Asian Journal of Environment & Ecology

17(3): 9-18, 2022; Article no.AJEE.84781
ISSN: 2456-690X

Assessment of Tree Vigour Models in University of Port Harcourt Park

F. S. Eguakun [a*] and C. J. Anisiofor [a]

[a] *Department of Forestry and Wildlife Management, Faculty of Agriculture, University of Port Harcourt, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2022/v17i330292

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/84781

Original Research Article

Received 17 January 2022
Accepted 24 March 2022
Published 26 March 2022

ABSTRACT

Trees are the unsung heroes of the environment that requires care and maintenance so as to continue its provision of quantifiable benefits. Hence a better understanding of the physical aspect of tree mechanics would help to provide basis for the proper management of trees. The study assessed the vigour of selected trees in University of Port Harcourt Park. Data were collected from four selected tree species based on their abundance in the study area. Tree growth parameters were measured and tree vigour estimated using live crown ratio. Different regression functions were used to model tree vigour. The selected tree species used were *Terminalia mantaly, Azadirachta indica, Mangifera indica and Terminalia cattapa* with frequency of 214 (32.8%), 123 (18.89%), 82 (12.60%) and 79 (12.14%) relatively. Tree growth parameters such as height, Diameter at breast height, crown variable measured showed significant correlation with tree vigour (live crown ratio). The prediction models revealed plausible regression coefficient of determination (R^2) value ranging from 0.247 - 0.953 and standard Error of Estimate (SEE) ranging from 0.0003 – 6.209. From the validation test, it was observed that all the models were good in prediction. However, the double log function was selected as the best model with R^2 value of 0.953 and SEE value 0f 0.0003. Conclusively the trees within the University of Port Harcourt Park are stable hence are not prone to wind throw.

Keywords: Models; stability; tree; urban; vigour.

**Corresponding author: E-mail: funmilayo.popo-ola@uniport.edu.ng;*

1. INTRODUCTION

Trees are the unsung heroes of the environment that provide quantifiable benefits [1] including basic and naturally regenerating material for timber and pulp industries, a living space for animals, insects, and plants, and recreation opportunities for people. As an important asset of the environment, trees require care and maintenance. Maintaining trees to function adequately requires an intact forest cover with mechanically stable trees. Forest management policy depends on societal value of trees and the evaluated mechanical stability of the forest [2]. Different tree management strategies affect tree vigour and protection levels differently. According to [3], tree vigour is the capacity of a tree to resist strain or capacity to survive under increasing stimulus that threatens survival.

The load experienced by a tree can be considered from the tree itself or climatic factors. Loading caused by the tree itself which is triggered by poor maintenance and management system such as excessive pruning, poor compartment, deformed stem, less branching pattern, thin bole and age effect, affects growth parameters thus reducing tree vigour. Secondly, climatic factors such as heavy rainfall, wind etc. can cause load on trees. Hence, trees has to be care and maintained in order to be vigorous enough to withstand the mechanical stress imposed on them, which in turn will prevent tree hazard. A better understanding of the physical aspects of tree mechanics would help to provide better basis for the management of tress with respect to their mechanical vigour and protective function [4, 5]. Vigorous trees which is characterized by well-formed root system has the ability to develop forces or moments that restore the original condition when disturbed from a condition of equilibrium or steady motion compared to trees with less vigour that is susceptible to falling.

Trees with less vigour can be classified as unhealthy trees. Unhealthy trees partly contradict the benefits provided to urban landscapes. Destruction or damage caused by unhealthy trees incurs more cost to the manager. The hazard created by unhealthy trees can disrupt everyday life by removing power to homes, destroying property such as cars or a roof, and possibly even lead to loss of life. These risks prove the importance of maintaining the health of our trees. Hazard created by the presence of a less vigorous tree can have multiplying effect on the environment. According to [6], the impacts of one hazardous event of a tree or trees are often aggravated by interaction with other hazards.

Tree vigour reduces mortality response to short and long term environmental stress. It improves the mechanical resistance to pest and diseases and also improves tree stability thereby making trees not to be susceptible to abiotic factors such as wind throw. University of Port Harcourt as an academic environment is highly populated and these human population must be protected from negative impact of less vigour tree hence it is imperative to know the vigour status of the trees within the university environment in relations to its growth parameters. Therefore, this study focus on assessment of tree vigour status, its effects and management in University of Port Harcourt Park.

