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TREE SPECIES COMPOSITION AND BIOMASS ALLOMETRIC EQUATION IN ERUKOT FOREST OF THE CROSS RIVER NATIONAL PARK, NIGERIA

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Abstract

This research was carried out to develop allometric model for estimating aboveground individual tree Biomass in Erukot Forest of Oban Division, Cross River National Park, Nigeria. Simple random sampling was used with sampling intensity of 0.3% to lay 15 nested plots (7mx7m, 25mx25m and 35mx35m). A total of 872 individual trees were identified and measured for diameter at breast height and total height (dbh ≥ 5cm). SPSS Software Version 2.0 was used for data analysis. The 872 individual tree species spread across 51 species belonging to 25 different tree families. Apocynaceae family shows dominance with a total of 92 trees spread across 8 species. This was closely followed by Irviginaceae and Ephorbiaceae families with 85 and 80 trees spread across 5 individual tree species. Diameter at breast height, total height and specific density of each wood species were used to determine aboveground biomass for each tree. The mean diameter at breast height and total height of 38.5cm and 12.5m were obtained. Mean basal area of 39.8 $m^2 ha^{-1}$ was obtained with a mean volume of 177.3 $m^3 ha^{-1}$. The data generated for this study was divided into two sets; 70% for model formulation and 30% for model validation. Bias percentage and Student's T-test were used for model validation. The individual tree biomass model developed for the forest showed that basal area is significantly related to tree biomass (R^2 = 99%). The actual and predicted biomass values were not significantly different (Paired T-test at $p < 0.05$). Estimated bias of 0.10% for selected biomass model means that the developed model can be used to predict the aboveground tree biomass in the study area without any adjustment. The research has provided an easy to use regression model for determining tree aboveground biomass. The fitted model will be very useful for carbon trade and assessment of carbon-dioxide emissions in the study area.

Keywords: Aboveground biomass, Dry biomass, Stand volume, Tropical rainforest and Reserve.

1.0 Introduction

Biodiversity is a marker that allows the understanding of links between the richness and the abundance of individuals' trees which reflects the degree of heterogeneity or stability of vegetation (Ifo et al, 2016). Nigerian forest contains thousands of plant and animal species and is home to many culturally diverse indigenous people (Aigbe *et al.,* 2014). Tropical regions forests account for about 52% of the total global forest, and they are known to be the most important areas in terms of biodiversity (Anbarashan and Parthasarathy, 2013). The land area identified as forest lands has been declining progressively due to the industrial and social development which competes for the same pieces of land upon which the forest stands (Alamu and Agbeja, 2011).

Carbon management is a serious concern confronting the world today. Since the beginning of the industrial revolution, carbon dioxide (CO_2) concentration in the atmosphere has been rising alarmingly; ranging from 270ppm prior to the industrial revolution to about 394ppm in December, 2012 (UNFCCC (2018). Furthermore, human activities cause climate change and this often happens when we send gases in greater quantity than required into the atmosphere through activities like cutting down forest, bush burning, manufacturing, driving and use of some household equipment. These gases are many and together they are 'green-house gases. The most dangerous of them all is carbon; and when so much of it is released through these various human activities into the atmosphere, it interacts with the sun and increases the earth's temperature to create 'global warming'. Climate change worsens as the earth's temperature increases (U UNFCCC (2018).

Globally, carbon sequestration plays a pivotal role in climate change mitigation strategies. According to the Intergovernmental Panel on Climate Change (IPCC), achieving net-zero emissions by mid-century is essential for limiting global warming to 1.5°C above pre-industrial levels (IPCC, 2018). Natural carbon sinks such as forests, oceans and soils absorb approximately 30% of anthropogenic CO_2 emissions annually (Le-Quéré *et al.,* 2018). Improving on these natural systems through reforestation and sustainable land management practices can significantly increase their capacity to sequester carbon.

