IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 4 Ser. I (April. 2020), PP 29-39
www.iosrjournals.org

Modelling Photosynthetic and Diameter Growth Variables of *Azadirachta Indica* (Linn) Planted As an Avenue Trees in Abuja Park, University Of Port Harcourt, Nigeria

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Abstract: *This study is aimed at establishing the relationship between growth diameter and photosynthetic variables of Azadirachta indica used as an avenue tree in Abuja Park, University of Port Harcourt. Two sources of data were used for the study which included photosynthetic variables such as photo intensity, relative humidity and temperature as well as the diameter growth variables namely Diameter at breast height (dbh), Tree Total Height (THT) and Crown Diameter (CD), while Crown Spread Ratio (CSR), Linear Crown Index (LCI) and Crown Projection Area (CPA) estimated indirectly from 208 standing Azadirachta indica trees planted as avenue trees along Abuja Road, University Park, University of Port Harcourt. The data obtained from photosynthetic variables and diameter growth variables from the study area were analyzed using descriptive, correlation and regression analyses; while the three categories of empirical models developed namely multiple, single log and double log were used in fitting the data from the net photosynthetic variables and diameter growth attributes to evaluate the fitness of the models and for the best the fit model. The results of the study revealed that there were fair association between the net photosynthetic variables and diameter growth attributes with correlation coefficients (r) ranging from -0.871 - 0.162 at P<0.05 level of significance. The results also indicated that models with temperature as dependent variables across the classification of 21 models developed have the relatively high coefficients of determination (R^2). This means that temperature models among photosynthetic variables studied could be recommended for prediction based on their reasonable relationships with the diameter growth variables of Azadirachta indica in the study area.*

Keywords: ***Diameter growth variables, modelling, photosynthetic variables, Azadirachta indica,***

Date of Submission: 21-03-2020 Date of Acceptance: 07-04-2020

I. Introduction

Generally, trees remove air pollution by the interception of particulate matter on plant surface and the absorption of gaseous pollutants through the stomata [12]. A tree is a perennial plant with an elongated stem, or trunk, supporting branches and leaves in many species. Like many aspects of nature, a tree's existence revolves around competition. It might be of worthy to note that the magnitude and value of the effects of trees and forests on air quality and human health in Nigeria remains unknown. However, the focus of this project is on the relationship between *Azadirachta indica* (Neem) diameter growth and net photosynthetic variables of light, oxygen, temperature, carbon (IV) oxide and exchange gas rate. The Neem tree (*Azadirachta indica*) is native to tropical South East Asia. It is a fast growing species that can survive drought and poor soil and keeps its leaves all year round. It is a tall tree, up to 30 meters high, with leafy spreading branches. Many white flowers which smell of honey appear for the first time when the tree is 2 to 3 years old, and the tree bears fruit after 3 to 5 years. The ripe fruit are about 2 centimeters (cm) long and oval shaped. Inside the fruit, there is a light coloured seed about 1.5 cm long. It is duly valued worldwide for its hardiness, medicinal properties, and nutritional value [6].

Physiologically based, large-scale models in mixed species forests have typically used lumped-parameter approaches [1], where for example, the photosynthetic rate of the entire forest canopy is represented by a single equation. Forest plays important roles in maintaining and providing important ecosystem services and functions.

However these important roles are under threat due to the combined effects of deforestation, degradation and forest fragmentation. Alarms about these threats have mainly focused on their impact on habitat quality, climate change, and particularly biological diversity. Tree diversity of forested ecosystem has important consequences on carbon storage, decomposition or mineral cycling, nutrient acquisition, communities of biota, and growth and productivity [11]. [12] reported that trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. According to the report, O_3, SO_2 and NO_2, most of the pollution is removed via leaf stomata and once inside the leaf, gases diffuse into intercellular spaces and

may be absorbed by water films to form acids or react with inner-leaf surfaces. The report indicated that trees directly affect particulate matter in the atmosphere by intercepting particles, emitting particles (e.g., pollen) and resuspension of particles captured on the plant surface. Some particles can be absorbed into the tree, though most intercepted particles are retained on the plant surface.

Although direct physiological measurements in mature broad-leaved deciduous forests are limited because canopy access is difficult, studies have established within-crown variation in environmental factors and their effects on photosynthesis ([2]; [4]). In developing a model, it is important to think in terms of controllable variable and the relationship that exist between them [8]. Non linear regression model is a form of regression analysis in which the data are fit to a model expressed as a mathematical function. [14] reported that nonlinear regression is a powerful technique for data analysis. Their study opined that although nonlinear regression calculations cannot be reasonably performed by hand, computer programs that perform these calculations are available for microcomputers found in many laboratories. Non-linear curve-fitting analyses are easy, fast, and practical for routine use; with parameter estimates that can be obtained using different methods such as: (i) ordinary least squares, which minimizes the sum of squared error between observations and predictions, and (ii) the maximum likelihood method, which seeks the probability distribution that makes the observed data most likely [3]. Though several works had be reported on the neems in Nigeria and many parts of the world ([9]; [13]; [18]; [17]; [7]); there is still paucity of information on evaluation of the relationships of diameter growth variables and surrounding photosynthetic variables of *Azadirachta indica* planted as avenue trees along Abuja road, University of Port Harcourt, Rivers State, Nigeria.