2. METHODOLOGY

2.1 Study Area

This study was carried out in University Park of University of Port Harcourt, Choba in Obio-Akpor Local Government Area of Rivers State, Nigeria. The University of Port Harcourt is located at Latitude 4^0 53’14” N through 4^0 54’42” N and longitude $6^0$54’00”E through $6^0$55’50”E (Fig. 1). The vegetation of University of Port Harcourt is tropical rain forest [7].

2.2 Sampling Techniques

Reconnaissance survey was carried out in order to identify and take inventory of the trees species within the University. Purposive sampling technique was used to select four major trees species for the study based on the abundance of the trees (Table 1). Complete enumeration of the selected sample trees was done.

Table 1. Selected tree species

Species	***Family***
Terminalia mantaly	Combretaceae
Azadirachta indica	Meliaceae
Mangifera indica	Anacardiaceae
Terminalia catappa	Combretaceae

2.3 Data Collection

Data were collected from all the selected trees species within the study area. The following tree growth variables were measured for all selected trees species:

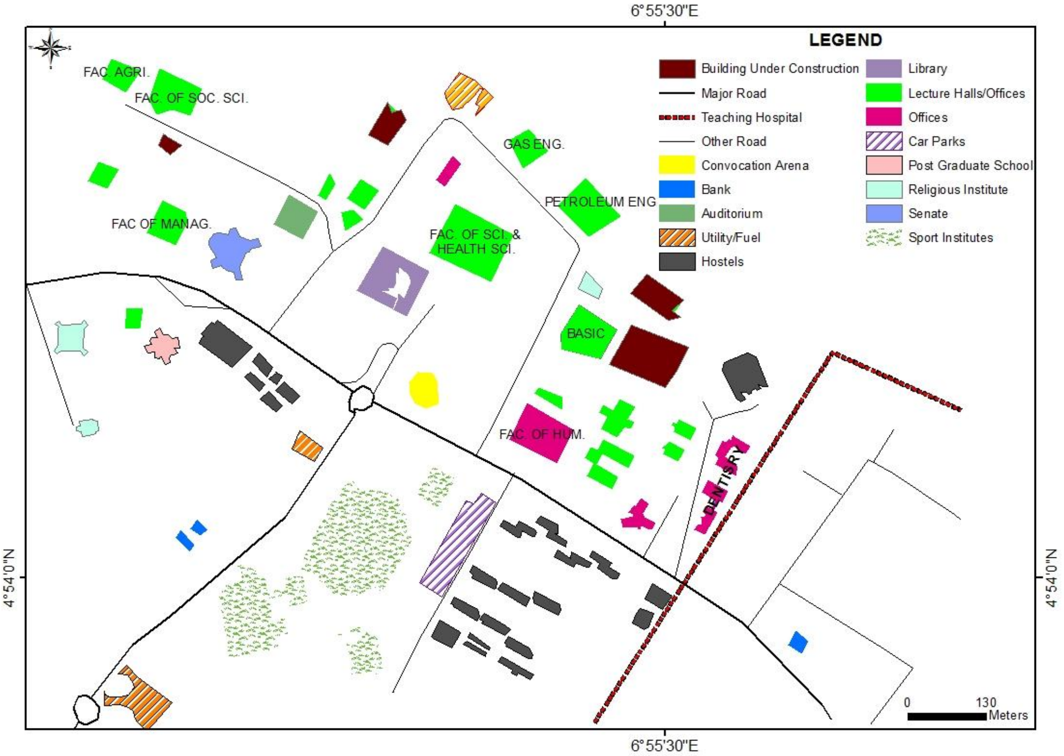

Fig. 1. Map of University of Port Harcourt park

i. Total height
ii. Clear Bole height
iii. Merchantable height
iv. Crown length
v. Crown diameter
vi. Diameter outside bark at breast height (DBH, 1.3m above the ground)

Clinometer and distance tape was used for the height and crown diameter measurements respectively while diameter tape was used to measure diameter outside bark at breast height.

2.4 Data Analysis

The data collected from tree's characteristic measurement was processed into suitable form for statistical analysis. Data processed includes Basal area estimation and tree vigour estimation.