2.0 METHODOLOGY

2.1 Study Area

The study was carried out in Oban East, Erukot forest of Oban Division of the Cross River National Park (CRNP). The Cross River National Park (CRNP) lies between latitudes 5^0 05'and 6^0 29'N and longitudes 8^0 15' and 9^0 30'E in Cross River State, Southeastern Nigeria (Figure 1). The Cross River National Park was created by a Federal decree in 1991, consolidating the existing Oban and Boshi-Okwangwo Forest Reserves which are some of the richest areas of tropical rainforest in West Africa. The Park covers 4000km^2 and is segmented into two non-contiguous Divisions -the Oban Division in the South covering 3000 km^2 which is ecologically contiguous with Korup National Park in the Republic of Cameroon and Okwangwo Division in the North covering 1000km^2 and is ecologically contiguous with Takamanda Forest Reserve also in the Republic of Cameroon (Uwem, 2004). The park has a tropical climate characterized by a rainy season between April and October and a dry season between November and April. The annual rainfall ranges between 2000 m to 3000m; relative humidity in and around the park is well over 30%. The temperature rarely falls below 19°C with an annual mean of 27°C.The moist green vegetation cover makes the forest an excellent place to view birds and butterflies (Eniang, 2001).

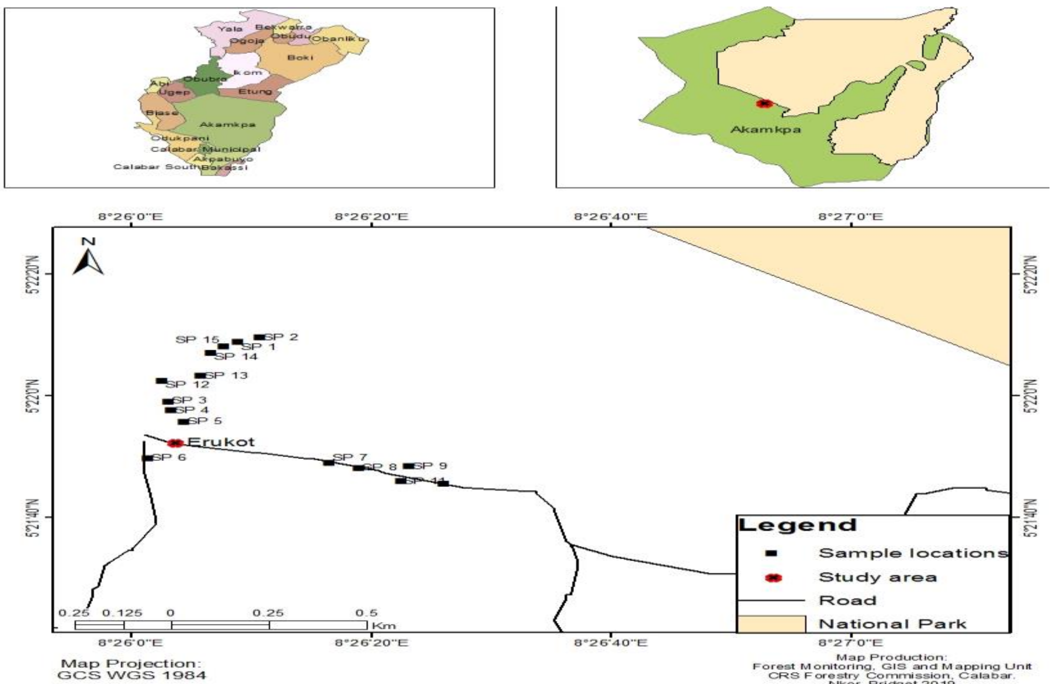

Figure1.0: Map of Erukot, Cross River National Park showing the various Sample Plots

2.2 Sampling Technique

At first, the geo-position of the forest was determined using GPS (Global Positioning System) – appendix 3.

