Regression Models for key Economic Savanna tree Species : A case study of Parkiabiglobosa (Jacq.) R. Br. ex G. Don f. in the Guinea Savanna Ecological Zone of Ghana

ABSTRACT

The rising demands for *Parkiabiglobosa* due to its numerous benefits and the lack of active conservation measures have endangered the species in most of its natural ranges. Data on its dendrometry, which is a prerequisite for its sustainable management, arelimited especially in Ghana. This study, therefore, investigated the relationships between fivedendrometryvariables and developed models for predicting them.The prediction models were developed using diameter at breast height and crown diameter as independent variables. Ten randomly distributed trees were sampled, and data collected and analyzed using Pearson correlation and simple linear regression. It was observed that stem diameter was positively correlated with all the other four variables measured. The correlation between stem diameter at breast height and crown diameter was 0.69.The co-efficient of determination between stem diameterat breast height and total height, crown diameter, crown ratio and crown heighthad R^2 values of 0.16, 0.48, 0.19 and 0.28, respectively. Crown diameter, as the second indicator variable, was also positively related with total height with correlation co-efficient of 0.97 and R^2 value of 0.09. The relationship between stem diameter at breast height and crown diameter was significant with f-value of 0.03 at 95% confidence level. The results will make significant contributions to the management of trees in the study area. The study will also be morale booster for similar studies to be conducted to assist improve the models developed.

K*ey words: Parkiabiglobosa, tree height, stem diameter, Ghana Guinea Savanna, Regression models*

1.0 INTRODUCTION

Parkiabiglobosa(Jacq.) R. Br. ex G. Don f.; belongs to the family Leguminosae and the subfamily Fabaceae.The species is a multipurpose tree and as such plays several important roles in the lives of the people of Northern Ghana [1] and throughout its ranges. It is used for food, medicinal, cultural, economic and magico-therapeutic purposes [2]. For instance, the fermented seeds, known as “dawadawa”, is a delicacy usedin making soup as it is rich in protein, lipids and vitamin B_2.The pulp can also be eaten raw or made into a drink and used as a sweetener in the production of alcoholic beverages [3]. [3], further argued thatmucilage from parts of fruit, in fluid form, is use for hardening earth floors and in pottery to give them a black glaze look whilst the pods and leaves are use as fodder. *Parkiabiglobosa* is a sustainable source of its products and due to its wide adaptability, drought resistance, multifunctional usage, it is mostly considered as a priority species [2]. The rising demands for its products have become a treat the to the species arising from factors such as sustained exploitation and inappropriate land use practices which inhibit the natural regeneration capacity of the species [4].As such, the population of the species is declining with no sustainable conservation measures currently in place[5].There is, therefore, the need to prioritize its management to ensure its sustainability. One of such measures is the need for efficient measurement of its dendrometry to aid afforestation efforts.