2.5 Computation of Model Variables

2.5.1 Basal area estimation

The basal area for each tree selected by purposive sampling techniques and measured was estimated using this formula:

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

Where;

BA = Basal Area (m^2)
D = Diameter at Breast Height (DBH)

2.5.2 Tree vigour estimation

A useful measurement to indicate tree vigour is live crown ratio. This is the ratio of crown length to total tree height or the percentage of a tree total height that has foliage.

Tree vigour was estimated for all trees using this formula:

$$LCR = \frac{CL}{TH}$$

Where,

LCR = Live Crown Ratio
CL = Crown Lenght
TH = Total Tree Height

2.6 Statistical Analysis

Descriptive Statistics was used to estimate growth parameters attributes and tree vigour. Inferential statistics such as regression and correlation analysis were also used in this study.

Regression analysis was used to develop tree vigour models for the selected trees *species*. Correlation analysis was used to evaluate the association between measureable tree characteristics and vigour of some trees within the study area.

2.7 Development of Tree Vigour Model

2.7.1 Model description

Model is expressed as mathematical equation showing basic structure of the relationship among variables. Two-third (2/3) of the data collected from the observed trees was used in developing the model while the remaining one-third (1/3) was used in model testing and validation. Different equation functions were used in developing tree vigour prediction model.

2.7.2 Model evaluation

The model that was formulated was evaluated with a view of selecting the best estimate for tree vigour prediction. The evaluation is based on the following criteria:

1 Coefficient of determination (R^2)
2 Standard Error of Estimate (SEE)
3 Significance of the overall Regression Equation (F-Ratio)
4 Significance of Regression Coefficient.

2.7.3 Model validation

For a model to be valid, the observed and predicted value should not be significantly different at 0.05 level of significance. The selected model was used to predict tree vigour for the trees species in the University. The values was compared with the observed value and the differences is expressed as residual (bias). Paired student t-test procedure was used to compare predicted values with observed values.

3. RESULTS

3.1 Tree Species Inventory

The reconnaissance survey carried out within the University of Port Harcourt Park enumerated a total of six hundred and fifty-one (651) trees comprising of thirteen (13) identified species belonging to eleven (11) families (Table 2). The first four species were used for the study due to their dominance in the University Park. The most abundant species presented is *Terminalia mantaly* that accounted for 32.87% (214) of the total population.

3.2 Tree Growth Variable Measurement

Results of the tree growth variables showed that *Terminalia mantaly* (0.43m) had the lowest mean DBH while *Mangifera indica* (0.69m) had the highest mean DBH. On average, *Azadirachta indica* recorded the lowest crown length, crown diameter, total height values of 12.18m, 12.85m and 15.08 respectively (Table 3).

3.3 Tree Vigour Estimation

Live crown ratio was used to estimate tree vigour. The result shows that *Azadirachta indica* (79.98) had the lowest averaged live crown ratio while *Mangifera india* (82.80) had the highest averaged value for live crown ratio. *Terminalia mantaly* and *Terminalia catappa* had almost similar averaged value of 80.80 and 80.78 respectively (Table 4).

Table 2. Composition of trees within the University of Port Harcourt Park

Species	Family	Frequency	Percentage composition
Terminalia mantaly	Combretaceae	214	32.87
Azadirachta indica	Meliaceae	123	18.89
Mangifera indica	Anacardiaceae	82	12.60
Terminalia catappa	Combretaceae	79	12.14
Delonix regia	Fabaceae	33	5.07
Psidium guajava	Myrtaceae	22	3.38
Persea americana	Lauraceae	20	3.07
Anacardium occidentale	Anacardiaceae	19	2.92
Lagerstroemia speciosa	Lythraceae	19	2.92
Hura crepitans	Euphorbiaceae	19	2.92
Gmelina arborea	Lamiaceae	9	1.38
Prunus domestica	Rosaceae	8	1.23
Milicia excelsa	Moraceae	4	0.61