2.3 Sampling Intensity (Number of Plots)

The number of plots sampled in the study area was determined based on the targeted level of precision, preliminary field data. The estimate of mean and the variance of a population or subdivision within a stratum are independent of the number of sampling units that was used. Therefore, both parameters were estimated from relatively few sampling units measured in a pilot survey (Avery and Burhart, 2002). Ratio of confidence interval to the mean was used to determine sampling intensity:

$$n = \left(t\ X\ \frac{cv}{E}\right)^2 \qquad \text{eq. 1}$$

$$CV = \frac{s}{\bar{x}} \times \frac{100}{1} \qquad \text{eq. 2}$$

$$n = t^2 \times \frac{s^2}{E^2\,\bar{x}} \qquad \text{eq.3}$$

where n= number of sample plots required

CV = coefficient of variation, t= t-value (n-1) degree of freedom

E = allowable margin of error (ratio of confidence interval to the mean =10%)

S = standard deviation

$\bar{X}$ = mean

2.4 Allocation of DBH to Nested Plots

In this study, a simple random sampling technique was used to lay 15 sample (35m x 35m) plots. Three nested plots were established within each sample (35m x 35m, 25m x 25m and 7mx7m as large, middle and small nest plots respectively) - see Table 1 and Figure 2 (Ajayi and Adie, 2018).

2.4.1 Data Collection

Tree diameters measured in each nest were:

i. Trees with DBH 50cm and above were measured in the large (35mx35m) nest.
ii. Trees with DBH 20-49cm were measured in the medium (25m x 25m) nest
iii. Trees with DBH 5cm-19cm were measured in the small (7mx7m) nest.
iv. Dead wood standing was measured in the large (35mx35m) nest
v. Dead woods lying were measured in the large (35mx35m) nest - see appendices 4 & 5

Table 1: Allocation of DBH Ranges to the Nested Plots

Nest Size	Dimension (m) (slope >10%)	Area (m^2)	DBH range (cm)	Vegetation type
Large nest	35m x 35m	1225	> 50	Trees >50cm
Medium	25m x 25m	625	30-49	Trees = 20-49cm dbh
				Bamboo >5cmdbh
Small	7m x 7m	49	5-29	Trees = 5-19cm dbh
				Lianas = >5cm dbh

Dbh = Diameter at Breast Height

Large plot =35mx35m

Trees >50cm DBH

Intermediate plot =25mx25m

Trees =30cm-49cm DBH

Small plot=7mx7m

Trees- 10cm-29cm DBH

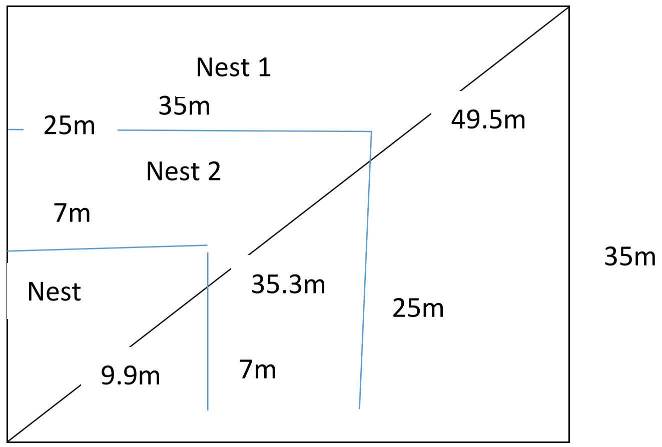

Figure 2: Schematic Diagram of Three-nest 35mx35m Square Sample Plots

2.5 Data Collection

Diameter tape and Sunto clinometer were used for tree diameter and height measurements respectively. Diameter at breast height and height were measured for all trees across plots while density of each of the tree measured was determined from the default values of the Pan tropical table (Chudoff, 1984) and wood density for tropical tree species (Gisel *et al*, 1992). The obtained values were used to estimate the biomass of each tree within the sample plots in the tropical high forest (Bassey *et. al.*, 2022).

