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Crown-Width Models for *Parkia biglobosa* Plantation in Wasangare, Oyo State

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Abstract
Information on tree growth variables is an important factor during an inventory exercise. This information is beneficial in sustaining proper forest stocking, thinning, pruning, economic evaluation of trees, making aesthetic choices, and in selecting appropriate growth measurements to monitor individual tree growth, wildlife habitat suitability, and in assessing forest health. In this study, crown-width models were developed for *Parkia biglobosa* plantations (seeds of this species were from Cameroon, Egypt, Guinea, Nigeria, and Tunisia and planted separately) in Wasangare, Oyo State, Nigeria. The diameter at breast height and Crown ratio were used as independent variables for developing the models. Four models were developed and tested in predicting the crown-width of the tree stands of this species. The 'R' programming statistical package was used to fit the models. To consider the best model, Akaike Information Criterion (AIC), Root Mean Square Error (RMSE) and the Welch two-sample test were used for evaluating the models. The summary of the assessment criteria for CW-DBH indicates that the AIC values are 250.07, 206.56, 171.43, 187.82, and 370.03 for Cameroon, Egypt, Guinea, Nigeria and Tunisia accessions respectively with power model function, saturation growth rate, simple linear function, and exponential model performed better.

Keywords: Parkia biglobosa, Akaike information criterion, crown-width models, power model function

Introduction

Modern forest management requires precise, accurate, timely, and complete forest information. Forest information can be acquired by forest inventory, which includes a collection of individual tree parameters such as location, diameter at breast height (dbh), tree height, tree crown size, and tree species within a sampled forest plot, and includes the derivation of forest stand measurements such as forest density, age, mean height, and crown closure, etc using statistical extrapolation of plot measurements (Maltamo, *et al*., 2006). Studies have shown that some variables such as diameter at breast height are easy to measure with no stress and simple instruments which are widely used by forest inventories (Toma Buba, 2013; Ezenwenyi *et al*., 2018). Tree crown is defined as that part of a tree bearing live branches and foliage (Helms, 1998; Ezenwenyi *et al*., 2018). The most important element of the tree structure is the crown, where fundamental living processes like photosynthesis take place (Dubravac *et al*., 2009). It is very relevant in studies of the growth of stands due to the close correlation between crown size and stem diameter, and the packing or density of trees in a stand (Hemery *et al*., 2005).

However, several studies have shown that other variables which are not so easily obtained are also good predictors of forest dynamics and they can improve the reliability of tools like growth and yield models. One of these parameters is crown size, which has received increasing attention to estimate tree growth (Bragg, 2001). Crown size is an important factor for tree growth which determines the amount of solar radiation intercepted by a tree (Tanka, 2006). Crown width is used in tree and crown level growth-modelling systems, where simple competition indices are not available to adequately predict recovery from the competition when a competitor is removed (Vanclay, 1994; Elmugheira and Elmamoun, 2014). Crown width is also used in calculating competition indices based on crown overlap (Elmugheira and Elmamoun, 2014) and predicting above-ground biomass.

Parkia biglobosa, also called the African Locust Bean tree is a multipurpose tree indigenous to the tropical regions of West Africa. *Parkia biglobosa* belongs to the family Mimosaceae (Leguminosae-Mimosoideae) (Ige *et al*., 2019). The matured tree can grow up to 30m in height with a crown large of low branches. *Parkia biglobosa* occurs in a diversity of agro-ecological zones, ranging from tropical forests with high and well-distributed rainfall to arid zones where mean annual rainfall maybe less than 400 mm. *P. biglobosa* has a wide distribution across the Sudan and Guinea savanna ecological zones. The range extends from the western coast of Africa in Senegal across to Sudan. *P. biglobosa* is found in nineteen African countries: Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Mali, Côte d'Ivoire, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central African Republic, Zaire, Sudan, and Uganda (Daniels *et al*., 1986; Biging and Dobbertin 1992; Modupeola, 2014). In Nigeria, *P. biglobosa* is found mostly in the savannah and derived savannah ecosystems.