Therefore this study would explore the relationship of diameter growth characteristics and photosynthetic variables using empirical models in *Azadirachta indica* planted as avenue trees along Abuja road, University of Port Harcourt, Rivers State, Nigeria.

II. Methodology

Study area

This study was carried out within University Park, University of Port Harcourt, Rivers State, Nigeria. It is geographically located at latitude $4^0\,45^{'}$ N, $4^0\,60^{'}$ E and longitude $6^0\,50^{'}$ E, $8^0\,00$ E (Figure 1). Avenue trees, as it is fondly called, are tree that is planted along the entrance of the Abuja campus of the University. It stretches from the Delta park entrance of the campus to the general park inside Abuja campus, University of Port Harcourt.

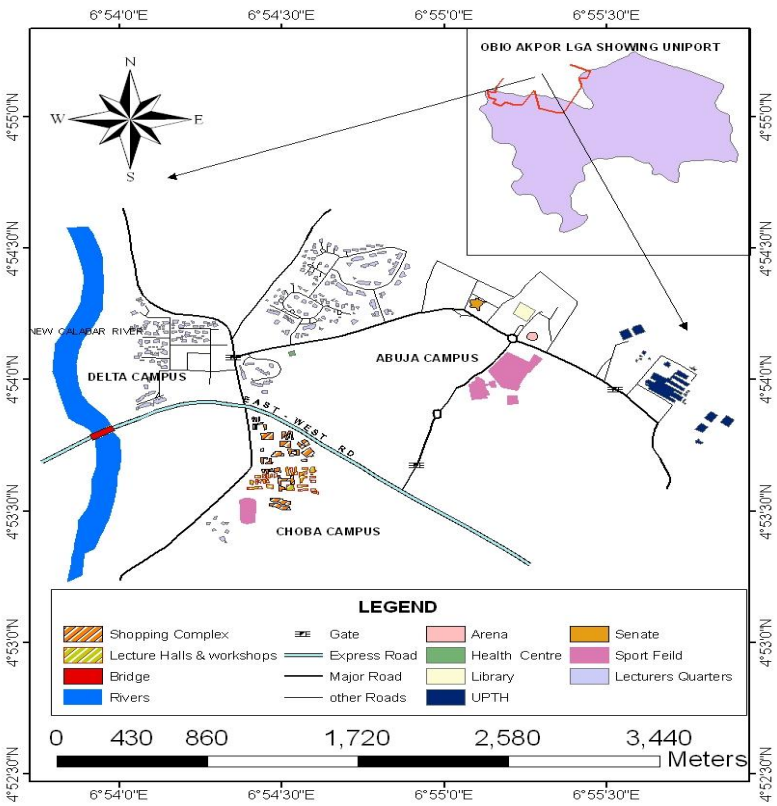


Figure 1: Map of University of Port Harcourt showing the study area

Data Collection

Two sources of data were used for this study; namely the photosynthetic variables, which comprise of (i) light intensity (ii) relative humidity and (iii) temperature. As well as direct tree growth variable measurements which include of Diameter at breast height (dbh), Tree Total Height (THT) and Crown Diameter (CD) while Crown Spread Ratio (CSR), Linear Crown Index (LCI) and Crown Projection Area (CPA) were estimated from collected data.

Tree Growth Variable Estimation

Diameter at Breast Height (Dbh)

The diameter at breast height (dbh) of all the trees was determined with the use of diameter tape at breast height point of 1.3m above the ground level.

Basal Area Computation

Basal area of individual trees at the study area was calculated using the formula:

$BA = \frac{\pi D}{4}$ ……..equation (1)

Where BA= basal area (m²),

D= diameter at breast height (cm) and

π=pi (3.142).

Crown Projection Area Computation

Crown diameters were measured using two ranging poles and 30m linen tape using crown projection technique. This was done through measuring the distance between edges of the crown in multiple of 2 or 3 directions. The two values that were obtained were averaged and the result was taken as crown diameter.

$CD = \frac{D1+D2}{2}$ ……equation (2)

CPA (crown projection area) was computed by the relation.

