Prediction Models for Ceiba pentandra in the Guinea Savanah Ecological Zone of Ghana

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Abstract

This study investigated the relationships between seven dendrometry variables in *Ceiba pentandra*. The relationships between stem diameter at breast height, total tree height, crown diameter, crown height, crown ratio, crown projection area and number of branches. Also, the relationship between Crown diameter and total tree height was studied. Regression prediction models were derived using simple linear regression analysis. Pearson correlation between variables was done using the Pearson's Correlation coefficient. Stem diameter at breast height and crown diameter were used as independent variables as they are readily easy to measure with high accuracy. The study showed that positive correlations exited between stem diameter at breast height and total tree height, crown diameter, crown height, crown projection area, number of branches and crown ratio. Again, a positive correlation exited between the crown diameter and total height (0.39). The value of Pearson correlation coefficient (r) between the stem diameter at breast height, total tree height, crown diameter and crown height was 0.98; that between stem diameter at breast height and crown projection area was 0.95; between stem diameter at breast height, number of branches and crown ratio was 0.96. The correlation coefficient between crown diameter and total height was also 0.98. The coefficient of determination (Ar^2) between the stem diameter at breast height, total tree height and crown height was 0.9; between stem diameter at breast height and crown diameter was 0.91; between stem diameter at beast height and crown projection area was 0.84; and 0.88 between stem diameter at breast height, number of branches and crown ratio. The coefficient of determination between crown diameter and total tree height was 0.9. Thus, the stem diameter at breast height accounted for about 90% of the total tree and crown heights. Also stem diameter accounted for 91% of crown diameter, 84% of crown projection area, and 88% of both crown ratio and number of branches. The crown diameter, on the other hand, accounted for 90% of the crown projection area. P-values were significant at 0.05 for all the variables studied ($P \leq 0.05$). The models developed will enhance decision making in forest management and save cost and time spent in collecting data on these dendrometry variables studied.

Keywords: *Ceiba pentandra*, diameter at beast height, prediction models

1.0 Introduction

Ceiba pentandra (L. Gaertn) belongs to the family Bombacaceae and is a native species of tropical America and tropical Asia (Siepel *et al*., 2004; Irvine, 1961). It is commonly called Ceiba, the silk or kapok tree and it is known to have a pantropical distribution (Dick *et al*., 2007; Lobo *et al*., 2005). Ceiba can be found in all types of forests in Ghana ranging from the moist-evergreen, moist and dry semideciduous forests to the dry and gallery forests (Hall and Swaine, 1981). Ceiba is a fast-growing pioneer species and tolerates low fertility soils making it potentially important choice for forest regeneration and timber production especially on disturbed lands (Cobbinah *et al.*, 2001). It can grow up to a height of 60 m with a diameter of 2 m or more and its buttresses can extend to 8 m up the bole (Irvine, 1961). It has a rotation period of 30 - 45 years with exploitable diameter of 50 cm (Cobbinah *et al.*, 2001). Its highest density of regeneration is about 1000 stems/km² at 5-30 cm breast height diameters in burnt forests (Hawthorne *et al*., 1995). The seeds are often dispersed by wind or water (Dick *et al*., 2007). The wood is used in a variety of wood works including drums, dugout canoes, plates and coffins, wooden sandals, particle boards and in paper production (Burkill, 1985; Irvine, 1961). The seeds are rich in unsaturated fatty acids such as palmitic, linoleic, oleic, and stearic acids (Burkill, 1985). The fibre, commonly called kapok, is used for stuffing cushions, pillows and mattresses, in insulation works and as an absorbent material. The gum of Ceiba is eaten to relieve stomach upset, whereas the leaves and fruits are used as a laxative. Infusion from the leaf is used for colic treatment in both human and livestock (Irvine, 1961). Ceiba is one of the species that has been selected for plantation development under the National Forest Plantation Development Programme in Ghana due to its multiple and desirable silvicultural traits (Ghana Forest Service Division, 2005). Hence the development of models to enhance its management will be a good complement to this national effort.

Forest trees, including Ceiba, exhibit great variation in their their dendrometry variables. These variabilities play many roles in the tree. For instance, the stem size in trees determines the ability of trees to withstand the forces acting upon them including tree weight and wind force (Arzai and Aliyu, 2010). Stem diameter at breast height has been shown to give accurate prediction of different tree dimensions and it is widely used in models that enable the efficient and effective estimation of tree total height, crown height, crown diameter and crown (Turan, 2009). Stem diameter at the breast height and the total tree height relationship is critical for developing growth and yield models for forest measurements. Height and stem diameter are needed to estimate timber volume, site index, and in forest growth and yield models (Tanka, 2006). Height estimates also give an estimate of standing trees volume (Petris *et al*., 2015) and in carbon stock measurements in recent times (Feldpausch *et al*. 2012). Forest managers use diameter-height equations to obtain accurate yield estimations in forest management decision making processes especially when information on height measurements are not readily available (Tanka, 2006). For instance, forest managers can use these equations to model costs and benefits, analyze management scenarios to determine the best management practices for sustainable forestry (Paula *et al.*, 2001). Height measurement, however, seems to be a bit problematic in under some circumstances in the forest. According to Larjavaara & Muller-Landau, (2013), tree heights measurements are normally reported with equipment used and often without description of the methodology and discussion of potential biases. Also, the method is usually limited to smaller trees below 10 m height even though it could be applied to larger and taller trees with difficulty. The authors argued that, even though the advent of lasers rangefinders provide a remedy to the traditional use of equipment in measuring taller trees, the method is saddled with some challenges such as the lack of clear view path especially in dense and multi-layered canopies of tropical forests, the blockage of visibility to the base of the tree by undergrowths, cases of leaning trees and uneven forest terrains. Besides, ground-based tree height measurements in neo-tropical forests can be challenging because trunks are often leaning, crowns being nearly as wide as the tree is high (King & Clark 2011) and low visibility due to the high leaf area index (Clark *et al*. 2008).