Tree exhibits its growth at diameter at breast height (dbh), this variable is easy to measure and reduces inventory cost and time. In modelling of crown-width, diameter at breast height can be used as a predictor to overcome the problem of higher inventory cost. The objective of this study is to develop crown-width models for *Parkia biglobosa* stands on Wasangare plantation. This will be useful for forest managers in the future to predict and evaluate forest resources in the plantation for sustainable management.

Methodology

The Study Area

This study was carried out at *Parkia biglobosa* plantation in Wasangare, Oyo State. It is located in the Savannah zone of Oyo State, Nigeria. The area lies between Latitude 8.8558°N to 8.8573°N and Longitude 3.42353°E to 3.42353°E (Fig 1). The plantation was established in 1955 through the Commission of the European Communities Directorate General for Science, Research and Development Programme. The project was aimed at Germplasm conservation and improvement of Parkia for multipurpose use. The accessions of *Parkia biglobosa* were from eleven (11) African countries and span across 10 hectares. This study assessed five (5) accessions: Cameroon, Egypt, Guinea, Tunisia and Nigeria. The climate is of tropical savanna or tropical wet and dry climate where it exerts enormous influence on the area. This climate exhibits a well-marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator. The average monthly temperature of the site is 26.18°C with the highest value recorded in March (28.1°C) and minimum in June and July (24.5°C each) and an annual rainfall of about 1,500 mm with a single rainfall maximum in September. Generally, the soil is sandy loam and slightly acidic with an outcrop of rocks (Ige *et al*., 2019).

Sampling Technique and Data Collection

A total enumeration of the plantation stands for each accession of *Parkia biglobosa* of 20 x 20m size was made for this study. Data were collected for tree growth characteristics such as diameter at the base, diameter at breast height, diameter at the middle, diameter at the top, stem height and crown length. The diameter at breast height (dbh) was measured at 1.3m above the ground level with the aid of a girthing tape. Spiegel Relaskop was used in measuring the stem height which is in meters. Basal Area, Tree Slenderness Coefficient, Crown width, Crown ratio, and Crown projection area were estimated using the following formula:

Basal area Estimation

The Basal Area (BA) of individual trees was estimated using the formula in equation 1 (Husch *et al*., 2003).

BA = ...1

Where, BA = basal area, π (pie) = 3.142, D= diameter at breast height (dbh).

Tree Slenderness Coefficient

The tree slenderness coefficient was estimated using the following formula:

$$\mathrm{TSC} = \frac{\mathrm{THT}}{\mathrm{DBH}} \ldots.\ 2$$

Where, TSC= Tree Slenderness Coefficient, THT= Tree Height, DBH= Diameter at Breast Height.

Crown Width Estimation

The crown width was calculated using the formula below:

$$\mathrm{CW} = \frac{\mathrm{CRL}}{2} \ldots..\ 3$$

Where, CW= Crown Width, CRL= Crown Length

Crown Ratio Estimation

The crown ratio was derived using the following formula:

$$\mathrm{CR} = \frac{\mathrm{CRL}}{\mathrm{THX}}\ \mathrm{X}\ 100 \ldots..\ 4$$

Where, CR= Crown Ratio, CRL= Crown Length, THT= total height/stem height.

Crown Projection Area Estimation

Crown projection area was calculated using the formula below:

$$\mathrm{CPA} = \frac{\pi \mathrm{CD}^2}{4} \ldots..\ 5$$

Where, CPA= Crown Projection Area, π (pie) = 3.142, CD= Crown Diameter.

Data Analysis

The data collected were summarized using descriptive statistics and for further analyses, linear and non-linear models were developed using 'R' programming language and CurveExpert Professional version 2.7.3.

