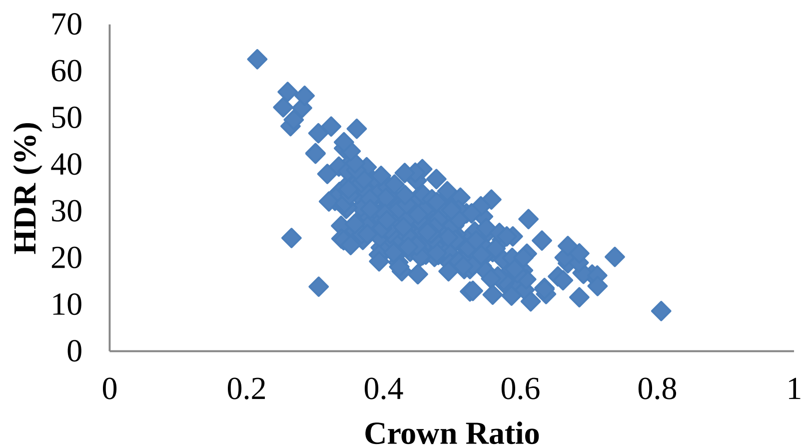

Figure 3: Relationship between crown ratio and height-diameter ratio

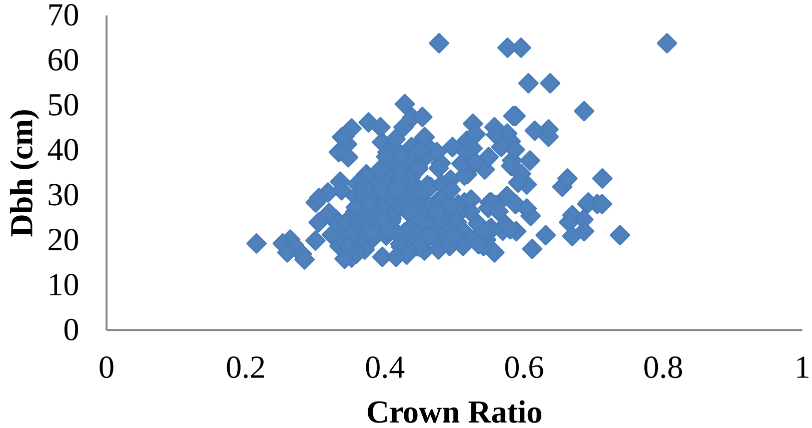

Figure 4: Relationship between crown ratio and diameter at breast height

The result of the tree crown ratio (CR) categorization (Figures 5 and 6) for the pooled data in the study area revealed that about 224 trees/ha (69%) trees in the study area are between 0.3-0.5 (Moderate), about 91 trees/ha (28%) trees are of High CR (>0.5) and 8 trees/ha (3%) fell under low CR (<0.3)

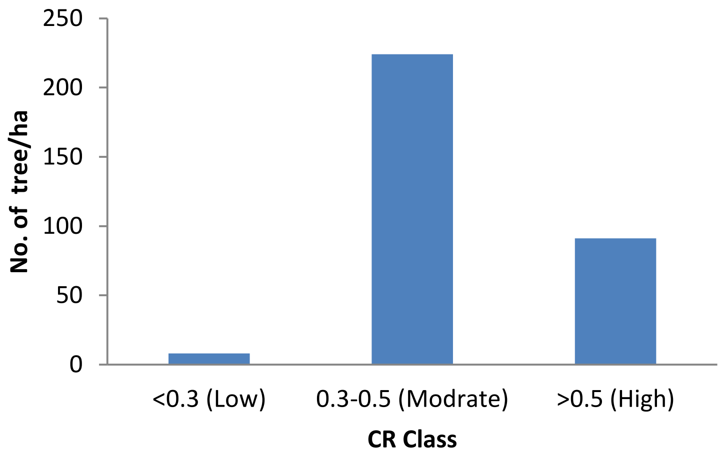

Figure 5: **Chart showing number of trees in crown ratio classes**

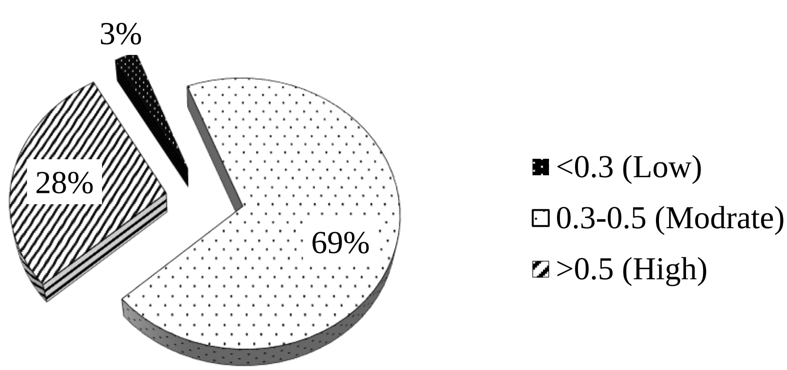

Figure 6: **Chart showing percentage of trees in crown ratio classes**

DISCUSSION

In this study, information on tree growth characteristics were collected and processed. The pooled summary of tree growth characteristics for the *P. africana* speciesfound in a natural forest within the University of Agriculture Makurdi, Nigeria. However, the study revealed significant variations across Ds, Dbh, Cd, Ht, BA, V, CL, HDR and HCB. The low associations or relationship among tree growth attribute of Ds, Dbh, Cd, BA, V, and CL indicates low impact of these tree attribute on the CR. This implies that there is less effect of horizontal increment of growth variables on tree vigour. This is in disagreement with the report of Popoola and Adesoye (2012) that correlated crown ratio with tree for *Tectona grandis* in Osho forest, Oyo State, Nigeria; that crown ratio decreased with increasing tree size. The results of the bivariate correlation between tree growth attributes and crown ratio of *P. africana* species in the study area indicated inverse associations with total height and HCB. This implies that CR decrease with increase in tree height. This result is in congruent with the report of Temesgen*et al*. (2005), that tall and slender trees have lower CR.

The result of classification of the crown ratio of *P. africana* species in the study area reveals that the larger percentages (69 and 28%) of the species are within the moderate and high vigour classes. Based on the CR classification considered in this study, the overall result shows the trees within the study area were vigorous, thereby; indicates that *P. africana* trees in the study are in moderate condition. This might be attributed to the location of the trees (within a University environment). Hence, there was little pressure and /or less exploitation on crown resources of the trees species investigated, because the University environment has some level of protection.

CONCLUSION

The assessment of tree growth attributes is the fundamental and most important aspect of estimating and managing trees in the forest stand. Findings from this study showed that, there is a strong negative correlation between the tree crown ratio and stemheight. Crown ratio shows significant variation with most tree growth variables in the study area. Majority of the *P. Africana* trees in the study area have moderate vigour. Therefore, an appropriate silvicultural treatment such as thinning is recommended for trees with CR <0.3 to ensure moderate, better stand stability and sustainability of the species benefits.

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