Among other things, tree crowns play a significant role in physical stability and susceptibility to fire (Aaron, 2003). Tree species vary in their crowns due to variation in light dependency and requirement for nutrients as well as susceptibility to stress intensity (Klepacki, 2017) serving several purposes to trees. For instance, crown sizes and total height determine the total amount of light that the tree intercepts for photosynthesis. Crown morphology such as the crown ratio plays several key roles such as light interception and in tree growth (Tanka, 2006). Crown ratio is also a good indicator of vigor, wood quality, stand density, competition, wind firmness and is, therefore, a feature of interest in forest management as well as an important habitat variable (Hailemariam *et al.,* 2005). Tree growth and its increments are also influence by the size of crown and its assimilatory apparatus (Klepacki, 2017). Tree crown parameters have, therefore, been used as predictor variables in diameter and height growth equations (Tanka, 2006). Though, tree crowns represent their potential for growth and development, it is difficult to obtain crown measurements (Bechtold *et al*., 2002). Again, open grown trees typically have live crowns that extend to ground level. However, measuring crown ratio can be time-consuming resulting in measures on only a subset of trees in plots. Also, the base of the live crown is very difficult to see in very dense stands and for very large trees (Temesgen *et al*., 2005). Therefore, a more easily measured tree variable, such as diameter at breast height is often used as a surrogate for a tree's crown dimensions (Roy *et al*., 2005).
Unfortunately, there is insufficient information on stem diameter relationships with tree total height, crown height, crown ratio, crown diameter and crown projections area for most of the economic tree species in Guinea Savannah Ecological Zone of Ghana, including Ceiba. Hence, the development of equations to predict these variables will enhance the sustainable management of this species in the Savannas of Ghana. The primary objective of this study was to develop regression prediction models for tree height, crown height, crown diameter, crown ratio and crown projection area and number of branches from stem diameter and crown diameter for *Ceiba pentandra* in Savannah Ecological zone of Ghana.

2.0 Materials and Methods

2.1 Study area

The study was conducted in four districts of the Northern Region of Ghana located in the Guinea Savannah Ecological Zone (Figure 1), namely Tamale Metropolitan Assembly, Savelugu, Sagnerigu and Tolon Districts (Table 1). Tamale Metropolis is located in the central part of the Region and shares boundaries with the Sagnarigu District to the west and north, Mion District to the east, East Gonja to the south and Central Gonja to the south-west spanning about 646.90180 km^2 (GSS, 2010). Geographically, the Metropolis lies between latitude 9º16 and 9º 34 North and longitudes 0º 36 and 0º 57 West. The Savelugu District is located at the northern part of the Region and is about 200.4 km². It shares boundaries with West Mamprusi to the North, Karaga to the East, Kumbungu to the West and Tamale Metropolitan Assembly to the South. The District lies between latitudes 9º16' and 9º 34' North and longitudes 0º 36' and 0º 57'. The Tolon District shares borders with North Gonja District to the west, Kumbungu District to the north, Central Gonja District to the south and to the east with Tamale Metropolitan. The District lies between latitudes 9° 15′` and 10° 0 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 Sagnerigu District covers a total land size of 200.4 km² and shares boundaries with the Savelugu - Nanton Municipality to the north, Tamale Metropolis to the south and east, Tolon District to the west and Kumbungu District to the north-west. Geographically, the District lies between latitudes 9º16' and 9º 34' North and longitudes 0º 36' and 0º 57' West. (Ghana Statistical Service, 2014).

The four Districts lie within the Savannah Woodland characterized by tree vegetation of varying sizes and density. The main vegetation is grassland, interspersed drought-resistant trees such as *Acacia longifolia* (Acacia), *Mangifera indica* (Mango), *Adansonia digitata* (Boabab), *Vitellaria paradoxa* (Shea), *Parkia bigloboza* (Dawadawa), *Azadirachta indica* (Nim), *Khaya Senegalensis* (Mahogany), *Anogeissus leiocarpus*, among other species. These economic trees form an integral part of livelihood of people in the Northern Region. The dense woodlands and forests, in the region, are found along river valleys especially areas along the basin of the White Volta and its tributaries in the Tolon District. The main soil types in the Guinea Savannah Ecological Zone are mostly sand, clay and laterite ochrosols. The soil is generally of the sandy loam type except in the lowlands where alluvial deposits are found. There are also deposits of gravel which are sold for economic value. The districts have a single rainy season, usually stretching from May to October. The season peak being usually between July and August. The dry season (November to March) is characterized by the dry Harmattan winds which present two extreme weather conditions, the extreme dry cold temperature of the early dawns and mornings and the very warm afternoons (Ghana Statistical Service, 2014).

