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Characterizing Measures of Aboveground Biomass Parameters of *Irvingia gaboneensis* (Bush Mango) and Rainforest in Isoko Region, Nigeria

Osokpor, Eloho [a] and Ndakara, Ofudjaye Emmanuel [a*]

[a] Department of Geography and Regional Planning, Delta State University, Abraka, Nigeria.

Authors' contributions

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

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ABSTRACT

This research characterised measures of aboveground biomass of isolated *Irvingia gaboneensis* stands within Isoko South Local Government Area's rainforest, Nigeria. The design of the study was based on quasi experimental approach. The region was divided into 10 based on the existing major communities using stratified sampling technique. From each community, an isolated *I. gaboneensis* stand was chosen while the adjacent mature rainforest served as control thus, gave a total of 20 sampling sites. Data collected were tree heights (TH) and diameters at breast height (DBH) which were easily obtained through quadrant (10metre x 10metre) approach. Measurement and methods of trigonometry were employed in the determination of TH, while measurement using tape was employed to measure the tree DBH. The data were analysed with the use of graphs, mean, standard deviation (SD), coefficient of variation (CV), t-test and regression statistics. Findings showed that: The mean, SD and CV for the TH were 28.57m, 2.08m, 7.28% for the stands of *I. gaboneensis;* and 34.50m, 1.17m, 3.39% for adjacent rainforest trees (ART). The mean, SD and CV values for tree DBH were 0.43m, 0.02m, 4.65% for the stands of *I. gaboneensis;* and 0.73m, 0.01m, 1.37% for the ART. With t-value and p-value of 6.9810 and 0.0000 for TH; 11.9940

**Corresponding author: E-mail: ndakaraoe@delsu.edu.ng;*

and 0.0000 for DBH, the differences in the aboveground biomass parameters between *I. gaboneensis* and ART are significant at 95% alpha level. Height of *I. gaboneensis* correlated weakly with DBH; while the relationship between TH and DBH is not significant at 95% alpha level, for *I. gaboneensis* and RF. The aboveground parameters of the standing *I. gaboneensis* shows that it supports effective productivity and functioning of the RF ecosystem thus, its conservation is necessary.

Keywords: Aboveground biomass; ecosystem functioning; Irvingia gaboneensis; tree diameter at breast height; tree heights.

1. INTRODUCTION

Aboveground biomass parameters of tree stands are essential in nutrient mobilisation and storage for productivity and functioning of rainforest ecosystem. Aboveground parameters of trees serve as part-ways for the transport of nutrient elements within standing trees for their growth, production and development [1]; [2]. Tree biomass attributes such as tree heights, tree girths, canopy cover, and litter production account meaningfully for the role of such tree stand and how it influences the soil underneath (Ndakara, 2012a). The levels of influence of individual tree species (TS) on the soil also vary due partly to the biomass attributes. It is therefore, important to study the biomass parameters of certain tree species such as the *Irvingia gaboneensis* which is an indigenous rainforest tree species in order to comparatively characterize them with those of other rainforest trees.

The height of trees within rainforest is an essential structural trait that is very critical in the ecological study of forest ecosystem, as well as for the important role in the estimation of aboveground biomass. Studies revealed that tree heights are not easy to ascertain in rainforest because of the dense nature and stratification of the trees contained. To achieve accuracy in the measurement of tree heights depends on several conditions such as the observer's experience and type of instrument used during measurement exercise [3], [4], [1]. However, a precise measure of tree height is an important approach for estimating carbon store in forest. Determining tree heights is necessary because trees within forest communities compete for sunlight which is a key determinant factor for trees that can flourish or be suppressed to death thus, giving ways to further plant succession [5].

One of the ecological relevance of tree height is its role as an essential indicator of forest ecosystem's fertility, productivity and suitability as habitat for organisms [1]. Tree height accounts for the health of any forest ecosystem since climate-induced activities can alter and affect growth processes. In most cases, measuring the height of trees in biodiversity and ecological studies characterizes the histories of tree species and their populations within the forest ecosystem [6], [7]. According to Ndakara [8], Englhart et al. [3], biomass determines the possible carbon emission which could be released into the atmosphere owing to deforestation, while biomass changes within forested region are associated with several important outcomes in forest ecosystem functional attributes, as well as climate change [9]. Plants biomass parameters such as tree heights and diameters at breast height absorb carbon (IV) during growth and release same during combustion thus, recycling atmospheric carbon [10].