Table 3. **Descriptive analysis of tree growth parameters**

Parameters	Species	Min.	Max.	Mean	Std. Error	Std. Deviation
DBH (m)	*T. mantaly*	0.24	0.70	0.43	0.01	0.09
	A. indica	0.38	0.89	0.59	0.01	0.10
	M. indica	0.29	1.24	0.69	0.03	0.22
	T. catappa	0.14	0.97	0.50	0.03	0.21
	Total	**0.14**	**1.24**	**0.55**	**0.01**	**0.19**
Crown Length (m)	*T. mantaly*	5.18	20.04	13.25	0.35	2.88
	A. indica	5.98	19.00	12.18	0.34	2.79
	M. indica	5.98	29.80	14.09	0.54	4.42
	T. catappa	1.19	27.14	13.65	0.64	5.19
	Total	**1.19**	**29.80**	**13.29**	**0.25**	**4.00**
Crown Diameter (m)	*T. mantaly*	6.26	22.10	14.48	0.36	2.93
	A. indica	8.90	18.05	12.85	0.23	1.87
	M. indica	5.55	21.65	13.79	0.46	3.76
	T. catappa	5.55	29.90	16.33	0.62	5.02
	Total	**5.55**	**29.90**	**14.36**	**0.23**	**3.79**
Clear Bole Height (m)	*T. mantaly*	1.68	6.65	3.11	0.13	1.08
	A. indica	1.52	5.40	2.90	0.08	0.62
	M. indica	1.46	4.36	2.72	0.09	0.69
	T. catappa	1.52	6.77	2.88	0.12	0.94
	Total	**1.46**	**6.77**	**2.90**	**0.05**	**0.86**
Total Height (m)	*T. mantaly*	7.08	23.73	16.35	0.38	3.10
	A. indica	9.55	22.02	15.08	0.32	2.60
	M. indica	9.15	32.64	16.81	0.55	4.43
	T. catappa	3.81	28.97	16.52	0.65	5.28
	Total	**3.81**	**32.64**	**16.19**	**0.25**	**4.03**
Merchantable Height (m)	*T. mantaly*	2.50	12.20	6.25	0.24	1.99
	A. indica	3.72	12.05	6.42	0.21	1.74
	M. indica	2.44	19.52	7.17	0.33	2.67
	T. catappa	1.52	14.52	6.98	0.38	3.12
	Total	**1.52**	**19.52**	**6.71**	**0.15**	**2.46**
Basal Area (m^2)	*T. mantaly*	0.05	0.39	0.15	0.01	0.07
	A. indica	0.11	0.62	0.28	0.01	0.09
	M. indica	0.06	1.21	0.42	0.03	0.26
	T. catappa	0.01	0.74	0.23	0.02	0.17
	Total	**0.01**	**1.21**	**0.27**	**0.01**	**0.19**

Table 4. Descriptive analysis of estimated tree vigour (live crown ratio)

Parameters	Species	Min.	Max.	Mean	Std. Error	Std. Deviation
Live Crown Ratio	*T. mantaly*	65.99	91.27	80.80	0.72	5.86
	A. indica	61.09	90.85	79.98	0.76	6.20
	M. indica	64.55	91.62	82.80	0.74	6.03
	T. catappa	31.20	93.68	80.78	1.14	9.23
	Total	**31.20**	**93.68**	**81.09**	**0.43**	**7.01**

3.4 Evaluation of Relationship between Vigour Measure and Tree Growth Parameter

There is significant relationship between LCR and all tree growth parameters (Total height, Merchantable height, Crown diameter, Clear bole height, Crown length, Diameter at breast height and basal area) as they yielded a p-value less than 0.05. Positive correlation was observed in LCR relationship with Total height (r = 0.57), Merchantable height (r = 0.34), Crown diameter (r = 0.43), Basal area (r = 0.39), Crown length (0.71) and DBH (r = 0.40) while negative correlation was observed only in LCR relationship with Clear bole height (-0.62) (Fig 2).