Fitting of Crown-Width Models

The data set was divided into two, 70% of the data set (calibrating set) were used to fit the crown-width models, while the remaining 30% was used for model validation as described by Akindele, (1990); Ige *et al*. (2019). Linear and Non-linear regression models were selected (Table 1), and used in fitting the crown-width models. Two independent variables were used all through for the fitting, these variables are diameter at breast height (dbh), and Crown Ratio (CR). The crown ratio was introduced as an independent variable for fitting because of the parameters used in deriving the formula which consist of crown length (CRL), and total height (THT). The model predictions function for each accession were compared using the root mean square errors, biases/residuals of stand diameter class. The absolute root mean square error (RMSE) was calculated as:

$$\text{RMSE} = \sqrt{\sum_{i=1}^{n}(\text{Vi} - \lambda\text{i})^2} / \text{n} \; ..... 6$$

Where: n = number of sample stands, Vi = diameter/height class of growing stock in stand i, λi = the diameter/height of stand i estimated from the predicted distribution. The bias of the predictions was calculated as:

$$\text{Bias} = \sum_{i=1}^{n}(\text{Vi} - \lambda\text{i})^2 / \text{n} \; ..... 7$$

Also, Akaike Information Criterion (AIC) was used for criteria selection and the models were ranked based on the AIC value. The lower the AIC value the better the model. The AIC is of the form:

AIC= 2 - 2log(L)*AICk*….. 8

Where:
K = number of estimated parameters in the model
Log = logarithm
L = the maximized value of the likelihood function for the model.

Results and Discussion

Results

The result from Table 2 shows the descriptive statistics summary of tree growth for each accession of *Parkia biglobosa*. The total enumeration of the tree stands was assessed with a total number of 375 stems. The mean and standard error of the dbh are 20.19±0.83, 18.057±0.990, 20.03±1.40, 21.63±1.15 and 18.72±0.75 for Cameroon, Egypt, Guinea, Nigeria and Tunisia respectively. Nigeria accession shows that *Parkia bilobosa* has a maximum dbh of 50.90 cm, while Guinea accession has the minimum dbh of 5.60cm. In terms of height, the Cameroon accession has a maximum height of 20m while the Tunisia accession has minimum height of 2.80m. The models that performed better were presented in Tables 3 and 4 for each of the accessions. The table indicates the assessment criteria of CW-DBH models and CW-CR models. This also show that there is a strong positive relationship between crown-width, diameter at breast height and crown ratio. The best fit models were selected based on the Akaike Information Criterion. The table revealed that the same model performed best for CW-DBH models and CW-CR models for each of the accessions simultaneously except for Guinea and Tunisia accessions where simple linear model performed best in Table 3 while saturation growth rate function performed best in Table 4 respectively. Tables 5 and 6 also show that there is no significance difference between the observed crown-width and the predicted models at 5% probability level, this is done using the Welch Two Sample t-test. The mean value of the observed and predicted models was also presented in Tables 5 and 6.

Discussion

The result of this study reveals the regression models established between crown-width, diameter at the breast, and crown ratio (in relation to crown height and stem height) of *Parkia biglobosa* in Wasangare plantation. It is observed that there is a strong positive correlation between crown-width, diameter at breast height, and the crown ratio which implies that trees with larger diameters have the tendency to have wider crown-width. In the same vein, Ezenwenyi and Chukwu (2017) observed a high correlation between crown diameter and crown projection area of *Tectona grandis* in Omo Forest Reserve, Nigeria. Tree crown distribution is an effective method for describing a forest stand because tree productivity, gaseous exchange, and health depend largely on the crown dimensions (Adesoye and Ezenwenyi, 2014; Chukwu *et al*., 2018). Most of the data collected during inventory are always based on tree growth characteristics neglecting the crown-diameter variables. Therefore, this study tends towards predicting crown-width models for each accession of the plantation. The Welch two sample t-test was used to deduce that, there is no significant difference between the observed and predicted models ($p<0.05$) which indicates that for further studies, diameter at breast height and crown ratio can be used as predictors for crown-width models. According to Popoola and Adesoye (2012), model fitting and evaluation are important factors when developing models. In this study, the simple linear model function, power model function, saturated growth model function, and exponential model function were used for model development. The power model function performed best out of the four models tested in Cameroon accession for both the CW-DBH and CW-CR models. This was similar to the previous study on DBH-CD as described by Avsar and Ayyildiz (2005) which states that the power function was most suitable for predicting crown diameter.