Tree height is an important physiognomic property of vegetation which accounts for the vegetation physiognomy that represents the functional characteristics of vegetation which explains plants adaptive role for survival in existing environment [8]. With respect to nutrient cycling, tree height plays a functional role in the spread of tree litter [5], [10]. Shorter tree stands tend to concentrate their litter directly underneath the tree stands, while taller trees spread their litter due to the influence of wind before they get to the ground.

Litter production has been presented as the weight of dead materials of both plant and animal origins which reach unit area of the soil surface within a standard period of time (Chapman, 1976, [11]. Indeed, researches have reported that it is not all materials that die that fall to the ground immediately [12], [13], [1]. The production of litter by the above ground vegetation represents a major component of the net primary production, and its measurement is important whether it be in relation to primary production, or for consideration of other relationships within the ecosystem [14]; [15]; [16].

Since mineral elements are being immobilized in the biomass parameters of trees, increase in nutrients within topsoil would depend on the balance between the loss of nutrients from the topsoils, and rate of mineral element replenishment in the topsoil [17]. The nutrient elements immobilized in the standing crop of fallow vegetation make up the total nutrients which would be available to crops during the cropping period; while nutrient storage varies amongst different ecosystems.

The main objective of this research was to ecologically characterize measures of the aboveground biomass of *Irvingia gaboneensis* in the rainforest environment of Isoko region. This is with the aim of ascertaining the essential qualities and resource values of *Irvingia gaboneensis,* and comparatively analysing its attributes with those of other rainforest tree species.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted within Isoko south in Nigeria, with land area covering about 668km^2. Geographically, Isoko south is latitudinal between 5^{0}33'N and 5^{0}14'N, and longitudinal between 6^{0}04'E and 6^{0}24'E (Fig. 1). The climate is that of Af Koppen's classification, with two different air-masses that influence the regional seasons. These air-masses are the tropical maritime (MT) and tropical continental (CT) commonly called the South-West and North-East trade winds respectively [18], [19], [20]. The vegetation comprises rainforest, fresh water swamp and derived savanna landscape. Trees within the rainforest maintained the structural tier which characterizes typical rainforest.

Several species of RF trees that were seen in the RF sites include species such as *Ricinodendron heudelotii, Terminalia superba, Ceiba pentandra, Antiaris toxicaria, Triplochiton scleroxylon, Piptadenastrium africanum* and *Pentaklepta macrophylla.* Owing to the prevalent agricultural practice of shifting cultivation, most of the original forest has been destroyed and the landscape is now dominated by a mosaic of different stages of farms and succession communities [12], this has reduced the progressive status of the rainforest due to anthropogenic activities, from sustainable development level (Zhang, Devers, Desch, Justice & Townshend, 2005; [21], [22], [23]. The rainforest vegetation depends on the total annual rainfall and its distribution throughout the year. According to Ndakara [24], the rainforest is the most species diverse of any vegetation. Geologically, the environment comprises well drained mesomorphic as well as hydromorphic soils, interspersed with alluvial, levee and delta formations. At the surface, the equivalents are the Ameki and Akata formations of Eocene-Oligocene age. At the end of the Pleistocene Ice Age, the gradual rise in sea level and ground water table produced the requisite hydromorphic environment for the podzolization of the base-deficient and deeply weathered sand-rich deltaic plain alluvium deposits to form the "white sand", especially in the swamps and abandoned river floodplains, where grassland vegetation type currently predominates [20,25].