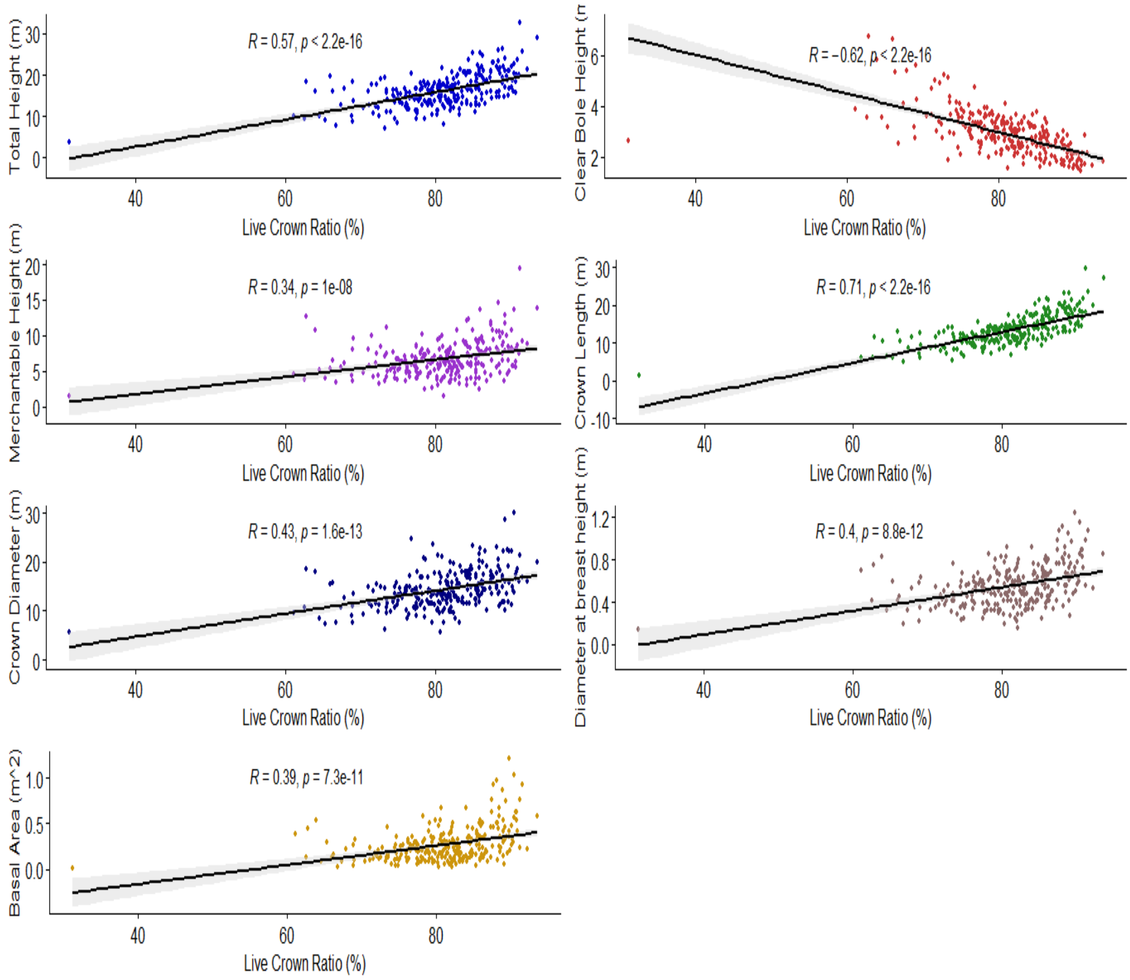

Fig. 2. 2 x 4 Scatter plot grid of live crown ratio and tree growth parameters showing trend line and correlation coefficient

3.5 Tree Vigour Predictive Model

Table 5 indicates various simple linear models developed with various growth parameters as independent and live crown ratio as the dependent. All models were statistically significant as they yielded a probability value less than 0.001. Among the simple linear regression model, having clear bole height as the predictor was the best model as it explained 53.2% (R^2 = 0.532) of the variability in the independent variable with SEE of 4.399 and the model with least representation is observed in equation involving merchantable height which produced an R^2 value of 0.067 and SEE of 6.209.

Result from Table 6 shows that in developing models using multiple predictors (growth parameters) to predict live crown ratio (LCR), the models were statistically significant at $p \leq 0.05$. All levels of combination of total height (X_1), clear bole height (X_2) and crown length (X_4) produced same coefficient of determination of 0.934 while the combination of all independent variables (0.941) yielded the best result of R^2.

Amongst the models in Table 7. semi log models developed using single predictors produced the least coefficient of determination and largest SEE (X_2 = 0.535, 0.056; X_4 = 0.443, 0.061). Multiple combination of all the independent variables was the best (R^2 = 0.923, SEE = 0.023).