Forestry activities and processes are concerned with diameter measurement as it varies with other key dendrometryvariables [6]. According to [7], diameter at breast height measurement is the most important stand variable assessed during most forest inventories due to the ease with which it is acquired and the relationship it has with other important tree variables which are relatively difficult to assess and measure. It was further argued that the ease of diameter measurement reduces errors [7].According to [8], diameter variable is derived from direct measurement of trees and often gives a good relationship with key variables such as volume.Diameter at breast height and the total tree heightrelationshipis used in developing growth and yield models. Measurements of height and stem diameter are also important in estimatingvolume and site index [9]as well as volumes of standing trees [10]and in carbon stock measurements [11]. Despite the critical roles these measurements play, tree height measurementmostly come withthe requirements for measuring instrumentswhich are not easily accessible to most people with interest in forest management, especially in the Sub-Saharan African region. Again, these instrumentationsoften requirewell trained human skillsand experience to achieve the desire results. Further, most measurements in forestry deploy sampling methodologies which involve complex errors and biases which are sometimes not properly quantified. Recent discovery of laser rangefinders, which have some level of high precision, has also been faced with numerous challenges including the lack of clear view path in dense and multi-layered canopies of tropical forests, poor visibility to the base of the tree due to under-growths, leaning trees and uneven forest terrains [12]. There is, therefore, the need for alternative modes of collecting data from forest trees including the use of prediction models as theysave time, money and other inventory resources. Studies have shown that stem diameter at breast heightyielded accurate predictions of different tree dimensions and as suchhas widely been used in models that enabled the efficient and effective estimation of tree total height, crown height, crown diameter and crown ratio, among other variables[13]. These equations are mostly used to model costs and benefits as well as analyze management scenarios for efficiency and effectiveness [14]. Tree crown parameters, on the other hand, have been used as indicator variables in the development of diameter and height growth equations as well as in the prediction the total height of trees[9]. This is because, variabilities in crown morphology arekey in light interception and in tree growth [9] and also serve as a good indicator of tree vigor, wood quality, stand density, competition and wind firmness [15]. Besides its usefulness, crown measurement is difficult to obtain directly [16] especially in very dense stands and for very large trees as the bases of the live crowns aresometimes very difficult to see [17]. Therefore, a variable that can easily be measured, such as diameter at breast height.is often used as an indicator for tree's crown dimensions [18]. Despite the key role tree models play in addressing difficult forest management challenges, there is insufficient information on their development and existence for *Parkiabiglobosa*in Ghana especially in the Savanna Ecological Zone. Hence, the objective of the current study was to investigate the relationships between diameter at breast height and total height, crown diameter, crown ratio and crown height. The study also sought to develop prediction models for these parameters. The development of models to predict these variables will bring great relief to key stakeholdersin forest management who hitherto are limited by equipment deficiency and low financing. The models developed will also serve as a morale booster for the development of similar models for other economic tree species in Ghana.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carried out in the Guinea Savanna Ecological Zone specifically the Tolon district of the Northern Region, Ghana.The districtis located between latitudes 9° 15'` and 10° 02' North and longitudes 0° 53'and 1° 25' West. It shares boundaries to the North with Kumbungu, North Gonja to the West, Central Gonja to the South, and Sagnarigu Districts to the East. The main vegetation of Northern Region is grasslandinterspersed with other drought-resistant economic trees such as *Mangiferaindica* (Mango), *Adansoniadigitata* (Boabab), *Azadirachtaindica* (Neem), *Khayasenegalensis* (Mahogany), *Vitellariaparadoxa* (Shea), *Anogeissusleiocarpus* and*Acacia longifolia* (Acacia) [19].

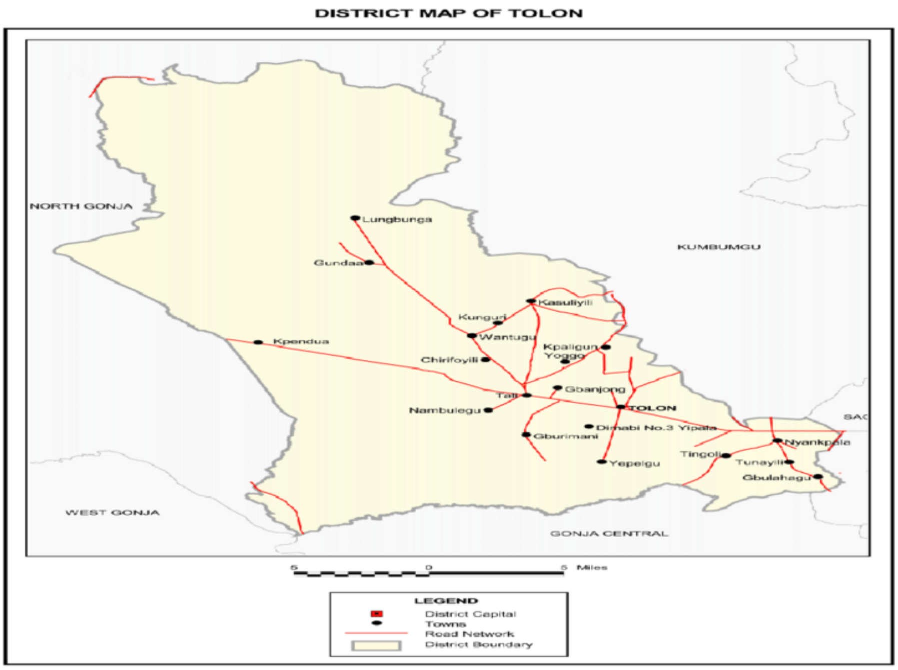

Figure 1: Map of Tolon District in the Guinea Savanna Ecological Zone [19].