2.2 Methodology

This study ecologically characterized the aboveground biomass of isolated *Irvingia gaboneensis* stands and RF trees in Isoko region of Nigeria. The study design was quasi experimental. Through stratified sampling, the region was subdivided into 10 quarters. From each quarter, 2 sites were established in each selected community as "*Irvingia gaboneensis* site and rainforest site respectively), giving 20 sites. Data collected were TH and DBH which were easily obtained through quadrant (10metre x 10metre) approach. Measurement and methods of trigonometry were employed in the determination of TH. The TH was measured by standing some distances away from tree stands to obtain the angles of elevations of tree tops using abney level and prismatic compass (where the use of both abney level and prismatic compass was to establish a check on the readings obtained from the other instrument). The distances from the tree stands, the angles of elevation and the heights of the observer were recorded for use in determining each TH respectively. DBH of each tree was ascertained by first measuring the tree girths at breast height using girthing tape, and their results converted into diameter values by considering tree girths as circumference. For the TH and DBH within RF sites, the mean values for the trees assessed within a given site were used. Data were presented with graphs, and analysed with mean, SD and CV; while t-test was employed to test the

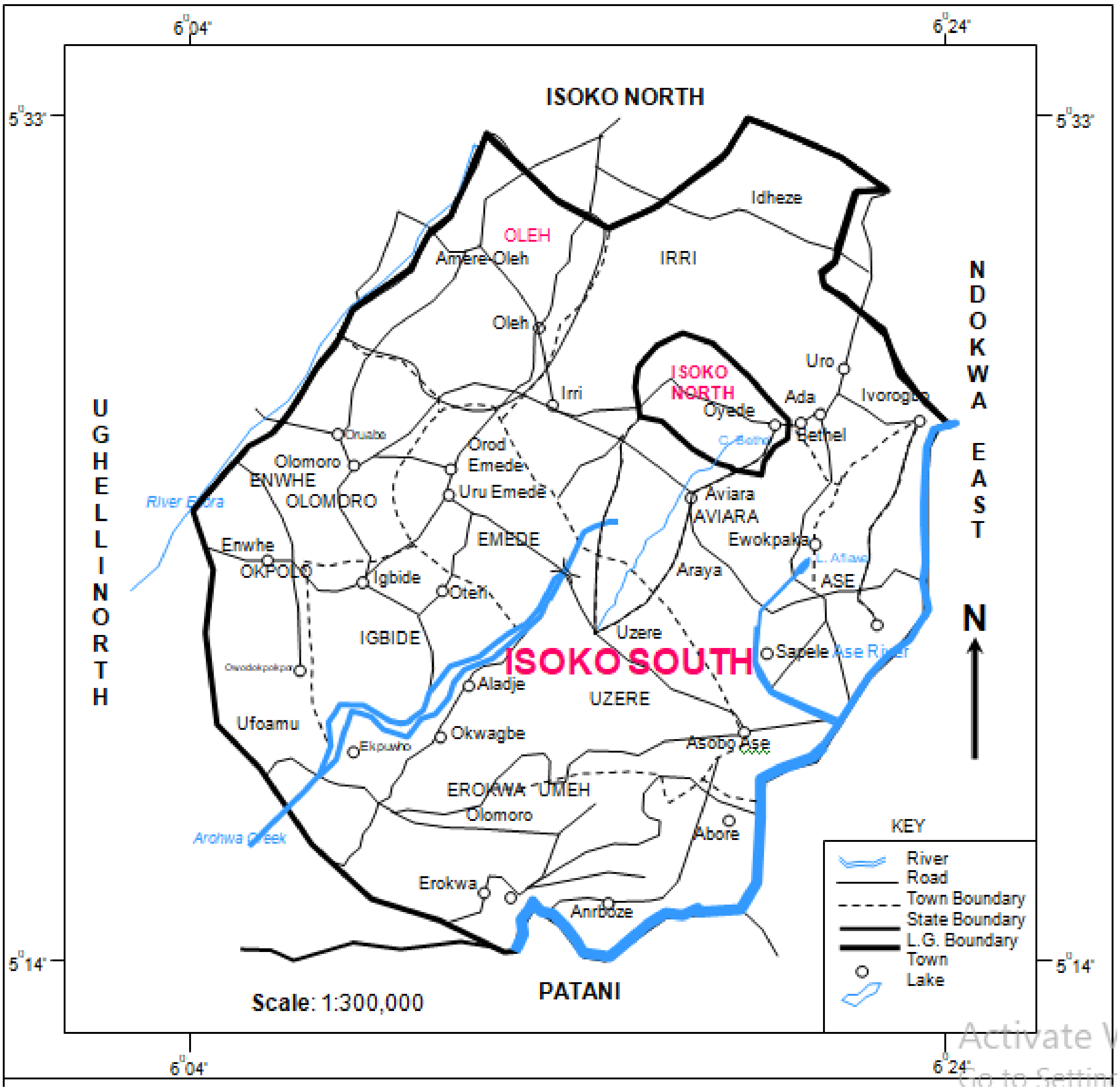

Fig. 1. Map of isoko south local Government area

Source: Ministry of Lands, Survey & Urban Development, Asaba, (2022)

difference between the aboveground biomass parameters (TH and DBH) of stands of *Irvingia gaboneensis* and the ART.

3. RESULTS AND DISCUSSION

3.1 Tree Height as Measure of Aboveground Biomass Parameters of I. Gaboneensis and ART

The heights of tree stands account for the vegetation physiognomy which represents the functional characteristics of vegetation that explains plants adaptive role for survival in existing environment [8]. With respect to soil nutrient status under trees, the height of trees plays a functional role in the spread of tree litter thus, central to the distribution of humus derived from litterfall [10]. Study by Ndakara [1] reported that shorter trees tend to concentrate their litter directly under them, while taller trees spread their litter due to the influence of wind before they could reach the ground where they could get decayed for mineralization and nutrients return to the soil.