$CPA = \frac{\pi C D^2}{4}$ ……..equation (3)

Where; CD = crown diameter,

D_1= Crown diameter 1,

D_2= Crown diameter 2,

π =pi (3.142), and

CPA = Crown Projection Area

Statistical Data Analysis

The following data analyses methods were applied in the namely:

Descriptive Analysis

The descriptive analyses were the measures of central tendency and measures dispersion. It also involved the use of tables and graphs for the presentation of data.

Correlation Analysis

This involved the determination of association of net photosynthetic variables on the diameter growth variables of the *Azadirachta indica* trees in the study area. This was determined using the correlation coefficient (r) given as:

$$r = \frac{\sum xy - \frac{(\sum x)(\sum y)}{N}}{\sqrt{\left\{\left[\sum x^2 - \frac{(\sum x)^2}{N}\right]\left[\sum y^2 - \frac{(\sum y)^2}{N}\right]\right\}}}$$ ……equation (4)

Where:

N = number of pairs of scores

∑xy = sum of the products of paired scores

∑x = sum of x scores

∑y = sum of y scores

$\sum x^2$ = sum of squared x scores

$\sum y^2$ = sum of squared y scores

Simple Regression Model.

This is expressed as:

$Y = \beta_0 + \beta_1 X$ …….. equation (5)

Where: Y is the dependent variable and β_0 is regression constant, β_1 is the regression slope and X is the independent variable.

Multiple Linear Regression Model:

$Y = b_0 + b_1X_1 + b_2X_2$ ……, b_nX_n…… equation (6)

Where: Y is the dependent predictor variable,
X_1, X_2, ……,X_n are the independent variables.
b_0, b_1, b_2……, b_n are the regression parameters.

Model Evaluation

The developed model was evaluated to know how well the model fit into the data. This would be done using the following Fit indices or criteria:

i. Regression Coefficient of Determination (R^2)

The coefficient of determination (denoted by R^2) is a key output of regression analysis. It is interpreted as the proportion of the variance in the dependent variable that is predictable from the independent variable. The coefficient of determination is the square of the correlation (r) between predicted y scores and actual y scores; thus, it ranges from 0 to 1. With linear regression, the coefficient of determination is also equal to the square of the correlation between x and y scores.

This is given as:

$R^2 = 1 - \frac{SSRegression}{SS\ Total}$ ……equation (7)

Where: $SS_{Regression}$ = Regression sum of square
SS_{Total} = Total sum of squares

ii. Standard Error of Estimate (SSE):

Given as:

$SSE = S_Y \sqrt{1 - r^2 \frac{n-1}{n-2}}$ ……equation (8)

$= \sqrt{\frac{1}{n-2} - \sum_{i=1}^{n} Y_i - a + bX_i^2}$ ……equation (9)

iii. Prediction Sum of Squares (PRESS) and is given as:

$$PRESS = \sum_{i=1}^{n} (Observed - \Pr edicted)^2$$ ……..equation (10)

Where:
Y_i = observed value of Y for observation i
Y* = Predicted value of Y or observation i as calculated from a regression equation.

III. Results

Descriptive Statistics

Table 1 shows the descriptive statistics of growth diameter and net photosynthetic parameter of *Azadirachta indica* in the study area. The summary statistics showed exploration of measures of central tendency alongside and that of the measure of dispersion within the data of tree growth variable and photosynthetic parameter of the individual trees of *Azadirachta indica* planted as an avenue tree at University of Port Harcourt, Abuja Park.

Table 1: Summary Statistics of Growth Diameter And Photosynthetic Variables of *Azadirachta Indica*

Variables	Mean± Standard Deviation	Minimum	Maximum
DBH (cm)	40.1 ± 0.173	14.000	257.000
BA (m^2)	0.149 ± 0.356	0.200	5.190
CD (m^2)	6.407 ± 1.103	3.100	9.450
C/RAD (m^2)	3.203 ± 0.551	1.550	4.700
CPA (m^2)	33.201 ± 11.233	7.550	70.150
THT(m^2)	7.987 ± 1.926	3.000	12.200
LCI	16.871 ± 3.756	3.670	26.560
CSR	0.860 ± 0.313	0.420	2.360
PHOTO(LUX)	3958.960 ± 2241.482	1060.000	9011.000
TEMP ^{0}C	34.573 ± 3.115	30.000	41.200
R/HUD %	66.524 ± 12.144	42.000	90.000

DBH- Diameter at breast height, BA- Basal area, CD- Crown diameter, C/RAD- Crown radius, CPA- Crown projection area, THT- Total height, LCI- Linear crown index, CSR- Crown spread ratio, PHOTO- Photo intensity, Temp- Temperature, RH- Relative humidity

Table 1 shows the summary statistic of the tree growth variables and net photosynthetic variable of *Azadirachta Indica*. The results of the growth diameter variable indicates that photo intensity mean value of 3958.960 ± 2241.482(Lux) was obtained with a minimum of 1060.00(Lux) and a maximum value of 9011.000(Lux) respectively. Meanwhile for the relative humidity with a mean value of 66.52±12.144% was obtained with a minimum value of 42.000% and a maximum value of 90.000% respectively. Furthermore, the CD with a mean value of 6.407±.1.103m^2 and was obtained with a minimum and maximum value 0f 3.100m^2 and 9.450m^2 respectively. Similarly, the table shows further that the tree total height (THT) has a mean value of 7.987± 1.926m^2 and the minimum and maximum values as 3.000m^2 and 12.200m^2.