3.0 Data Analysis

3.1 Basal Area Estimation

The diameter at breast height was used to calculate the basal area.

Basal Area $(BA) = \frac{\pi D^2}{4}$ eq.4

where: D = diameter at breast height (cm)

π = 3.142

BA = Basal Area.

3.2 Volume Estimation

Individual tree volume was estimated using the regression model below:

$LnV = -8.2525 + 2.209LnD$ (Ajayi and Obi, 2016) eq.5

Where, V= Tree volume (m^3)

D= Diameter at breast height (cm)

Ln = natural log

Relative Dominance of Species

Relative dominance = $\frac{total\ basal\ area\ of\ a\ species}{total\ basal\ area\ of\ all\ species}\ x\ 100$ eq.6

3.4 Aboveground Biomass Estimation for Single Live/Dead Tree

$AGB = 0.0673 \times (P \times D^2 \times H) \times 0.976$ eq. 7

where AGB= aboveground biomass (kg)

P = species specific wood density (g/cm^3),

D= diameter at breast height (cm), H= tree height (m) (Stanley and Ajayi, S. 2024).

3.5 Aboveground Live Green Biomass Estimation per Hectare

The summation of the biomass calculated for all trees in a sample produced the total plot biomass (AGBplot). This per plot estimate of aboveground (in kg) was divided by 1000 to express it in metric tons. This was then converted to per hectare estimate (AGBha) by using the equation

$AGBper\ ha = \left(\frac{Ah}{Ap}\right) \times AGBplot$ eq. 8

where: AGBha= aboveground biomass (metric tons per hectare)

Ah= area of one hectare in m^2

Ap= area of the plot (m^2) (Stanley and Ajayi, S. 2024).

3.6 Aboveground Dry Biomass Estimation

Aboveground dry biomass estimation was calculated from:

$W = \frac{AGBh \times 0.725}{1000}$ eq.9

where W= aboveground dry biomass (metric tons)

AGB_h = aboveground green biomass (kg ha^{-1}) (Stanley and Ajayi, S. 2024).

3.7 Determination of Carbon Sequestration

$$Sc = W \times 0.5 \qquad \text{eq.10}$$

where; Sc = sequestered carbon (tha^{-1})

W= aboveground dry biomass ($t\ ha^{-1}$) (Stanley and Ajayi, S. 2024).

3.8 Aboveground Tree Model Formulation

The data was divided into two groups in the ratio of 70% and 30% respectively.

In this study, Models for individual tree biomass equations were of the form:

i. $Y = bo + b_1 BA$ Mod. 1
ii. $Logy = b_o + b_1 BA$ Mod. 2
iii. $Logy = b_0 + b_1 D$ Mod. 3
iv. $Logy = b_o + b_1 logD$ Mod. 4
v. $Y = b_o + b_1 BA^{-1}$ Mod. 5
vi. $Logy = b_o + b_1 D^{-1}$ Mod. 6
vii. $Ln = b_o + b_1 LnD$ Mod. 7
viii. $Logy = b_o + b_1 logBA$ Mod. 8

where; D = diameter at breast height (cm)

BA = Basal Area (m^2)

3.9 Criteria for Model Selection

The selection of the best biomass models was based on:

i. Significant variance ratio (F) at 5% probability level
ii. A goodness of fit with highest coefficient of determination (R^2)
iii. Least Root Mean Square (RMSE)
iv. High Durbin Watson value.

3.10 Validation of Selected Models

Paired T-test and test of bias were carried out to validate the formulated model,

$$t = \frac{\bar{D}}{SD/\sqrt{n}} \qquad \text{eq.11}$$

where: T= t-statistics

$\bar{D}$= mean of the difference between pairs (ton)

SD= standard deviation of the difference between pairs (ton)

n= number of paired observation (degree of freedom is n-1)

$$Bias = \frac{\sum residual}{\sum Actual\ observation} \times \frac{100}{1} \quad \text{eq.12}$$

Data generated were analyzed using SPSS version 20 on windows 2.0.