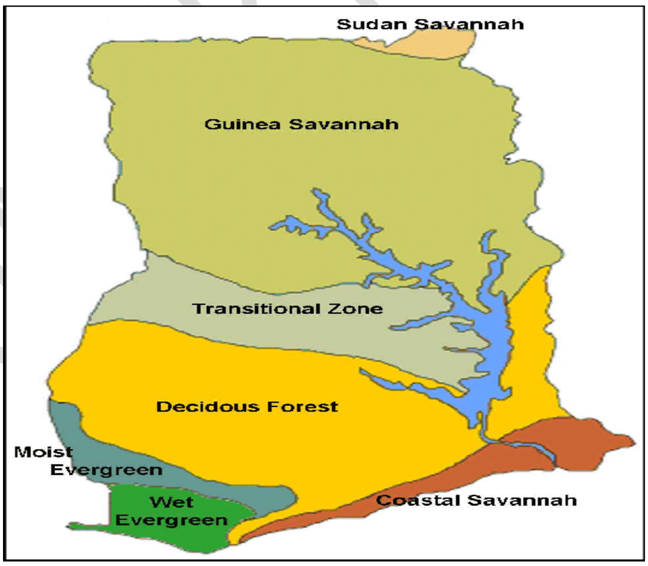

Figure 2. Vegetation Map of Ghana Showing the Location of the Study Area (Guinea Savanna Ecological Zone) [27]

2.2 Data collection and analysis

Data for the study was collected from ten individual solitary trees of *Parkiabiglobosa*randomly selected in the natural range of the species. Four variables were measured from all the selected trees; stem circumference at breast height, total tree height, crown diameter and the distance from the first live crown to the ground. Stem circumference was measured at a height of 1.3m above the base of the sampled tree using a tapemeasure and the values were recorded in centimeters and used to compute the stem diameter at breast height. Total tree height was measured using the Haga Altimeter set at a fixed distance scale of 30 m. A reference tape measure was pegged at the base of the sampled tree to be measured and stretched to a 30 m distanceaway to correspond to the distance on the Altimeter scalefollowing [20]. To measure the total height, the peak of the tree was sighted with Altimeter at the 30 m distance and the corresponding value of the Altimeter recorded as the top height to a precision of 0.01 m [6].Consequently, the height at base of the tree was recorded after releasing trigger of the Altimeter. A fixed height of 1.3 m, the eye-level height of the Altimeter's operator, was added to all the values recorded from the treetops following Altimeter's operational manual. The procedure was repeated for all the ten trees measured. The crown diameter was estimated by taking the average of two directional crown measurements: diameter of crown from the North to South and that from East to West[21]. Crown ratio was computed using the values of the crown diameter and total height. The distance between the first live crown and the ground was also measured using a tape measure lined up on a pole. This was used, together with the total height measurements, to compute the crown height.Diameter measurements were taken in centimeters and converted into meters to ensure uniformity with measurements from other variables which were all measured in meters. Diameter (D) at breast height was computed as follows:

Stem circumference (C) = C/π. where π = 3.14 [22].

The total tree height was determined as the sum of the height at the tree peak and the fixed eye-level height of the Altimeter's operator minus the height at the base of the tree. The crown ratio wascomputed by dividing crown diameter by the total tree height whereas the crown height was determined as the total tree height minus the distance from the first live crown to the ground [6][22]

[23]. The data was analyzed in Microsoft (MS) Excel using Simple Linear Regression and Pearson Correlation. The chosen method is in line with the fact that regression analysis, as a statistical methodology employed in quantitative scientific investigation,assist highlight the average relationship between two or more variables [17] [23]. Analysis of variance (ANOVA) was used to test for significant differences at 95% confidence level.

3.0 RESULTS and DISCUSSION

The means for stem diameter at breast height, total height, crown diameter, crown ratio and crown height for *Parkiabiglobosa*were 1.91±0.40 m, 23.23±5.40 m, 19.94±10.00m, 0.08±0.02 m and 14.44±5.91, respectively. Stem diameter measurements ranged between a minimum of 1.44 m and a maximum of 2.61 m (Table 1). Stem diameter was positively correlated to all the other four variables measured for *Parkiabiglobosa.* The strongest correlation was observed between stem diameter and crown diameter at 0.69, using stem diameter at breast height as the indicator variable.Crown diameter, as the second independent variable, was also positively correlated with the total height at 0.31. Crown height and total height were strongly correlated with a value of 0.97. Total height was, however, negatively correlated crown ratio at -0.62. Similarly, crown height was negativelycorrelated with crown ratioat -0.49 (Table 2).The coefficients of determination between stem diameterand totalheight, crown diameter,crown ratio and crown height hadR^2 values of 0.16, 0.48, 0.19 and 0.28, respectively. Crown diameterwas positivelycorrelated with total height with R^2 value of 0.09 but with a negative adjusted R^2 value of -0.02. There was a significant relationship between stem diameter at breast height and crown diameter with f-value of 0.03 at 95% confidence level. The models developed are as shown in Table 3. The analysis of variancesis asillustrated in Tables 4 to 8.The scatter diagrams depicting the relations between the variables studied are as shown in Figures 3 - 7.