Also in Table 8, double log models produced with single independent variables produced the least coefficient of determination and largest SEE (X_2 = 0.511, 0.058; X_4 = 0.459, 0.061) respectively. Multiple combination of the independent variables (X_1 and X_4; X_1, X_2 and X_4; and X_1 …. X_7) produced absolute vale of 1.000 for coefficient of determination and SEE less than 0.000

Table 5. Tree vigour predictive model using simple linear models

S/N	Model	R^2	SEE	Prob	Coefficient in equation
1	$Y=b_0+b_1X_1$	0.247	5.578	<0.001	$Y = 67.574 + 0.825(X_1)$
2	$Y=b_0+b_1X_2$	0.532	4.399	<0.001	$Y = 95.685 – 5.030(X_2)$
3	$Y=b_0+b_1X_3$	0.067	6.209	<0.001	$Y = 76.327 + 0.671(X_3)$
4	$Y=b_0+b_1X_4$	0.464	4.704	<0.001	$Y = 65.802 + 1.147(X_4)$
5	$Y=b_0+b_1X_5$	0.152	5.918	<0.001	$Y = 71.269 + 0.671(X_5)$
6	$Y=b_0+b_1X_6$	0.129	5.997	<0.001	$Y = 74.008 + 12.337(X_6)$
7	$Y=b_0+b_1X_7$	0.134	5.983	<0.001	$Y = 77.385 + 12.875(X_7)$

Y = Live crown ratio; X_1 = Total height; X_2 = Clear bole height; X_3 = Merchantable height; X_4 = Crown length; X_5 = Crown diameter; X_6 = Diameter at breast height; X_7 = Basal area; b_0 = intercept; b_1, b_2 … b_7 = slope for respective independent variable; Significant at $p \le 0.05$

Table 6. Tree vigour predictive model using multiple linear models

S/N	Model	R^2	SEE	Prob	Coefficient in equation
1	$Y=b_0+b_1X_1+b_2X_2$	0.934	1.654	<0.001	$Y = 80.820 + 1.070(X_1) – 5.810(X_2)$
2	$Y=b_0+b_1X_1+b_2X_4$	0.934	1.653	<0.001	$Y = 80.822 – 4.740(X_1) + 5.810(X_4)$
3	$Y=b_0+b_1X_2+b_2X_4$	0.934	1.654	<0.001	$Y = 80.820 – 4.740(X_2) + 1.070(X_4)$
4	$Y=b_0+b_1X_1+b_2X_2+b_3X_4$	0.934	1.658	<0.001	$Y = 80.822 – 4.362(X_1) – 0.377(X_2) + 5.432(X_4)$
5	$Y=b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7$	0.941	1.585	<0.001	$Y = 78.120 – 6.575X_1 + 1.911X_2 – 0.214X_3 + 7.740X_4 + 0.042X_5 + 8.448X_6 – 9.659X_7$

Y = Live crown ratio; X_1 = Total height; X_2 = Clear bole height; X_3 = Merchantable height; X_4 = Crown length; X_5 = Crown diameter; X_6 = Diameter at breast height; X_7 = Basal area; b_0 = intercept; b_1, b_2 … b_7 = slope for respective independent variable.

Table 7. Tree vigour predictive model using semi log models

S/N	Model	R^2	SEE	Prob	Coefficient in equation
1	$\ln Y=b_0+b_1X_2$	0.535	0.056	<0.001	$\ln Y = 4.580 – 0.065(X_2)$
2	$\ln Y=b_0+b_1X_4$	0.443	0.061	<0.001	$\ln Y = 4.201 + 0.014(X_4)$
3	$\ln Y=b_0+b_1X_1+b_2X_2$	0.917	0.024	<0.001	$\ln Y = 4.394 + 0.013(X_1) – 0.074(X_2)$
4	$\ln Y=b_0+b_1X_1+b_2X_4$	0.917	0.024	<0.001	$\ln Y = 4.394 – 0.061(X_1) + 0.074(X_4)$
5	$\ln Y=b_0+b_1X_2+b_2X_4$	0.917	0.024	<0.001	$\ln Y = 4.394 – 0.061(X_2) + 0.013(X_4)$
6	$\ln Y=b_0+b_1X_1+b_2X_2+b_3X_4$	0.917	0.024	<0.001	$\ln Y = 4.394 – 0.072(X_1) + 0.011(X_2) + 0.085(X_4)$

Y = Live crown ratio; X_1 = Total height; X_2 = Clear bole height; X_3 = Merchantable height; X_4 = Crown length; X_5 = Crown diameter; X_6 = Diameter at breast height; X_7 = Basal area; b_0 = intercept; b_1, b_2 … b_7 = slope for respective independent variable.