Correlation matrix between net photosynthetic and growth variables of A*zadirachta indica*.

Table 2 below shows the correlation matrix between growth diameter and net photosynthetic variable of temperature, light and relative humidity of *Azadirachta indica* in the study area. The analysis shows the progressive degree of association between response variable (dependent) and independent variables.

The results revealed the relationship between the growth diameter and the net photosynthetic variables with relatively low association between the diameter growth variables and net photosynthetic variables. Correlation coefficient (r) of photosynthetic variables gave very low values with several of the diameter growth variables; for instance photo intensity with THT gave the highest r = 0.162 and the lowest r value of -0.045 with CD. The coefficient of correlation (r) of Temperature was highest with THT; r-= 0.119 and lowest with CD with r = -0.075. Relative humidity (RH) and crown diameter had r = 0.127 while the lowest was recorded with basal area with r = -0.025 at < 0.05 level of significant. Covertly, the connection between Dbh with Photo, crown diameter (CD) with temperature, Basal area (BA) with RH where negatively correlated which implies that there is a decrease in one of the attribute with an increase to the other one. The table also shows that when a variable correlates with itself, it gives absolute value.

	DBH (cm)	BA (m^2)	CD (m^2)	C/RAD (m^2)	CPA (m^2)	THT (m^2)	LCI	CSR	PHOTO (Lux)	TEMP (^{0}C)	RH (%)
DBH (cm)	1										
BA (m^2)	0.941	1									
CD (m^2)	0.284	0.222	1								
C/RAD (m^2)	0.284	0.222	1.000	1							
CPA (m^2)	0.323	0.261	0.993	0.993	1						
THT (m^2)	0.144	0.123	0.095	0.095	0.100	1					
LCI	-0.539	0.347	0.405	0.405	0.377	0.073	1				
CSR	0.023	0.004	0.425	0.425	0.415	-0.777	0.254	1			
PHOTO(Lux)	-0.033	0.026	-0.045	-0.045	-0.039	0.162	-0.018	-0.153	1		
TEMP (^{0}C)	0.084	0.067	-0.075	-0.075	-0.064	0.119	-0.130	-0.120	0.096	1	
RH (%)	-0.015	-0.025	0.127	0.127	0.122	-0.028	0.070	0.061	0.062	-0.871	1

Table 2: Correlation Matrix Between Photosynthetic and Diameter Growth Variables of *Azadirachta Indica*

DBH- Diameter at breast height, BA- Basal area, CD- Crown diameter, C/RAD- Crown radius, CPA- Crown projection area, THT- Total height, LCI- Linear crown index, CSR- Crown spread ratio,
PHOTO- Photo intensity, Temp- Temperature, RH- Relative humidity

Table 3: Parameter Estimates of Multiple Linear Models for *Azadirachta Indica* in the Study Area

	Model	Parameter	Coefficient	R^2	S.E.E	F-value	P-value
1	Photo = b_o+ b_1DBH+b_2CD+b_3THT	b_0	3214.113	0.031	2222.106	2.209	0.088
		b_1	-566.765				
		b_2	-98.473				
		b_3	200.668				
2	Temp= b_o+ b_1DBH+b_2CD+b_3THT	b_0	34.426	0.031	3.086	2.143	0.096
		b_1	1.789				
		b_2	-0.322				
		b_3	0.187				
3	R/HUD= b_o+ b_1DBH+b_2CD+b_3THT	b_0	59.520	0.020	12.110	1.390	0.247
		b_1	-3.581				
		b_2	1.590				
		b_3	-0.219				
4	PHOTO=b_o+b_1BA+b_2CRAD+b_3CPA+b_4LCI+b_5CSR	b_0	7085.696	0.027	2238.409	1.114	0.354
		b_1	-303.748				
		b_2	-1491.184				
		b_3	80.823				

		b_4	1.749				
		b_5	-1181.452				
5	$Temp = b_o+b_1BA+b_2CRAD+b_3CPA+b_4LCI+b_5CSR$	b_0	40.453	0.028	3.108	1.183	0.319
		b_1	0.181				
		b_2	-2.469				
		b_3	0.121				
		b_4	-0.072				
		b_5	-0.924				
		b_0	52.991				
		b_1	-1.899				
6	$R/HUD=b_o+b_1BA+b_2CRAD+b_3CPA+b_4LCI+b_5$ CSR	b_2	5.874	0.019	12.174	0.796	0.554
		b_3	-0.136				
		b_4	-0.036				
		b_5	0.123				