Table1.Summary of descriptive statistics of the data used in the regression and correlation analysis on *Parkiabiglobosa*

Variable	Mean	Se	Md	Sd	Sv	Ku	Sk	Min	Max	Co	CI(95.0%)
Sd (m)	1.91	0.12	1.85	0.40	0.16	-0.17	0.86	1.44	2.61	10.00	0.28
Th (m)	23.23	1.71	21.30	5.40	29.20	-0.15	0.73	16.30	33.80	10.00	3.87

Cd (m)	19.94	3.16	16.18	10.00	100.09	8.95	2.94	14.60	47.85	10.00		7.16
Cr	0.08	0.01	0.09	0.02	0.00	0.04	-1.06	0.05	0.10	10.00		0.01
Ch (m)	14.44	1.87	12.20	5.91	34.97	-0.78	0.23	5.10	24.30	10.00		4.23

Sd = stem diameter, Th = Total height, Cd = Crown diameter, Cr = Crown ratio, Ch= Crown height, m=meters, Se = Standard error, Md = Median, Sd = Standard deviation, Sv =Sample variance,Kur = Kurtosis, Min = Minimum value, Max = Maximum value, Cl = Confidence Level

Table 2. Correlation matrix between Stem diameter at breast height and stem height, crown diameter and crown ratio of *Parkiabiglobosa* in the Savanna Ecological Zone of Ghana

Variable	*SD (m)*	*Th (m)*	*Cd (m)*	*Cr*	*Ch (m)*
Sd (m)	1.00				
Th (m)	0.40	1.00			
Cd (m)	0.69	0.31	1.00		
Cr	0.44	-0.62	0.25	1.00	
Ch (m)	0.53	0.97	0.38	-0.49	1.00

Sd = stem diameter, Th = Total height, Cd = Crown diameter, Cr = Crown ratio, Ch= Crown height,

Table 3. Regression prediction model, correlations coefficient (R) and correlation coefficient of determination (R^2) of the different tree dimensions of *Parkiabiglobosa*in the Savanna Ecological Zone of Ghana

Variables	R	R^2	AdR^2	Se	Obs	Pm	*F-value*
SD vrsTH	0.40	0.16	0.06	5.25	10	$TH = 5.4814x_1 + 12.774$	0.25
SDvrs CD	0.69	0.48	0.42	7.64	10	$CD = 17.572x_1 - 13.584$	0.03*
SD vrs CR	0.44	0.19	0.09	0.02	10	$CR = 0.0189x_1 + 0.0482$	0.20
SD vrsCh	0.53	0.28	0.19	5.31	10	$Ch = 7.9348x - 0.6961$	0.11
CD vrsTH	0.31	0.09	-0.02	5.45	10	$TH = 0.1659x_2 + 19.923$	0.39

*D = Stem diameter(x_1), H = Total height, CD = Crown diameter(x_2), CR = Crown ratio.Ch=Crown height, Se =Standard error, AdR^2=Adjusted r^2, Pm= Prediction Model. Obs= No of trees measured. The correlation f-values with * are significant at P = .05.*

Table 4. Analysis of variance in stem diameter and total height of *Parkiabiglobosa*

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	42.23333	42.2333297	1.531944	0.25
Residual	8	220.5477	27.5684588		
Total	9	262.781			

df = degree of freedom, SS= Sums of square, Mean sum of squares

Table 5. Analysis of Variance in Stem diameter and crown diameter of *Parkiabiglobosa*

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	433.999	433.99905	7.438397	0.03*
Residual	8	466.7662	58.345775		
Total	9	900.7653			

*df = degree of freedom, SS= Sums of square, Mean sum of squares. * = f is significant at P = .05.*

Table 6. Analysis of Variance in Stem diameter and crown ratio of *Parkiabiglobosa*

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000504	0.00050393	1.926786	0.20
Residual	8	0.002092	0.00026154		
Total	9	0.002596			

df = degree of freedom, SS= Sums of square, Mean sum of squares

Table 7. Analysis of Variance in Stem diameter and crown height of *Parkiabiglobosa*

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	88.499458	88.4994581	3.129615	0.11
Residual	8	226.22454	28.2780677		
Total	9	314.724			

df = degree of freedom, SS= Sums of square, Mean sum of squares

Table 8. Analysis of Variance in crown diameter and total height of *Parkiabiglobosa*