Conclusion

The study revealed that there is a strong positive relationship between diameter at breast height, and stem height which is the total height, crown length, and crown ratio. The summary assessment criteria for CW-CR indicates that the saturation growth rate model performed best for Egypt, Guinea, and Tunisia while the power model function and exponential model performed best for Cameroon and Nigeria respectively. Furthermore, CW-DBH and CW-CR models of *Parkia biglobosa* generated can be estimated using the adopted model functions.

References

Adesoye, P.O. and Ezenwenyi J.U. (2014). Crown Diameter Prediction Models for *Tectona grandis*

Linn. Fin Omo Forest Reserve, Nigeria. *Journal of Forestry Research and Management*.11:72-87.

Akindele, S. O. (1990). Site quality assessment and yield equation for Teak plantation in the dry forest zone of Nigeria. Ph.D Thesis, Department of Forest Resources Management, University of Ibadan, Nigeria. 180p

Avsar, M. D. and Ayyildiz, V. (2005). The Relationships between diameter at breast height, tree height and crown diameter in Lebanon Cedar (*Cedrus libani* A. Rich.) of the Yavsan Mountain, Kahramanmaras, Turkey. *Pakistan Journal of Biological Sciences* 8(9): 1228- 1232.

Biging, G. S. and Dobbertin M (1992). A comparison of distance-dependent competition measures for height and basal area growth of individual conifer trees. *For. Sci.*, 38:695-720.

Bragg, D. C. (2001). A local basal area adjustment for crown width prediction. *Northern Journal of Applied Forestry*. 18:22-28.

Chukwu, O., Dau, J. H. and Ezenwenyi, J. U. (2018). Evaluation of Parameter Estimators for fitting Weibull Distribution to crown area Of *Parkia biglobosa* Jacq. and *Prosopis africana* Guill & Perr. in Makurdi, Nigeria. *Journal of Forestry Research and Management*.7:186-196.

Daniels, R. F., Burkhart, H. E. and Clason, T. R. (1986). A comparison of competition measures for predicting growth of loblolly pine trees. *Can. J. For. Res.* 16:1230-1237.

Dubravac, T., Dekanic, J., Vrbek, B., Matosevic, D., Roth, V., Jakovljevic, T,. and Zlatanov, T. (2009). Crown volume in forest stands of pedunculate oak and common hornbeam. *Periodicum Biologorum.* 111(4): 479-485.

Elmugheira M. I and Elmamoun H. O (2014). Diameter at Breast Height-Crown Width Prediction Models for *Anogeissus Leiocarpus (DC.) Guill & Perr* and *Combretum Hartmannianum Schweinf.* Pp. 191-197

Ezenwenyi, J. U., Chukwu, O. and Ezeano, C. I. (2018). Modelling Crown Diameter and Canopy Cover Estimation for *Tectona Grandis* Linn. F. Plantation in University of Ibadan, Nigeria.

Helms, J. A. (1998). The Dictionary of Forestry. Bethesda MD, Society of American Foresters. Pp.224

Hemery, G. E., Savill P. S. and Pryor S. N, (2005). Applications of the crown diameter stem diameter relationship for different species of broadleaved trees. *Forest Ecol. Manage*., 215(3): 285-294.

Husch, B., Charles, I. M. and Thomas, W.B. (2003). Forest Mensuration. The Ronald Press Company, New York, U. S. A. pp 120-123.