2.2 Data collection

Twenty (20) solitary individual trees of *Ceiba pentandra* were randomly selected from the four Districts and data collected from them (Table 1). The trees with no sign of possible prunning so as to obtain reliable values of the species-specific maximum reach of the crown. A minimum distance of 100 meters was allowed between the selected trees to avoid sampling of trees that are genetically related. All the selected trees were on level terrain. The individual trees selected varied in sizes when observed visually. Six dendrometry variables were measured from all the selected trees. These included stem circumference at breast height, total tree height, crown diameter, crown height, crown projection area and number of branches. Stem circumference was measured at 1.3m from the base of the tree using a diameter tape and the values recorded in centimeters. The stem diameter was then computed as shown in section 2.3. Total tree height was measured using the Haga Altimeter set at 30 m scale. A reference tape measure was then installed at the base and the 30 m distance determined on the ground (Ogunyebi *et al.*, 2018) away from the tree to be measured. To measure the total height, the peak of the tree was sighted via the eye aperture of the Altimeter at the 30 m distance. The height at the treetop was recorded by pressing the trigger to lock the dial and the corresponding value on the horizontal scale recorded. The trigger was released before the height at base was sighted and recorded as previously described. A fix height of 1.6 m (eye-level height) of the Altimeter operator was added to the height values recorded from the treetops following the instructions of the user manual of the Altimeter. This was repeated for all the twenty trees sampled. Tree heights was measure to a precision of 0.01 m (Klepacki, 2017). The tip of the measuring tape was raised up, with the aid of a pole, to the base of the first live crown and the distance to the ground level determined. The Crown heigh was calculated as shown in section 2.3. The crown diameter was estimated (Section 2.3) by taking the average measurements of the longest and the shortest diameters of the crown zone (North to South and East to West). Live branches which originated from the main stem were visually counted and their number recorded per each sampled tree. The Geographical Positioning System (GPS) addresses of all the twenty trees were recorded using the GhanaPost GPS (version 2023.01.11, developed by Afrifanom) to enable easy back sampling and third- party verification of the measured values.

2.3 Data analysis

Diameter (D) at breast height was estimated by dividing the stem circumference (C) by the value of pie (3.14). That is C = $\pi D = C/\pi$. where π = 3.14 (Ngomanda *et al*., 2012). Diameter measurements were taken in centimeters and later converted into meters using the standard rule for the conversion of SI units to ensure uniformity and easy interpretation of the data. The total tree height was determined as the sum of the heights at the treetop and at eye-level of the Altimeter operator minus the height at the base of the tree. The crown height was estimated as the total tree height minus the distance from the ground level to the base of the first live crown. The tree crown projection area was determined using the formula (CPA): $\pi CD^2/4$; where CD = Crown diameter (Oyebade and Onyeoguzoro, 2017). Crown ratio was estimated as the crown diameter divided by total tree height (Ngomanda *et al*., 2012; Klepacki, 2017; Oyebade B.A and Onyeoguzoro T.C (2017). The raw data was analyzed in Microsoft (MS) Excel using Simple Linear Regression and Correlation at 95% confidence level. This method was preferred as it is one of the statistical methodology employed in quantitative scientific investigation to highlight the average relationship between two or more variables (Temesgen *et al*., 2005; State *et al*., 2017).

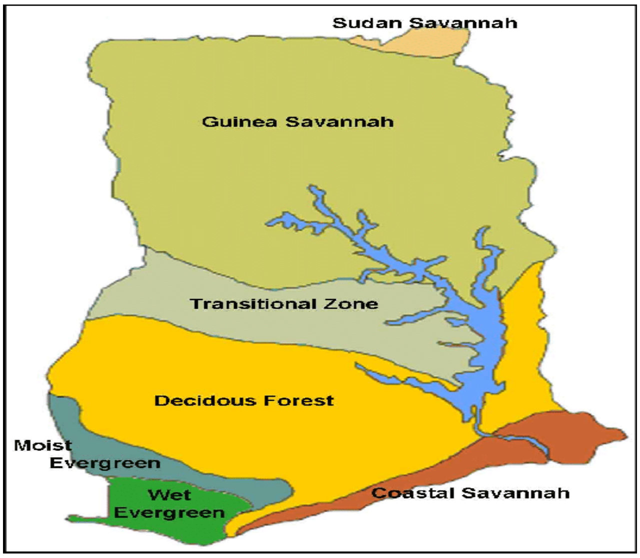

Figure 1. Vegetation Map of Ghana Showing the Location of the Study Area (Guinea Savannah Ecological Zone). Source: (Appiah, D. O., Osman & Boafo, 2014).