4.0 Results

4.1 Parameters of Aboveground Tree Biomass in Erukot Forest of Oban Division, Cross River National Park, Cross River State, Nigeria

The result presented in Table 2 indicated that a total of 872 individual tree species were measured for both diameters at breast height (DBH) and total height. An average dbh of 38.7cm and average total height of 12.52cm were obtained while mean basal area was $39.80m^2ha^{-1}$ with a mean volume of 177.26 $m^3\ ha^{-1}$.

Table 2: Parameters of Aboveground Tree Biomass in Erukot Forest of Oban Division, Cross River National Park, Cross River State, Nigeria

S/N	Parameters	Summary	Min.	Max.	Std. Error	Std. Deviation	Skewness	Kurtosis
1	No. of sample plots measured	15	-	-	-	-	-	-
2	No of trees measured	872	-	-	-	-	-	-
3	Average DBH (cm)	38.47	1.00	250.00	0.7883	23.277	4.475	30.33
4	Average height	12.52	0.40	105.20	0.2368	6.699	8.172	90.34
5	Mean basal area ha^{-1}	39.8000	22.95	49.20	1.916	7.42	-.789	.201
6	Mean volume ha^{-1}	77.2647	0.00	225.10	18.99	73.56	-2.203	3.720
7	Sampling intensity	0.3%	-	-	-	-	-	-

4.2 Identified Tree Species and their Families in the Erukot, Forest Cross River National Park, Cross River State, Nigeria

The result in Table 3 showed the list of individual tree species identified and their families in the study area; it has a wide range of tree species. A total of 872 individual trees spreading across 51 tree species and belonging to 25 different tree families were identified. Apocynaceae family shows dominance with a total of 92 trees from 8 species. This was closely followed by Irviginaceae and Euphorbiaceae families with 85 and 80 from 5 tree species respectively. Capparaceae, and celsalpiniodeae families have 4 tree species each, followed by Burseraceae with 3 individual tree species. However, Ebeneceae, Leguminaceae, Fabaceae and Moraceae have two species each while, Rutaceae, Annacardaceae, Anisophylleaceae, Bogaraceae, Palmea, Tiliceae, Sterculiaceae and Guttiferae, Cluciaceae, Lecythidaceae, Mysticaceae, Samydaceae, Compretaceae and Passifloraceae have 1 tree species each.

Table 3: Identified Tree Species and their Families in the Erukot Forest of the Cross River National Park, Cross River State, Nigeria

S/N	Family	Species	No. of Species	No. of Individual	No. of Family
1.	Apocynaceae	*1. Funtumia elastic*		31	
		2. Distemonanthus Benthamianus		17	
		3. Tabernaemontana Pachysiphon		19	92
		4. Alstonia boonie		4	
		5. Alstonia macrophylla		2	
		6. Carapa procera		6	
		7. Gossweilerodendron Balsamiferum		12	
		8. Trichoscypha arborea	8	4	
2	Capparaceae	1. *Drypetes spp*		27	
		2. Drypetes flouribunda		4	
		3. Drypetes dipters		6	43
		4. Mitragyra ciliate	*4*	6	
3.	Ebeneceae	1. *Diospyros spp*		61	77
		2. Diospyrose mespiliformis	*2*	16	
4	Rutaceae	1. *Zanthozylum guileti*		28	28