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	24.79078	24.7907763	0.833338	0.39
Residual	8	237.9902	29.748778		
Total	9	262.781			

df = degree of freedom, SS= Sums of square, Mean sum of squares

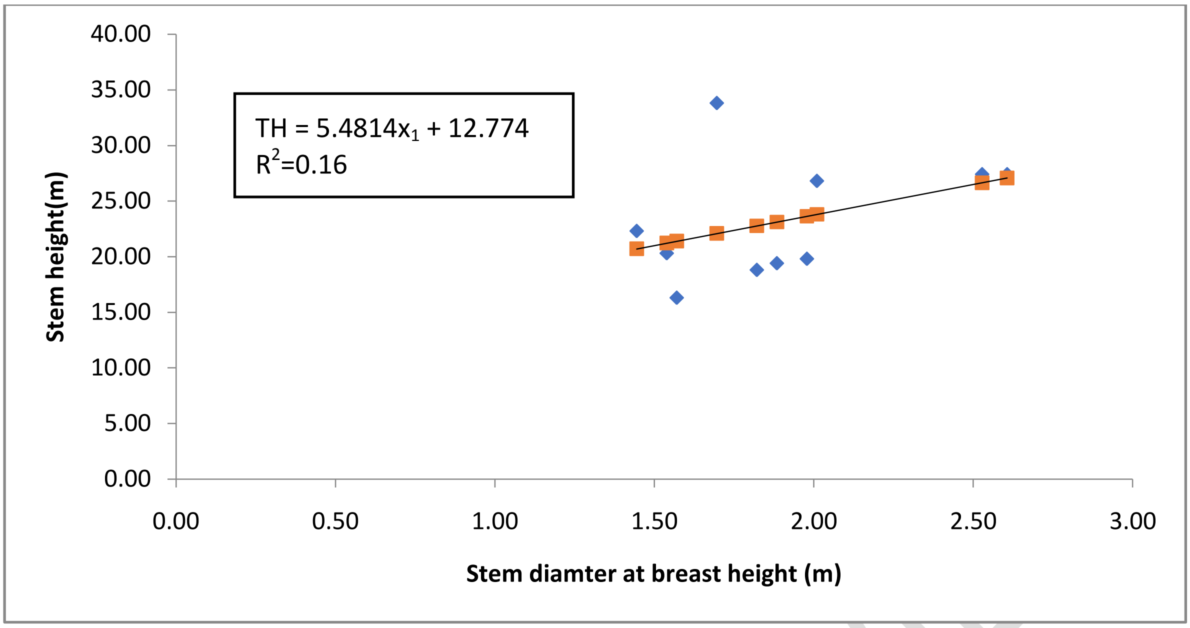

Figure 3.Regression analysis showing a positive relationship between stem diameter (m) and total height (m) of *Parkiabiglobosa*