3.0 Results

The twenty (20) trees sampled trees, their locations (districts and communities) and corresponding GPS addresses are as shown in Table 1. The mean stem diameter at breast height was 1.14±0.23 m with a minimum value of 0.76 m. Total tree height had a mean value of 22.69±4.53 m with a minimum value of 15.60 m. The mean value for crown diameter was 19.93±4.05 and a minimum value of 13.05 m. The mean values for Crown height, number of branches and crown ratio were 19.28±4.12 m, 17.4±3.98 m and 0.9±0.19 m respectively. Their corresponding minimum values were 12.83 m, 12.0 m, and 0.35 m (Table 2). The study showed that stem diameter at breast height has positive correlation with all the other variables studied with the highest correlation of 0.52 observed between it and crown diameter. The weakest correlation was observed between the stem diameter at breast height and the crown ratio at 0.07. Crown ratio was negatively correlated with total tree height, crown diameter and number of branches at -0.55, -0.56 and -0.25 respectively. Crown diameter and tree height was also positively correlated at 0.39. Crown height and total tree height had the strongest correlation at 0.98 (Table 3). The linear regression analysis, on the other hand, revealed that stem diameter at breast has a strong positive relationship with all the other six variables studied with only small variations among them (0.01 - 0.05). The coefficient of determination (r^2) between stem diameter, total tree height and crown height was 0.95. R^2 values of 0.96 and 0.90 was observed between stem diameter, crown diameter and crown projection areas respectively. The r^2 value of 0.93 observed between stem diameter at breast height and with both the number of branches and crown ratio. Crown diameter and total tree height are also positively related, significantly with a coefficient of determination (r^2) value of 0.95. The Adjusted R values were also high ranging from 0.84 to 0.91 indicating the accuracy of the models. The highest Adjusted R value of 0.91 was observed between stem diameter at breast height and Crown diameter. P-values were significant at 0.05 for all the variables studied (Table 4). The scatter diagrams also confirmed the positive the relations between stem diameter at breast height, total height, crown diameter, crown height, crown projection area, number of branches and crown ratio (Figures 1 – 7). Again, the scatter diagram in figure 8 confirmed is the positive relationship between crown diameter and total height. The regression models developed are showed in Table 4.

Table 1. Distribution of Samples and their GPS Addresses

S/n	GPS	District	Community	No/District
T1	NS-733-3470	Sagnerigu	Koyni	6
T2	NS-752-1228	Sagnerigu	Koyni	
T3	NS-786-9372	Sagnerigu	Koyni	
T4	NS-814-7662	Sagnerigu	Yilonayili	
T5	NV-0506-3990	Savelugu	Yilonayili	
T6	NV-0042-3307	Savelugu	Savelugu	
T7	NT-0135-0422	Tamale	Sagnerigu	3
T15	NT-0018-2295	Tamale	Tamale	
T13	NT-1454-9214	Tamale	Kasalgu	
T8	NS-041-9137	Sagnerigu	Sagnerigu	5
T9	NS-065-9362	Sagnerigu	Kasalgu	
T10	NS-114-4222	Sagnerigu	Kasalgu	
T11	NS-182-2358	Sagnerigu	Kasalgu	
T12	NS-319-2933	Sagnerigu	Kasalgu	
T14	NL-1488-5091	Tolon	Nyankpala	6
T16	NL-1250-6029	Tolon	Nyankpala	
T17	NL-1479-7520	Tolon	Nyankpala	
T18	NL-1361-9001	Tolon	Nyankpala	
T19	NL-1363-4879	Tolon	Nyankpala	
T20	NL-1363-1631	Tolon	Nyankpala	
				Total = 20

T1= Tree number 1, etc. Sagnerigu = 9, Savelugu =2, Savelugu =2, Tamale =3, Tolon = 6

Table 2. Summary of Descriptive Statistics of the Data Used in the Regression and Correlation Analyses

Variable (m)	M	SE	Median	SD	Min	Max	Count	Cl(95%)
Stem diameter	1.14	0.05	1.12	0.23	0.76	1.50	20	0.11
Total Height	22.69	1.01	23.10	4.53	15.60	34.10	20	2.12
Crown diameter	19.93	0.91	20.05	4.05	13.05	30.30	20	1.90
Crown height	19.28	0.92	19.20	4.12	12.83	28.00	20	1.93
No. Branches	17.40	0.89	17.00	3.98	12.00	24.00	20	1.86
Crown ratio	0.90	0.04	0.90	0.19	0.53	1.21	20	0.09
CPA	323.97	30.10	315.59	134.60	133.69	720.70	20	62.99

CPA=Crown Projection Area, m=Meters, M=Mean, SE=Standard Error, Md=Median, SD=Standard Deviation, Cl =Confidence Level, Min=Minimum, Max=Maximum

Table 3. Correlation Matrix Between Stem Diameter at Breast Height and Six other Dendrometric Variables of *Ceiba pentandra* in Savanna Ecological Zone of Ghana

	SD (m)	Th (m)	Cd (m)	Cd (m)	No.b	(CPA)	Cr
SD (m)	1.00						
TH (m)	0.34	1.00					
Cd (m)	0.52	0.39	1.00				
Ch(m)	0.38	0.98	0.37	1.00			
Nb	0.15	0.43	0.24	0.48	1.00		
CPA	0.51	0.40	0.99	0.38	0.28	1.00	
Cr	0.07	-0.55	0.54	-0.56	-0.25	0.51	1.00

SD=Stem diameter, Th=Total height, Cd=Crown diameter, Ch=Crown height, CPA=Crown projection area, Nb=Number of branches, Cr=Crown ratio

Table 4. Regression Prediction Model, Correlations Coefficient (R) and Correlation Coefficient of Determination (R^2) of the Different Tree Dimensions