Ige, P.O., Adeoti, O.O. and Animashaun, Z.T. (2019). Nonlinear height-diameter relationship models for four accession of *Parkia biglobosa* (Jacq.Benth) plantation in Wasangare, Oyo State, Nigeria. *Journal of Agriculture and Environment,* 15 (2): 181-194.

Maltamo, M., Malinen, J., Packalen, P. Suvanto, A. and Kangas, J. (2006). Non-parametric estimation of stem volume using Laser scanning aerial photography and stand register data. *Canadian Journal of Forest Research*, 36:426-436.

Modupeola I.B. (2014). Parkia biglobosa (AFRICAN LOCUST BEAN TREE). *World Journal of Pharmaceutical Research*, 3(2): 1672-1682.

Popoola F.S. and Adesoye P.O. (2012). Crown Ratio Models for *Tectona grandis* (Linn. f) stands in Osho Forest Reserve, Oyo State, Nigeria. *Journal of Forest Science*, 28:63-67.

Tanka, P. A (2006). Prediction of Distribution for Total Height and Crown Ratio Using Normal versus Other Distributions", M.Sc. Thesis, Graduate Faculty of Auburn University, 2006, p. 92.

Toma Buba (2013). Relationships between stem diameter at breast height (DBH), tree height, crown length, and crown ratio of *Vitellaria paradoxa* C.F. Gaertn in the Nigerian Guinea Savanna. *African Journal of Biotechnology*, 12(22): 3441-3446.

Vanclay J. K. (1994). Modeling forest growth and yield. Applications to Mixed Tropical Forests. C A B International, Wallingford, 312p.

Vanclay J. K. (1994). Modelling forest Growth and Yield. Applications to mixed Tropical forests. CAB, International publisher, Wallingford UK. ISBN0851989, 136 – 312pp.

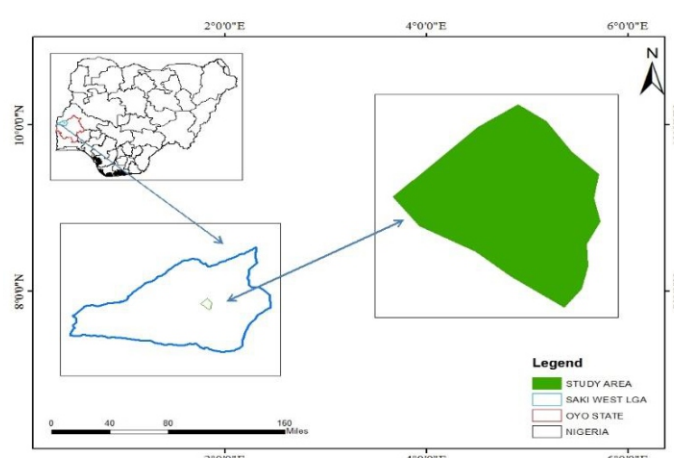

Figure 1: The Study Area

Table 1: Adopted Models

Model Name	Function	Predictor	Eq. No
Simple Linear	? = +? ?h	Dbh	6
	? = +?	CR	
Power	? = ?h	Dbh	7
	? = ?h	CR	
Saturation Growth Rate	? = ?h/(? + ?h)	Dbh	8
	? = /(? +)	CR	
Exponential	? = ? h	Dbh	9
	? = ? ?	CR	

CW=Crown-Width, dbh=diameter at breast height, CR=Crown Ratio, a and b= model parameters