5.	Euphorbiaceae	1. *Maesobotrya sp*		10	
		2. *Maesobotrya barteri*		42	
		3. *Uapaca staudti*		15	80
		4. *Mitrigyna cyliata*		12	
		5. *Uapaca guineense*	5	1	
6.	Leguminaceae	1. *Parkia bicolor*	2	7	32
		2. *Dialum guineense*		29	
7.	Buseraceae	1. *Dacryodes edulis*		35	
		2. *Canarium spp*		5	90
		3. *Baphia nitida*	3	46	
8	Annacardaceae	1. *Trichoscypha arborea*	1	11	11
9	Anisophylleaceae	1. *Anisophyllea purperum*	1	16	16
10	Bogaraceae	1. *Bridelia macrantha*	1	22	21
11	Palmae	1. *Raphia spp*	1	50	50
12	Tiliceae	1. *Grewia mollis*	1	21	21
13	Celsalpiniodeae	1. *Hylodendron gabonense*		8	
		2. *Symphonia globulifera*		1	
		3. *Canthium subeordatum*		4	18
		4. *Canthium spp*	4	5	
14	Sterculiaceae	1. *Cola edulis*	1	72	72
15	Guttiferae	1.*Harungana madagascariensis*	1	4	4
16	Fabaceae	1. *Pterigota macrocarpa*	2	5	8
		2. *Pterygota nigerana*		3	
17	Irvinginaceae	1. *Xylopia virosa*		6	
		2. *Klainedoxa gabonensis*		30	
		3. *Irvingia gabonensis*		9	
		4. *Hylodendron gabonense*		28	
		5. *Xylopia ethiopica*	5	12	85
18	Annonaceae	1. *Cleistopholis patens*	1	20	20
19	Moraceae	1. *Musanga circropiodes*	2	25	42
		2. *Steculia oblonga*		17	
20	Cluciaceae	1. *Alablankia flouribunda*	1	2	2
21	Lecythidaceae	1. *Combretodendron Microcarpa*	1	3	3
22	Mysticaceae	1. *Staudtia stipitata*	2	5	25
		2. *pycanthus angolensis*		20	
23	Samydaceae	1. *Homalium letestui*	1	12	12
24	Compretaceae	1. *Terminalia spp*	1	8	8
25	Passifloraceae	1. *Barteria nigritana*	1	7	7
Total	25		51	872	872

4.3 General Models Developed for Individual Biomass Estimation

The results in Table 4 presented a linear regression analysis used in developing allometric models for estimating individual tree biomass using only tree DBH, basal area and their logarithmic transformations as predictor variables. The result also showed the regression constants and coefficients, R^2, Root Mean Square Error (RMSE), F-ratio and Durbin Watson for logarithmic, non-logarithmic and inverse of logarithm expressions of the dependable variable in the study area. Model one was judged and selected because it has the highest F-ratio value (40225.132), lowest RMSE and highest (0.072) Durbin Watson value (1.663) with R^2 value of (99%). Ranked very closely were models 4 and 7 with the same R^2 values of 93 % and the same F-ratio values of 4652. 891. Model 4 can be ranked second because it has 0.00 MSE.

Table 4: General models Developed for Biomass Individual Biomass Estimation in Erukot Forest, Cross River National Park, Cross River State, Nigeria

Mode	Dep. Vari.	Reg. Constant	Reg. Coefficient	R^2 %	F-ratio	RMSE	Durbin Watson	Remark
i.	Y	0.045	0.350BA	99	402.13	0.072	1.663	Selected
ii.	Logy	-1.675	0.024BA	1	24.509	0.569	21.247	unsuitable
iii.	Logy	-1. 844	0.498D	23	113.19	0.467	1.266	unsuitable
iv.	Logy	-0.316	2. 323LogD	93	465.81	0.00	1.213	Suitable
v.	Y	0.240	$-3.329E-0.5BA^{-1}$	00	0.055	7.713	2.005	unsuitable
vi.	Logy	-1.369	$-0.058D^{-1}$	41	261.91	0.358	1.372	unsuitable
vii.	LnY	-727	2.323lnD	93	465.89	0.242	1.213	Suitable
viii.	Logy	-194	1.161logBA	93	460.91	0.46	1.213	Suitable