		S/n		Variable	r	r^2	Ar^2	SE	Pm	P-value
		1		SD vrs Th	0.98*	0.95(95%)	0.90	5.18	$Th = 6.74x_1 + 14.98$	0.005*
		2		SD vrs Cd	0.98*	0.96 (96%)	0.91	3.95	$Cd = 9.09x_1 + 9.53$	0.003*
		3		SD vrs Ch	0.98*	0.95(95%)	0.90	4.45	$Ch = 6.72x_1 + 11.60$	0.006*
		4		SD vrs CPA	0.95*	0.90(90%)	0.84	116.0	$CPA = 296.12x_1 - 14.45$	0.009*
		5		SD vrs Nb	0.96*	0.93(93%)	0.88	4.87	$Nb = 2.57x_1 + 14.46$	0.002*

		6		SD vrs Cr	0.96*	0.93(93%)	0.88	0.25	Cr= 0.06x_1 + 0.83	0.002*
		7		Cd vrs Th	0.98*	0.95(95%)	0.90	5.03	Th= 0.43x_2 + 14.07	0.002*

*S/n= Serial number, SD=x_1 =Stem diameter, Th=Total height, Cd=x_2=Crown diameter, Ch=Crown height, CPA=Crown projection area, Nb=Number of branches, Cr=Crown ratio. SE=Standard error, Ar^2=Adjusted r^2, Pm=Prediction model. The correlation r-values with * are significant at P = 0.05.*