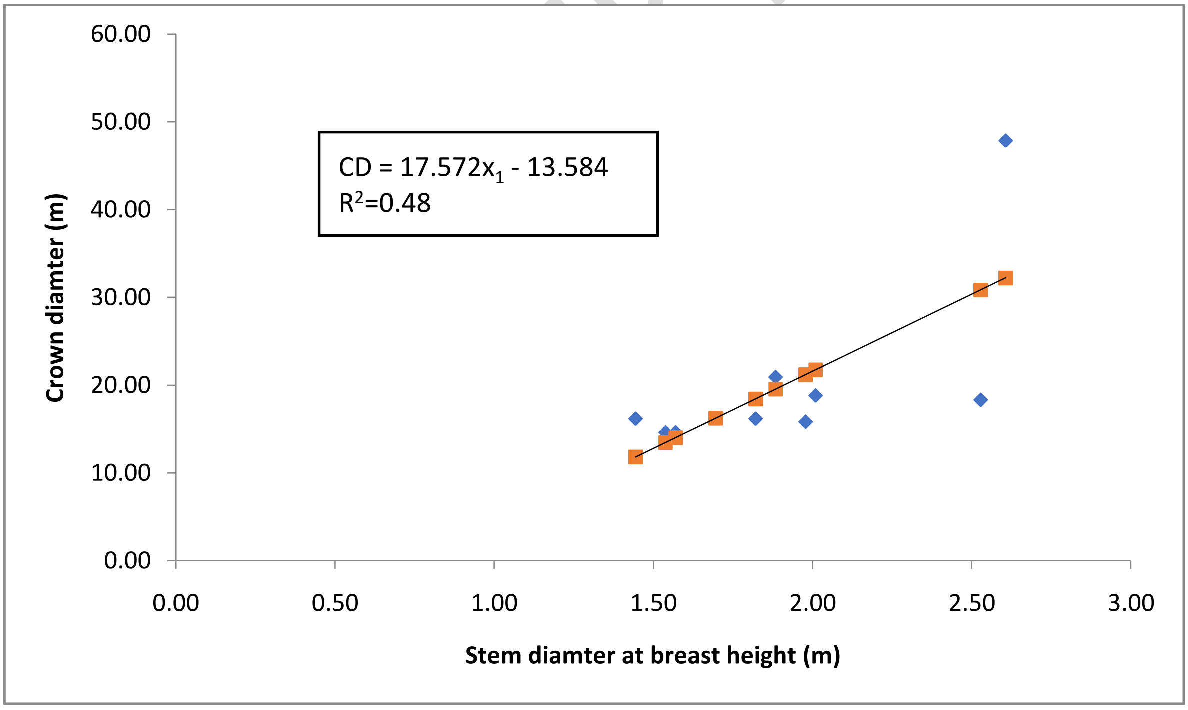

Figure 4.Regression analysis showing a positive relationship between stem diameter (m) and crown diameter (m) of *Parkiabiglobosa*

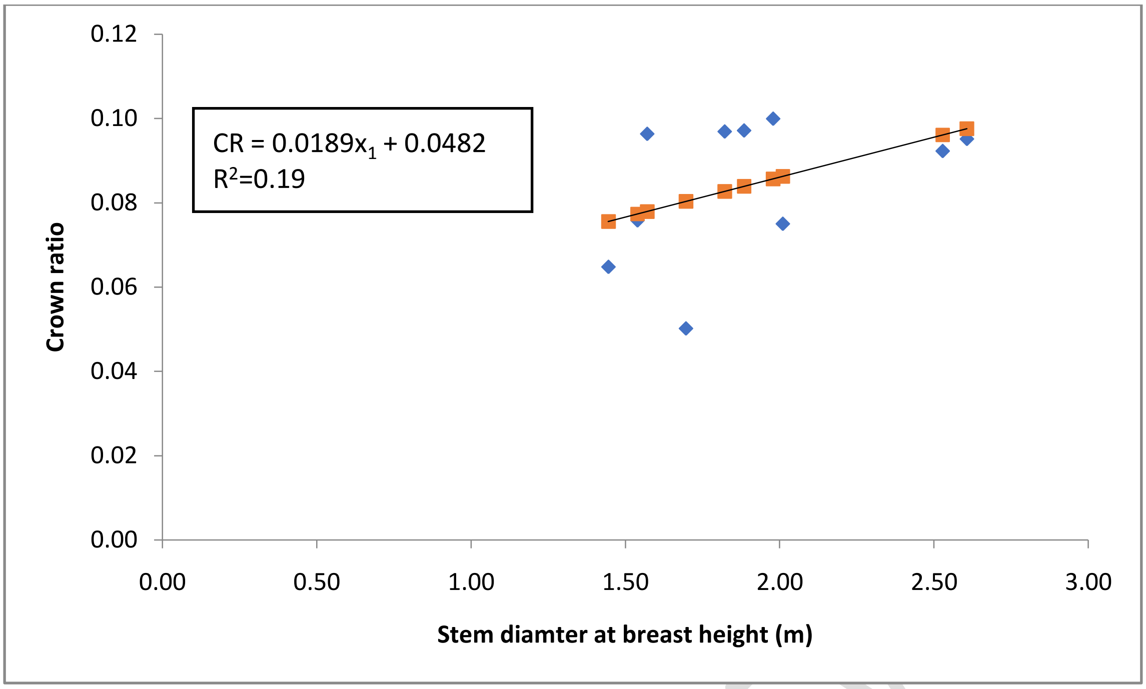

Figure 5. Regression analysis showing a positive relationship between stem diameter (m) and crown ratio of *Parkiabiglobosa*