R^2 : Coefficient of Determination, SEE: Standard of Estimation, F-Value: Significance of the Overall Regression Equation And P-Value: Probability Significance

Table 4: Parameter Estimates of Single Log Models for *Azadirachta Indica*

	Model	Parameter	Coefficient	R^2	S.E.E	F-value	P-value
		b_0	4.079				
1	$InPhoto = b_o+ b_1DBH+b_2CD+b_3THT$	b_1	-0.047	0.016	0.186	1.074	0.361
		b_2	0.022				
		b_3	-0.002				
		b_0	3.540				
2	$InTemp = b_o+ b_1DBH+b_2CD+b_3THT$	b_1	0.053	0.032	0.088	2.284	0.080
		b_2	-0.010				
		b_3	0.005				
		b_0	4.079				
3	$InR/HUD = b_o+ b_1DBH+b_2CD+b_3THT$	b_1	-0.047				
		b_2	0.022	0.016	0.186	1.074	0.361
		b_3	-0.002				
4	$InPhoto = b_o+ b_1InTHT$	b_0	7.355	0.025	0.623	5.200	0.024
		b_1	0.366				
5	$InTemp = b_o+ b_1InTHT$	b_0	3.470	0.010	0.089	2.145	0.145
		b_1	0.034				
6	$InR/HUD = b_o+ b_1InTHT$	b_0	4.195	0.000	0.187	0.022	0.883
		b_1	-0.007				

R^2 : Coefficient of Determination, SEE: Standard of Estimation, F-Value: Significance of the Overall Regression Equation And P-Value: Probability Significance

Table 5: Parameter Estimate of Double Log for *Azadirachta Indica*

	Model	Parameter	Coefficient	R^2	S.E.E	F-value	P-value
		b_0	7.824				
1	$InPhoto = b_o+ b1InCPA+b2InLCI+b_3InCSR$	b_1	0.080				
		b_2	-0.026	0.029	0.625	2.024	0.112
		b_3	-0.375				
		b_0	3.633				
2	$InTemp = b_o+ b1InCPA+b2InLCI+b_3InCSR$	b_1	0.002				
		b_2	-0.038	0.030	0.889	2.110	0.100
		b_3	-0.032				
		b_0	4.957				
3	$InR/HUD = b_o+ b1InCPA+b2InLCI+b_3InCSR$	b_1	0.050				
		b_2	0.020	0.014	0.186	0.980	0.403
		b_3	0.011				
4	$InPhoto = b_o+ b_1 DBHTHT$	b_0	8.049	0.003	0.622	0.622	0.431
		b_1	0.017				
5	$InPhoto= b_o+ b_1CDTHT$	b_0	7.936	0.007	0.628	1.471	0.227
		b_1	0.003				
6	$InTemp = b_o+ b_1 DBHTHT$	b_0	3.521	0.016	0.089	3.369	0.068
		b_1	0.006				
7	$InTemp= b_o+ b_1CDTHT$	b_0	3.522	0.004	0.089	0.736	0.392
		b_1	0.000				
8	$InR/HUD= b_o+ b_1 DBHTHT$	b_0	4.188	0.001	0.816	0.147	0.702
		b_1	-0.002				
9	$InR/HUD= b_o+ b_1 CDTHT$	b_0	4.156	0.002	0.186	0.367	0.545
		b_1	0.000				

R^2 : Coefficient of Determination, SEE: Standard of Estimation, F-Value: Significance of the Overall Regression Equation And P-Value: Probability Significance

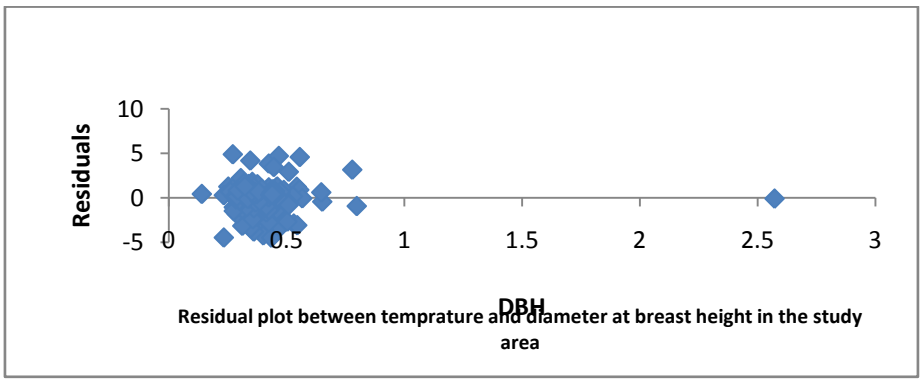
Relationship Between Model and their Parameters