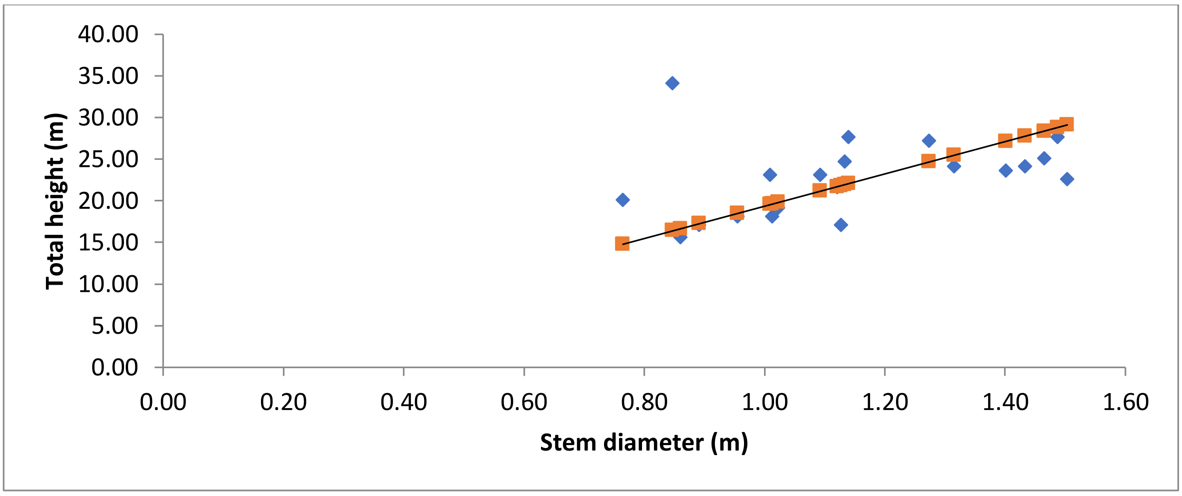

Figure 1. Relationship Between Stem Diameter and Total Height

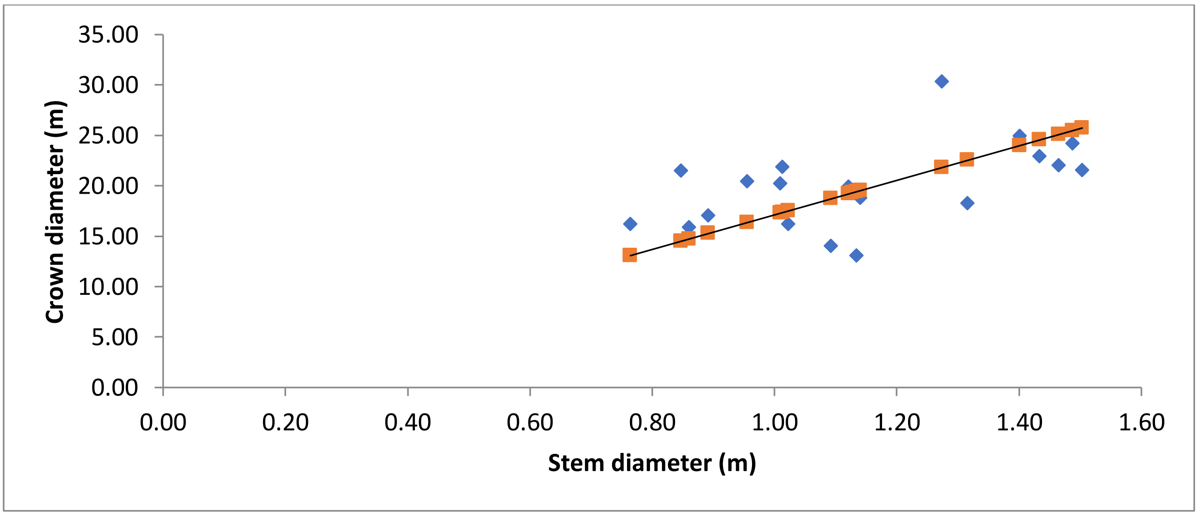

Figure 2. Relationship Between Stem Diameter and Crown Diameter

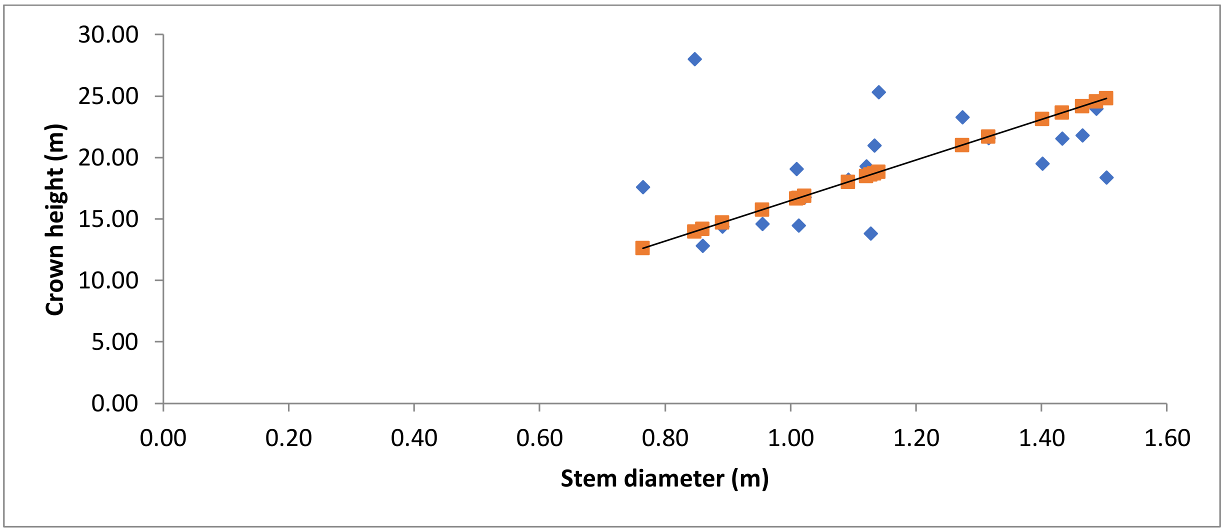

Figure 3. Relationship Between Stem Diameter and Crown Height

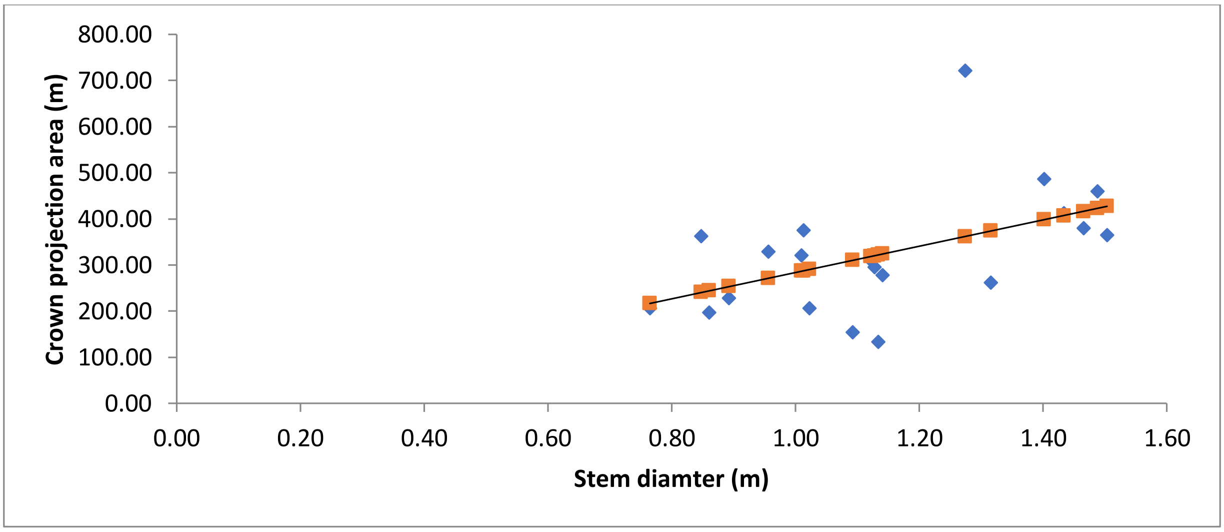

Figure 4. Relationship Between Stem Diameter and Crown Projection Area

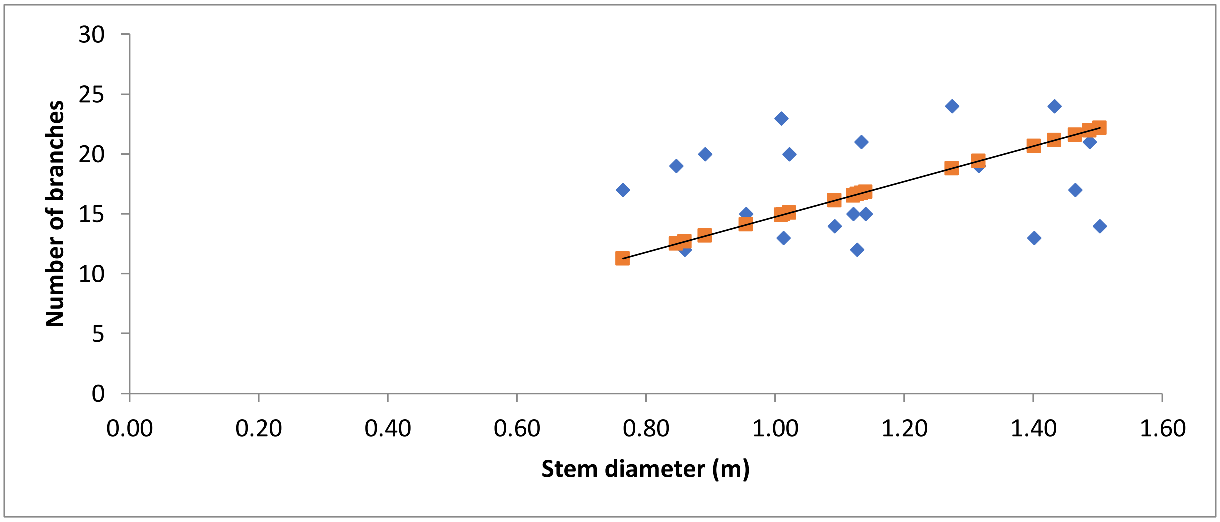

Figure 5. Relationship Between Stem Diameter and Number of Branches

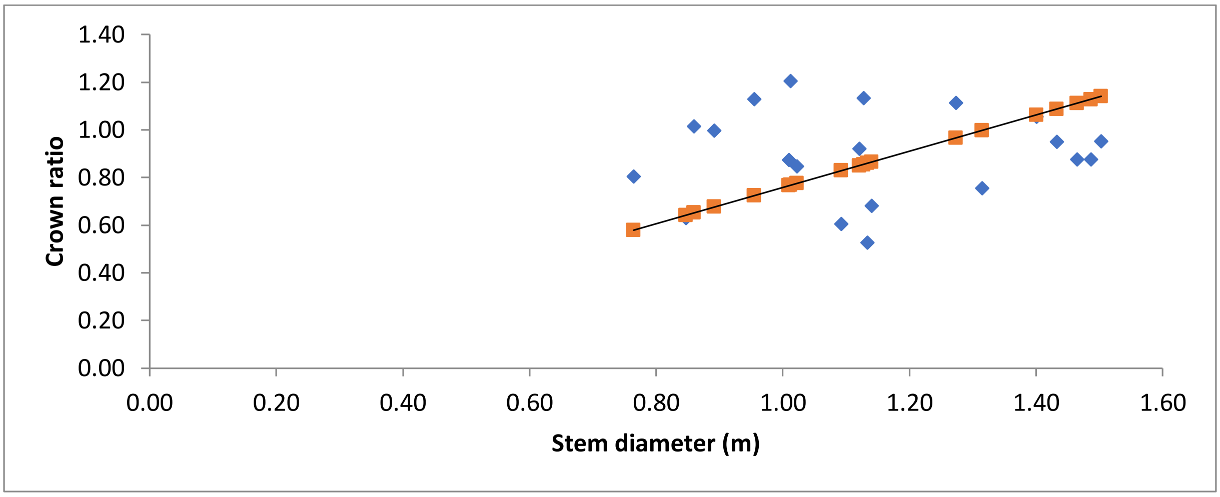

Figure 6. Relationship Between Stem Diameter and Crown Ratio

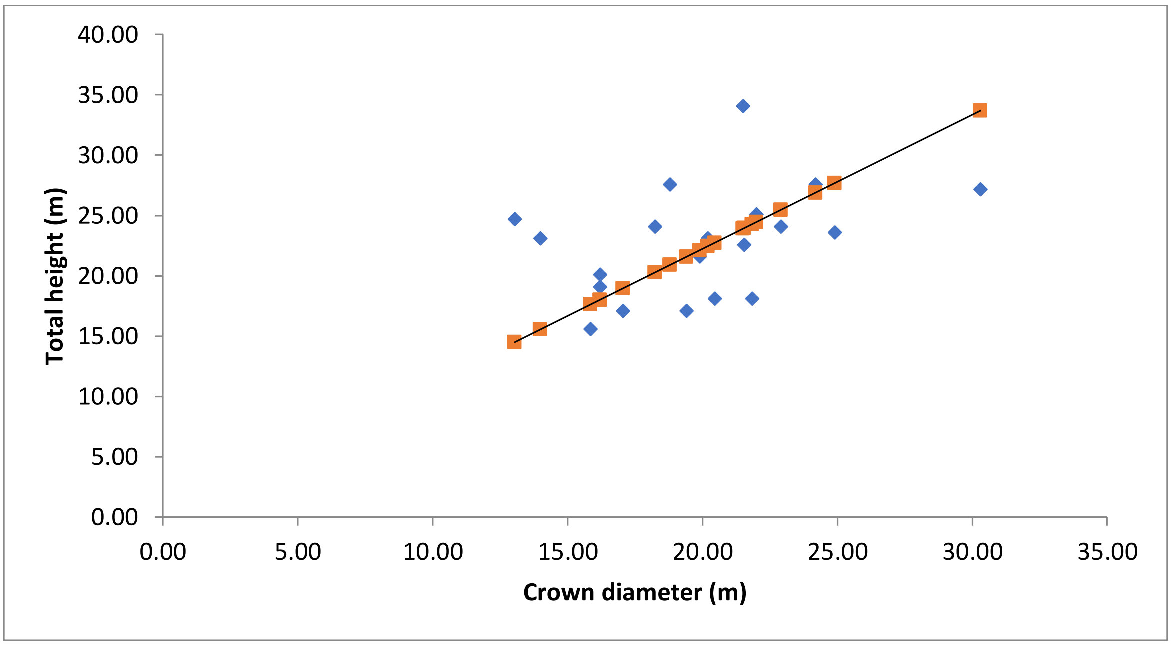

Figure 7. Relationship Between Crown Diameter and Total Height

4.0 Discussion

The study analysis emphasized the degree of association between six response variables and stem diameter as an independent variable. Also, the association between total tree height as a response variable and crown diameter as the independent variable was shown in the studied. There was a significant positive correlation in the relationships between stem diameter as an independent variable against total tree height, crown height, crown diameter and crown ratio, crown projection area and number of branches of *Ceiba pentandra*. The coefficient of determination (r^2) between stem diameter, total tree height, crown diameter and crown projection area were 0.95, 0.96, 0.90 respectively. This means that stem diameter at breast height accounted for 95%, 96% and 90% of the variation in total tree height, crown diameter and crown projection area respectively. Stem diameter accounted for 93% of the variation in the number of branches and crown ratio with r^2 value of 0.93. The results also suggested that using stem diameter at breast to predict crown diameter will give the most accurate results since the association has the highest adjusted r^2