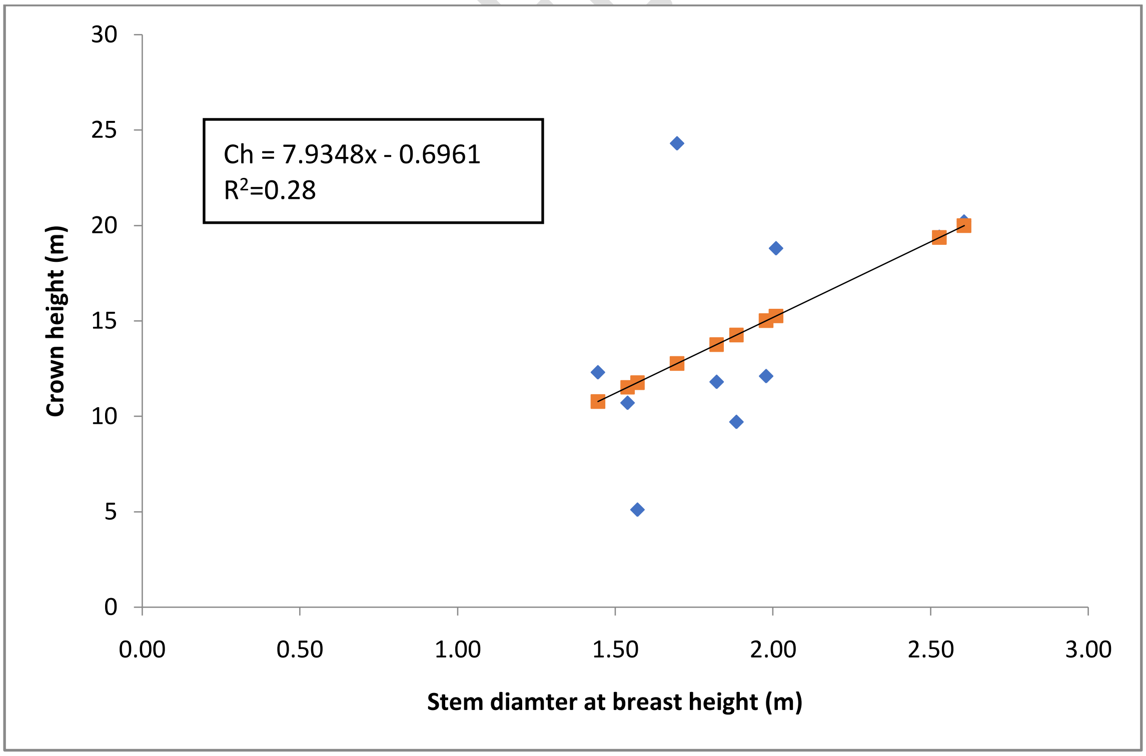

Figure 6. Regression analysis showing a positive relationship between stem diameter (m) and crown height of *Parkiabiglobosa*