Table 2: Tree growth characteristics summary for each accessions

Accessions	Variables	DBH	THT	TSC	CPA	CRL	CR	CW
Cameroon	Mean±SE	20.19±0.83	9.05±0.46	46.77±2.13	34.47±2.70	4.06±0.21	50.85±2.64	6.20±0.25
	Minimum	6.00	3.60	15.38	2.84	0.80	10.84	1.90
	Maximum	40.00	20.00	109.29	103.88	8.50	94.44	11.50
	Stem No	87						
Egypt	Mean±SE	18.057±0.990	8.907±0.395	55.740±3.097	36.345±3.002	3.694±0.244	42.706±2.308	6.340±0.293
	Minimum	6.000	3.000	10.606	0.786	0.500	5.224	1.000
	Maximum	50.800	15.200	136.609	102.084	8.300	94.318	11.400
	Stem No	72						
Guinea	Mean±SE	20.03±1.40	8.25±0.49	44.57±2.17	43.00±8.47	3.13±0.22	39.42±2.20	6.39±0.52
	Minimum	5.60	2.60	20.49	3.14	0.60	12.00	2.00
	Maximum	49.50	16.00	93.36	268.84	7.50	100.00	18.50
	Stem No	53						
Nigeria	Mean±SE	21.63±1.15	8.96±0.30	46.04±1.86	31.19±2.55	3.93±0.29	42.56±2.39	5.97±0.25
	Minimum	7.60	3.80	20.00	2.01	1.00	12.50	1.60
	Maximum	50.90	14.20	80.00	109.37	9.50	85.71	11.80
	Stem No	67						
Tunisia	Mean±SE	18.72±0.75	8.20±0.35	48.97±2.57	48.90±7.31	3.64±0.21	8.33±91.07	6.98±0.38
	Minimum	6.00	2.80	18.54	4.91	0.4	8.33	2.50
	Maximum	42.50	18.00	130.00	615.83	10.2	91.07	28.00
	Stem No	96						

DBH = Diameter at breast height, THT = Tree total height, TSC = Tree slenderness coefficient, CPA = Crown projection area, CRL = Crown length, CR = Crown ratio and CW = Crown width

Table 3: Summary of the assessment criteria for CW-DBH models

Accessions	Models	Model Parameters		RMSE	AIC
		a	b		
Cameroon	Power	19.84	0.71	1.54	250.07
Egypt	Saturation Growth Rate	13.80	0.20	2.16	206.56
Guinea	Simple Linear	0.19	32.17	1.75	171.43
Nigeria	Exponential	3.99	1.78	1.51	187.82
Tunisia	Simple Linear	3.57	19.50	2.67	370.03

Table 4: Summary of the assessment criteria for CW-CR models

Accessions	Models	Model Parameters		RMSE	AIC
		a	b		
Cameroon	Power	10.5872	-0.1404	2.291657	282.68
Egypt	Saturation Growth Rate	6.5153	0.4655	2.802812	215.7325
Guinea	Saturation Growth Rate	8.6515	8.4755	2.80033	215.73
Nigeria	Exponential	4.4289	0.0068	1.780503	196.52
Tunisia	Saturation Growth Rate	7.8242	2.4842	2.858062	380.9955

Table 5: Validation result for CW-DBH with Welch Two Sample t-test

Accessions		mean	t-value	p-value	remark
Cameroon	Observed	6.168462	-0.24956	0.804	ns
	Predicted	6.314174			
Egypt	Observed	6.156818	0.047309	0.9626	ns
	Predicted	6.124581			
Guinea	Observed	5.168750	-1.1738	0.2502	ns
	Predicted	6.117931			
Nigeria	Observed	5.962500	0.1118	0.9118	ns
	Predicted	5.903506			
Tunisia	Observed	6.239655	-1.5575	0.128	ns
	Predicted	7.090545			

ns=not significant

Table 6: Validation result for CW-CR with Welch Two Sample t-test

Accessions		mean	t-value	p-value	remark
Cameroon	Observed	6.168462	-0.293	0.772	ns
	Predicted	6.300706			
Egypt	Observed	6.156818	-0.425	0.675	ns
	Predicted	6.415042			
Guinea	Observed	5.168750	-3.729	0.00178	ns
	Predicted	7.070447			
Nigeria	Observed	5.962500	0.0050394	0.996	ns
	Predicted	5.959906			
Tunisia	Observed	6.239655	-1.7064	0.09718	ns
	Predicted	7.148600			