value of 0.91. The results of the study is supported by the argument by State *et al*., 2017 that the coefficient of determination of the regression shows the proportion of variance explained by the regression model determines how significant the relationship between the variables is. The authors further argued that the higher the R^2 value, the stronger the relationship. A similar study of *Parkia biglobosa* in the Savannah Zone of Nigeria revealed that stem diameter at breast height had a significant and positive correlation with tree height, crown diameter, crown height with r^2 values of 0.680, 0.760 and 0.715 respectively. Diameter at breast height was also observed to have positive correlation with crown ratio, tree height, crown diameter, crown length (height) and crown projection area in *Hevea braziliensis* in Nigeria even though the values are low between 0.04 - 0.07 (Oyebade and Onyeoguzoro, 2017). Positive correlations were also observed to be highly significant between stem diameters at breast height, crown diameter, crown depth and tree height, crown depth and crown diameter in *Acacia Senegal* in Northern Senegal (Diallo *et al*., 2013). The same study reported the values of Pearson correlation coefficients of determination (r^2) between the stem diameter at breast, height and crown diameter, crown diameter and depth crown diameter and crown depth, crown depth and height to be 0.60, 0.78, 0.77, and 0.99, respectively (Diallo *et al*., 2013). These findings are similar to those of the current study.

Crown diameter accounted for 95% of the total variation total tree height with r value of 0.95 (Table 4). This is supported by the findings of Oyebade and Onyeoguzoro (2017) who also found crown diameter to have a positive correlation with tree height in *Hevea braziliensis* even though the value was low at 0.04. Again, crown diameter was found to have a significant positive correlation with tree height and crown height with r^2 values of 0.529 and 0.602 respectively (Buba, 2015). According to Roy *et al*., 2005, tree crown dimensions, especially the horizontal ones (radius or diameter) are well correlated with a tree's diameter at breast height. The findings of the current study fit well within this observation. Hence, the strong positive relationship revealed in the study means that the stem diameter and crown diameter, which are easier to measure, can be used to estimate the remaining variables. Therefore, the prediction models developed in the study have high chances of giving accurate results.