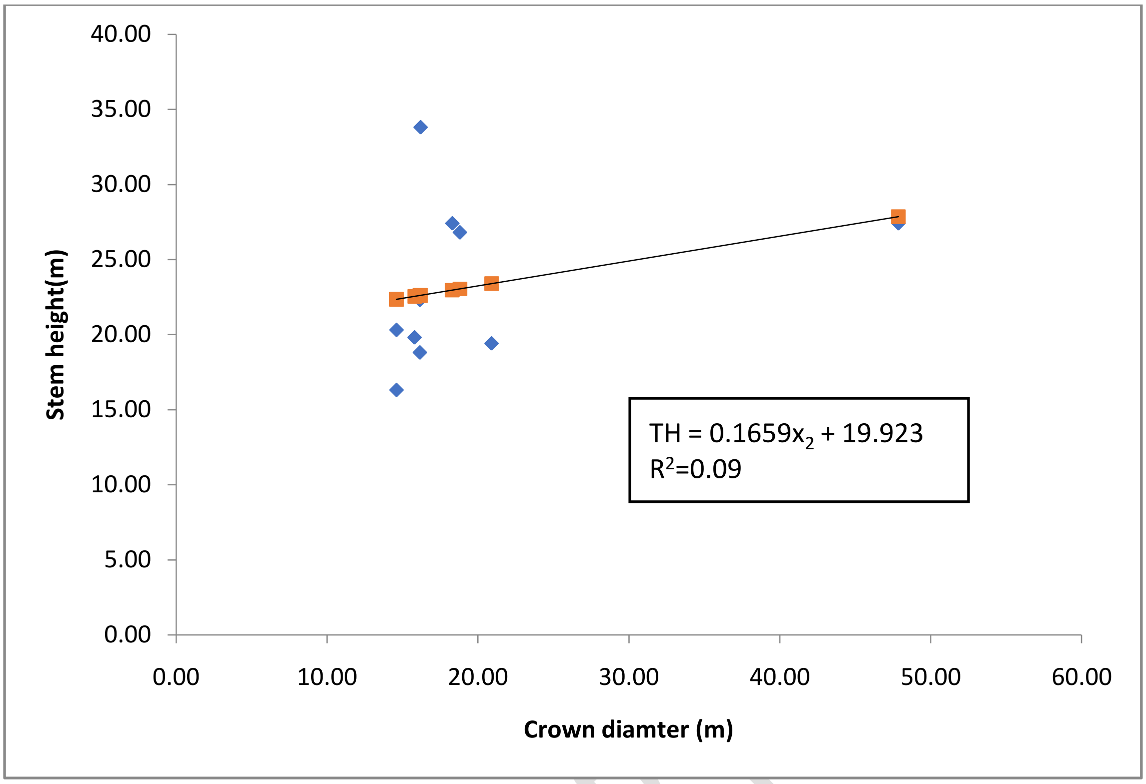

Figure 7.Regression analysis showing a positive relationship between crown diameter (m) and total height *Parkiabiglobosa*

The focus of the study was to investigate the degree of association and develop prediction models between four response variables with stem diameter as the first and independent variable. Also, the association between crown diameter, as the second independent variable, with total tree height. The results showed that stem diameter at breast height had positive correlation with all four dependent variables namely; total height, crown diameter, crown ratio and crown height at 0.40, 0.69, 0.44 and 0.53, respectively(Figures 3- 7). This positivity implies that stem diameter can be used to predict these variables to the levels as indicated in the study (Tables 2 and 3). These findings are supported by work done by [24] who reported stem diameter to have significant and positive correlation with tree height, crown diameter, crown height with R^2 values of 0.680, 0.760 and 0.715, respectively, in the same*Parkiabiglobosa*species in the Savanna Zone of Nigeria. [23]also reported diameter to have positive correlation with crown ratio, height, crown diameter, crown length (height) and crown projection area in *Heveabraziliensis* in Nigeria with low values between 0.04 - 0.07.

The coefficient of determination (R^2) between stem diameter, total height, crown diameter, crown ratio and crown height were 0.16, 0.48, 0.19 and 0.28 respectively. Thus, stem diameter, accordingly, accounted for 16%, 48%, 19% and 28% of the total variations in these variables, respectively. These relationships were, however, not significant except that between stem diameter at breast height and crown diameter. The second indicator variable, crown diameter, also had a positive correlation with total height even though it was not significant. According to [24] coefficient of determination of the regression shows the proportion of variance explained by the regression model and determines how significant the relationship between the variables is. It wasfurther argued that the higher the R^2 value, the stronger the relationship is and with least estimate of the standard error. This implies that using stem diameter at breast height to predict crown diameter will give the highest accuracy of 48% in the current study (Table 3) [23]. A positive correlation between crown diameter and tree height was observed to have a low value of 0.04 in *Heveabraziliensis*[23]. The values of the study, however, are lower compared to values reported in other studies. For instance, [26] reported Pearson correlation coefficients of determination (R^2) between stem diameter at breast height and crown diameter, crown diameter and crown depth, crown depth and height were reported to be high and positive at 0.60, 0.78, 0.77 and 0.99, respectively, for *Acacia senegal*ensis. Again, crown diameter was also found to have a significant positive correlation with tree height and crown height with R^2 values of 0.529 and 0.602 [24]. The findings of this study havesome support of literature.For instance, [28] reported R^2 values between 0.66 – 0.77 across even prediction models in *Pinusroxburghii*in the Himalayas.According to [29] correlation coefficients lower that ±0.40 (whether negative or positive 0.40) are said to be low, between ±0.40 and ±0.60 are moderate, and above 0.60 are high. Hence it can be deduced that the findings of the study are within the moderate correlation class.

5.0CONCLUSION AND RECOMMENDATIONS

The study showed positive correlations between stem diameter at breast height and the four response variables studied. The best adjudged model was the relationship between stem diameter at breast height and crown diameter. Hence it can be expected that trees with big stem diameter will have larger crowns and hence larger crown projection areas. Again, crown diameter had strong positive correlation with tree height. So, by using the stem diameter at breast height and crown diameter, both of which can easily me measured, parameters which are difficult to measure can be estimated with a degree of certainty as indicated in the study. The study has also provided quantitative information on tree models for *Parkiabiglobosa*in the Savanna Ecological Zone of Ghana. Hence, the result of this study can be used for tree stem modeling studies in other parts of the Savanna Ecological Zone. The models developed in the study were based on data collected from the Savanna Ecological Zone of Ghana and should be used cautiously outside this area as plants show plasticity due to climatic and soil variability.It is recommended that further studies involving larger sample size be done to improve the models developed. Also, similar models should be developed for this species in the high forest zones of Ghana to enhance the management of Ghana's forest resources.

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