Table 8. Tree vigour predictive model using double log models

S/N	Model	R^2	SEE	Prob	Coefficient in equation
1	$\ln Y=b_0+b_1\ln X_2$	0.511	0.058	<0.001	$\ln Y = 4.594 – 0.197(\ln X_2)$
2	$\ln Y=b_0+b_1\ln X_4$	0.459	0.061	<0.001	$\ln Y = 3.909 + 0.190(\ln X_4)$
3	$\ln Y=b_0+b_1\ln X_1+b_2\ln X_2$	0.929	0.022	<0.001	$\ln Y = 4.025 + 0.222(\ln X_1) – 0.237(\ln X_2)$
4	$\ln Y=b_0+b_1\ln X_1+b_2\ln X_4$	1.000	0.0003	<0.001	$\ln Y = 4.605 – 1.000(\ln X_1) + 0.999(\ln X_4)$
5	$\ln Y=b_0+b_1\ln X_2+b_2\ln X_4$	0.953	0.018	<0.001	$\ln Y = 4.119 – 0.194(\ln X_2) + 0.186(\ln X_4)$

Y = Live crown ratio; X_1 = Total height; X_2 = Clear bole height; X_3 = Merchantable height; X_4 = Crown length; X_5 = Crown diameter; X_6 = Diameter at breast height; X_7 = Basal area; b_0 = intercept; b_1, b_2 … b_7 = slope for respective independent variable

Table 9. Model Validation

Model	MOV	MPV	P-Value	Remark
Simple linear models				
$Y=b_0+b_1X_2$	81.797	81.795	0.999	NS
Multiple linear models				
$Y=b_0+b_1X_1+b_2X_2+b_3X_4$	81.797	82.503	0.548	NS
Semi log models				
$\ln Y=b_0+b_1X_1+b_2X_2$	4.397	4.410	0.452	NS
Double log models				
$\ln Y=b_0+b_1\ln X_1+b_2\ln X_4$	4.397	4.397	0.999	NS

Y = Live crown ratio; X_1 = Total height; X_2 = Clear bole height; X_4 = Crown length; b_0 = intercept; b_1, b_2 … b_7 = slope for respective independent variable; MOV = Mean observed value; MPV = Mean predicted value; significant at $p \leq 0.05$; NS = Not significant

3.6 Model Validation

The results of the validation test of the selected models are presented in Table 9. Non significant differences between the observed value and the predicted values of the selected simple, multiple, semi logarithm and double logarithm model exist. Hence, all models are therefore suitable for current and future prediction but double log model gave the best result with highest R^2 and lowest SEE.

4. DISCUSSION

The University being a place of learning attracts numerous people together which make it not to differ from other urban environment. The inventory of tree species in University of Port Harcourt Park shows the presence of different tree species in which *Mangifera indica, Terminalia mantaly, Azardirachta indica* and *Terminalia catappa* are most dominant. Sociologist, psychologist and the masses supports the notion that the quality of urban life rely greatly on the quantity and quality of green spaces close to it or around it. The university environment is rich with diverse tree species because of the benefit of trees in the environment [8]. *Terminalia catappa* and *Azadirachta indica* are among the most dominant species in the University of Port Harcourt park. Researcher have also observed these species in various urban environment [9,10]. Tree vigour classes as modified by [11] are low vigour for LCR < 0.30, moderate vigour for LCR= 0.30 - 0.50 and high vigour for LCR > 0.50. it was observed that the studied trees species in the University park had high vigour (79.98-82.80) which implies high stability and low risk or susceptibility to wind throw and breakage.

In this study effort was directed towards obtaining tree vigour prediction models. Assessing tree vigour gives an understanding of the structural stability of tree roots which are inaccessible and also create a guideline on the maximum and stable height of a tree. Live crown ratio has been used as an indicator of tree vigour [12, 13] and a useful variable for assessing forest health condition. Before the models were developed, correlation analysis was carried out to give an insight of the association between tree vigour (live crown ratio) and the growth variables. Positive correlation was observed in LCR relationship with tree total height, merchantable height, crown diameter, Basal area, crown length and diameter at breast height while negative correlation was observed only in LCR relationship with clear bole height. Similar report of both positive and negative correlation between LCR and growth variables was observed in the findings of [14]

Model fitting and evaluation are important parts of model building. Fitting of tree vigour models were based on the total data set. A number of different models were examined for predicting tree vigour using simple linear equation, multiple linear equation, semi-logarithm and double logarithm functions. All the models showed strong fit to tree vigour though double logarithm gave the best result. One unique independent variable that features in all the models is clear bole height. This proves that clear bole height is one of the factors contributing to the tree vigour.