Y = 0.045 + 0.350BA

T-calculated = 0.319, T-tabulated = 1.645

Residual mean=0.010504. Bias = 1.25/9.36 x100 therefore, Bias= 13%

5.0 Discussion

The Erukot Forest of the Cross River National Park showed high species abundance with a mean volume per hectare of $177.2647m^3h^{-1}$. This volume is slightly below the report forwarded by Ajayi and Adie, (2018) ($212.588m^3h^{-1}$), which is greatly below the volume of $250m^3h^{a-1}$

recommended by Dianyuan Han (2012) for a normal tropical high forest. This therefore reflects high level of encroachment into the park. Thus, efforts should be made to control and reduce encroachment level through good management approach such as integrated management system and anti-poaching patrol. Mean basal area was 38.8000$m^{2/}h^{-1}$, this agrees with findings made by Ajayi, and Adie (2018) (38.5 m^2h^{-1}) in Okpon Forest Reserve, Cross River State, while mean dbh and height were determined to be 38.47cm and 12.52m respectively.

Most studies have recommended the use of models where tree biomass is determined from DBH as the only predictor variable because it has practical measurement advantage over other growth variables (Innocent, 2014). It was stated by Segura and Kannien (2005) that DBH is easy to measure accurately in the field. The individual tree biomass assessment, model one (Y = 0.045 + 0.350BA) was judged suitable and selected because it has the highest F-ratio value (40225.132), lowest RMSE and highest (0.072) Durbin Watson value (1.663) with R^2 value of (99%) as stated by (Ajayi and Adie, 2018). This high R^2 value (R^2= 99%) agrees with the findings of Kridiborworm *et. al,* 2012, who stated that the main parameter that is usually used in defining the relationship is biomass and DBH. Bragg (2011) also stated that the estimate of carbon stock in any forest is based on allometric equation relating either carbon or biomass to diameter at breast height (DBH). Diameter at breast height was the main explanatory tree variable used to estimate the tree biomass components for all species. Several authors have noted that inclusion of total height does not usually lead to a substantial increase in the predictive ability of diameter-based biomass regressions, and they also assume that diameter is sufficient to yield a reliable tree biomass prediction (Porté, 2002; Jenkins *et al.,* 2003). However, other authors have found a significant improvement in model fits (Bartelink, 1996) or an increase in the accuracy of the biomass estimates when dbh is also used as a predictor (Johansson, 1996). The selected individual tree aboveground model recorded a non-significant difference (P>0.05) with the actual biomass computed from the field; hence, the model is defined to be fit for individual aboveground biomass in the study area as reported by Ajayi and Adie (2018). The percentage bias for the selected model was 13% which agrees with the findings of Adekunle (2002) that the percentage bias as low as 30% is an indication of good fit model. Therefore, the individual selected model can conveniently be used to predict individual aboveground tree biomass in the study area. This is based on the facts that, the higher the regression coefficient, the better the reliability and accuracy of the model (Innocent, 2014; Ajayi and Adie, 2018).

6.0 Conclusion

Remarkable development of models remains a valuable tool on policy, monitoring and supply systems as interventions in combating the challenges of climate issues in the study area. The effectiveness of reducing emissions depends greatly on the formulation of accurate models for proper management of the forest ecosystem. Also, biomass assessment is critical to understanding the influential role of forest in global carbon stock cycle and climate change mitigation. Precise models, specific to local conditions and good quality ground data are accurate for biomass assessment. This study explored the feasibility of using models to estimate aboveground biomass in a tropical rainforest of Erukot forest of the Oban Division of Cross River National Park. Therefore, models developed in the study area for the estimation of aboveground biomass will significantly enhance the capacity to accurately estimate aboveground biomass without destructive harvest.

Recommendations

The following recommendations are made based the research outcome:

1. Encroachment level into the Park, therefore, possible integrated management approach should be put in place for the sustenance of the protected area
2. Establishment of Permanent sample plots should be encouraged in the study area to enhance and promote research work in the study area.

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