The relationship between photo intensity, temperature, light as dependent variable and other independent variable show significant relationship with low values of coefficient of determination (R^2) and in F-value in the table below. Importantly, to produce a best fit model the coefficient of determination has to be high, the standard error of estimation has to be low, F-value has to be high and the P-value has to be low. But from the table above shows that temperature has a high relationship with the other growth variable but with low values in the different categories:

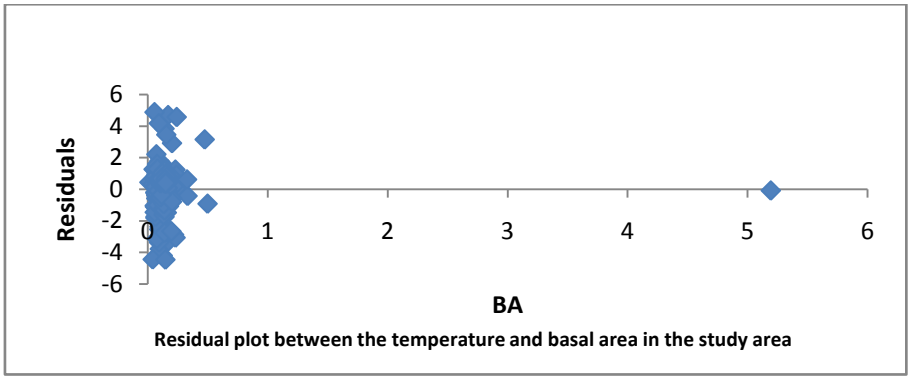
Temperature=$b_0+b_1THT+b_2CD+B_3DBH$

Ln Temperature =b0+b1Dbh +b3 THT

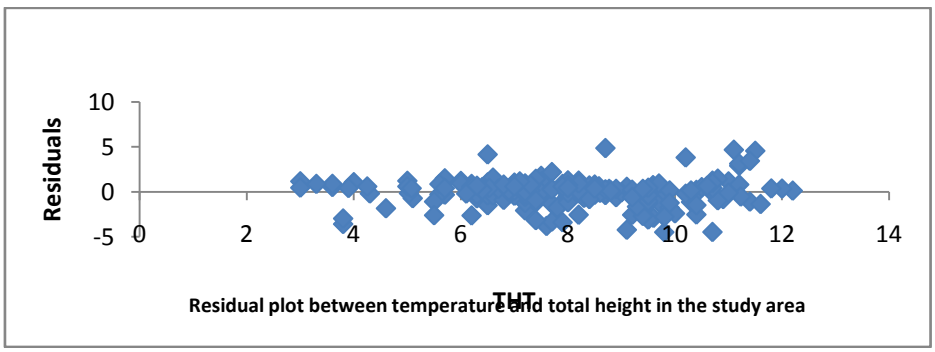
Ln Temperature = b0+b1lnCPA+ InLCI + In CSR



Residual plot between temprature and diameter at breast height in the study area



Residual plot between the temperature and basal area in the study area



Residual plot between temperature and total height in the study area

Fig.2: Residual plots between temperature and growth attributes of *Azadiratha indica* in the study area