Specific tree species tend to have characteristic crown shapes, especially when growing in an open environment which are modified by the physical environment including competition between tree crowns through physical abrasion from wind events. Crown shape therefore represents the physical space a tree utilizes for growth as modified by the physical environment (Roy *et al*., 2005). Ceiba, like other tree species, is sparsely distributed in the Savannah Ecological Zone of Ghana and hence have enough space to grow (Ghana Statistical Service, 2014). This, together with other favourable environmental factors such as its ability to growth in soil with little fertility (Cobbinah *et al.*, 2001) may account for the large dendrometry values observed in the study.

5.0 Conclusion and Recommendations

The study of *Ceiba pentandra* showed positive correlations between stem diameter at breast height, total tree height, crown diameter, crown height, crown ratio. The results showed that the best adjudged model was the relationship between stem diameter and crown diameter.

Also, the study showed a strong positive correlation between crown diameter and tree height. Hence it can be expected that trees with big stem diameter can have taller stems, bigger and taller crowns as well as 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, which can easily me measured Forest Managers and Research Scientists will be able to estimate more difficult parameters such as total height and crown height with higher accuracy. The study has also provided quantitative information on tree models for *Ceiba pentandra* in the Savannah Ecological Zone of Ghana. Hence, the result of this study can be used for the species stem modeling studies in zones in other parts of the Savannah Ecological Zone for sustainable forest management in Ghana.

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Authors biography
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