The result of the test of significance of tree vigour sampled showed no significant difference (P=0.05) between the observed value and the predicted values, hence all model are therefore suitable for current and future prediction. This study is in agreement with the study of [15], in which all models were found to be significant at (P=0.05) using slenderness coefficient to assess the risk of *Tectona grandis* plantation. The selected models can be useful for prediction of tree vigour among trees within the range of data used in model development.

4. CONCLUSION

Tree vigour model was developed in other to assess the stability of most abundant trees in University of Port Harcourt Park. Based on the parameters measured, the result of modelling tree vigour with growth parameters showed that live crown ratio is a useful tool in tree vigour estimation. The observation from the study can be useful information on stability of trees to wind throw. This information can help forest managers know the trees which have good vigour in relationship with its growth parameters and the right silvicultural treatment in other to prevent damages by windthrow.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Oyebade BA, Popo-Ola FS, Itam IS. “Perception of urban dwellers about the benefits and management of urban trees in

Uyo metropolis, Akwa Ibom State, Nigeria". ARPN Journal of Science and Technology. 2013;3:767-773.

2. Brang P, Schönenberger W, Frehner M, Schwitter R, Thormann J, Wasser B. Management of protection forests in the European Alps: an overview". Forest Snow and Landscape Research. 2006;80:23-44.
3. Petrokas R. Growth vigor in Wych Elm (Ulmus glabra Huds.)", Baltic Forestry. 2008;14:204-215, 2008.
4. Nicoll BC, Gardiner BA, Rayner B, Peace AJ. Anchorage of coniferous trees in relation to species, soil type, and rooting depth. Canadian Journal of Forest Research. 2006;36:1871-1883.
5. Sellier D, Brunet Y, Fourcaud T. A numerical model of tree aerodynamic response to a turbulent airflow", Forestry. 2008;81:279-297.
6. Marzocchi W, Garcia-Aristizabal A, Gasparini P, Mastellone ML, Di Ruocco A. Basic principles of multi-risk assessment: A case study in Italy", Nat. Hazards. 2012;62:551-573.
7. Eludoyin OS, Oladele AT, Iyanda OM. Mapping and Assessment of Ethno-Medicinal Trees in Built Up Areas - University of Port Harcourt, Nigeria. South-east European forestry. 2015;6:129-140.
8. Oladele AT, Eguakun FS, Ugbaja UC. Amenity trees diversity in selected tertiary institutions within Port Harcourt Metropolis, Rivers State, Nigeria. J. Appl. Sci. Environ. Manage. 2020;24:2175-2181.
9. Mulani RM, Khan KZ. Study of Avenue Tree Diversity of Urban Area of Nanded District Maharashtra State India. International Journal of Science and Research (IJSR). 2015;6:2154-2156.
10. Ogwu MC, Osawaru ME, Obayuwana OK. "Diversity and abundance of tree species in the University of Benin City, Nigeria" Applied Tropical Agriculture. 2016;21:46-54.
11. Schultz PW. The structure of environmental concern: Concern for self, other people and the biosphere. Journal of Environmental Psychology. 2001;21:327-339.
12. Hasenauer H, Monserved RA. A crown ratio model for Australia forest. Forest ecology and management. 1996;84:49-60.
13. Popoola FS, Adesoye PO. Crown Ratio Models for *Tectona grandis* (Linn. f) Stands in Osho Forest Reserve, Oyo State, Nigeria", Journal of Forest Science. 2012;28:63-67.
14. Chukwu O, Ezenwenyi JU. Models for estimating crown projection area from stump diameter for *Tectona grandis* Linn. f. in the tropical rainforests of Nigeria", Forestist; 2012

    DOI:10.5152/ forestist. 2020.
15. Eguakun FS, Oyebade BA, Olayiwola VA. Simulation study on risk assessment of Tectona grandis plantation in osho forest reserve, Oyo State, Nigeria. J. of Trop. For. Res. 2014;30:119-126.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/84781