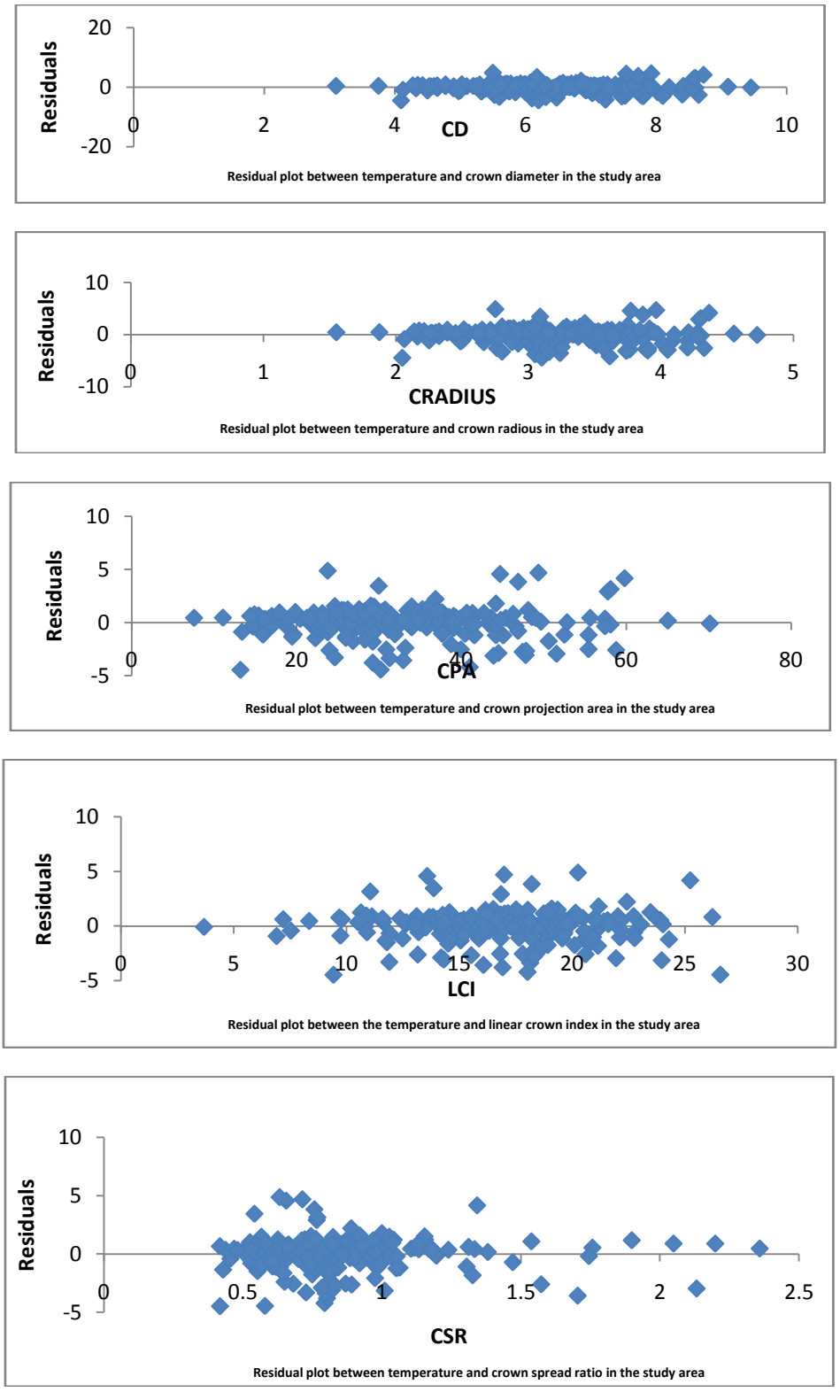


Fig. 3: Residual plots between temperature and crown attributes of *Azadiratha indica* in the study area