ns=not significant

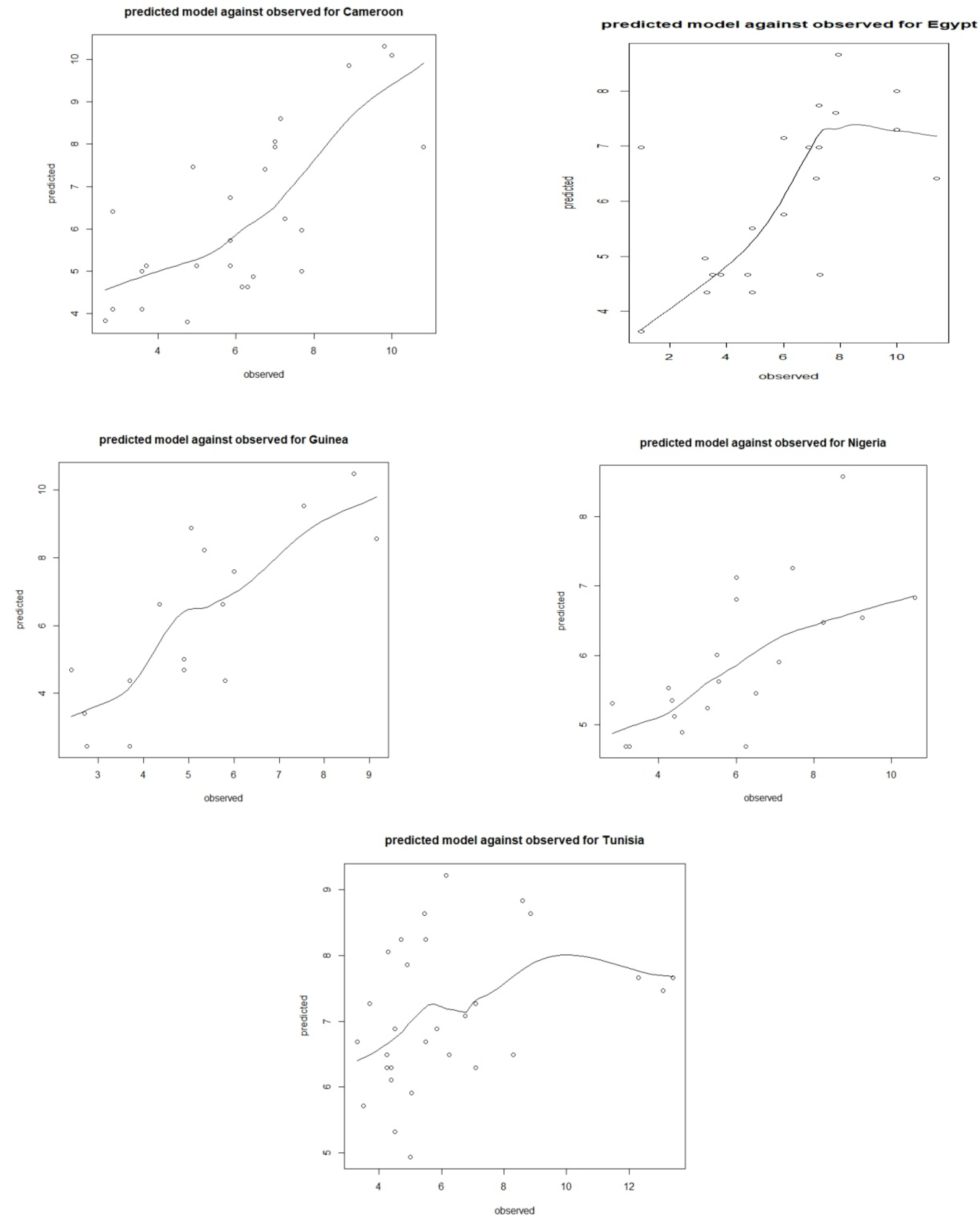

Figure 2: Scattered plots of predicted model against observed for each accessions