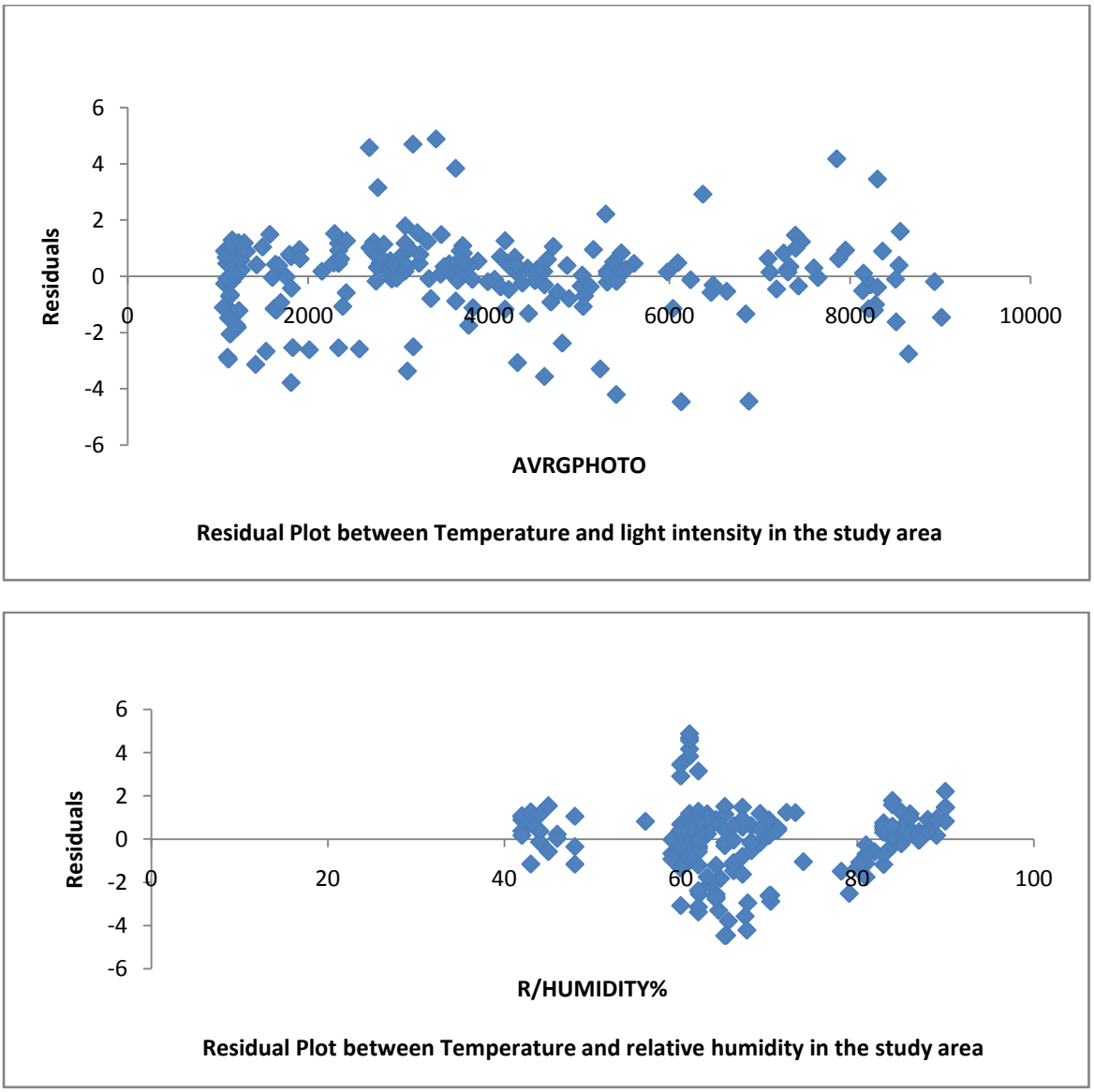


Fig.4: Residual plots between temperature and photosynthetic variables of *Azadiratha indica* in the study area

IV. Discussion

Diameter Growth and Photosynthetic Variables

This study provided information on the relationship between growth diameter and photosynthetic variables of *Azadirachta indica*. Diameter growth of the crown projection area has a high mean value of 33.201 ± 11.233, followed by linear crown index with a mean value of 16.871 ± 3.756, while that of basal area has a lower mean value of 0.149 ± 0.356 followed by diameter at breast height with a mean value of 0.401 ± 0.173. The tree total height of the stand has a mean value of 7.987m which tends to indicate that the tree height influence the crown spread ratio and crown radius, therefore the crown projection area has a relatively high mean value than the crown diameter which means that the crown diameter decreases while the crown projection area increases indicating that there is a corresponding influence on crown ratio. The results of the photosynthetic attributes namely photo intensity has a mean value of 3958.960 ± 22441.482, relative humidity has a mean value of 66.524 ± 12.14, and temperature has a mean value of 34.573 ± 3.115 which indicates that the higher the light intensity the lower the temperature and the higher the relative intensity in the avenue trees.

Relationship between Diameter Growth and Photosynthetic Variables

The results on correlation analysis indicated association between the diameter growth and the photosynthetic variables. The shows that when some diameter growth values correlate with themselves they tend to have a significant value, but when it associated with other attributes like photosynthetic variables the value reduces in the range of significance. This might be evidence of lower association between the diameter growth

variables and the photosynthetic variables. For instance, the correlation coefficient between photo intensity and total height gave fairly significant with the r –value = 0.162 at 0.05 level of significant. Though this is positive, the association between the majority of the growth variables and photosynthetic attributes were either low or negatively correlate which was indication of increase in one and at the decreasing pattern of others. Similarly, the regression analysis is a set of statistical processes for estimating relationship among variables, when the focus is on the relationship between a dependent variable and one or more independent variables ([15], [16]). The result of the regression analysis shows that the temperature double log models across the three categories of models the data were fitted into had the best fit for the relationship between growth diameter and representative model of the photosynthetic variables that was evaluated. The implication of this would mean that temperature models across the different models that developed could give a fair prediction or be said to give a good best fit model when used for any modeling prediction. This may be indicative of providing ecophysiological meaning for certain threshold of temperature and light intensity prediction relating to PAR or photosynthetic active radiation ([10]; [5]).

V. Conclusion

The study revealed that out of the 21models that was developed in 3 different categories, one model was found to be best fitted. The best model is temperature, in each of the categories respectively. Thus it can be seen to produce a fair prediction or forecast if is going to be use to determine future prediction about the trend of diameter growth in *Azadirachata indica*. And also based on the result of the research we can clearly see the reason while student can freely walk under the *Azadirachta indica* planted as an avenue tress in the study area which was clearly state that the higher the light intensity the lower the temperature and the higher the relative intensity in the avenue trees. Furthermore study should be done based on the relationship between other photosynthetic variables like Oxygen, Co_2, and gas exchange that could lead to more rigorous investigative study on net photosynthetic variables of *Azadirachta indica* with its growth diameter attributes in the study area.

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