From Table 1, the mean, standard deviation (SD) and coefficient of variation (CV) for the height of trees were 28.57m, 2.08m and 7.28% for *I. gaboneensis;* and 34.50m, 1.17m and

3.39% for RF. The values indicate that *I. gaboneensis* have lower mean height than Rf trees. The CV values showed that *I. gaboneensis* varied more in height than RF trees. This is as to be expected because the species of trees investigated with the RF were those that belong to a particular tier level since rainforest trees feature in strata. Although *I. gaboneensis* is indigenous to RF, the results about its height could probably be explained that it falls within the RF trees that range within the middle storey in the RF stratification.

Table 1. Tree heights (M) for *Irvingia gaboneesis* and rainforest control

Sample sites	*Irvingia gaboneensis* (Bush mango)	Rainforest control
1	30.87	35.10
2	31.97	34.65
3	30.22	32.02
4	28.86	34.30
5	29.12	35.02
6	27.03	33.38
7	26.76	35.81
8	25.81	34.69
9	28.86	34.04
10	26.20	36.01
Mean	28.57	34.50
SD	2.08	1.17
CV (%)	7.28	3.39

Source: Field work, 2023

From Fig. 2, the highest mean height of trees (36.01) was observed in the RF site, while the shortest tree (25.81) was observed in *I. gaboneensis.* Generally, the mean TH in each site within the RF sites was higher than TH of any *I. gaboneensis*. This shows that height as a biomass parameter, vary amongst species of RF trees since *I. gaboneensis* is also a species of RF. Expectedly, all the trees investigated in the RF may not have been taller than *I. gaboneensis.* The TH within the RF is within the observed height of trees reported within lowland rainforest by Ndakara [8].

3.2 Tree DBH as Measure of Aboveground Biomass Parameters of I. Gaboneensis and ART

The mean values for the tree DBH varied between *I. gaboneensis* and the RF.

The RF trees are larger in DBH than the *I. gaboneensis* which appeared generally smaller in all the sites. From Table 2, the mean, SD and CV values for the tree DBH were 0.43m, 0.02m and 4.65% for *I. gaboneensis;* and 0.73m, 0.01m and 1.37% for the RT. Findings revealed that *I. gaboneensis* does not posses very large trunks; whereas, other RT species examined have larger trunks within the control sites, possibly because of their morphology as reported by Ndakara, [1]. The highest mean value (79m) was recorded in the RF sites while the lowest value (37m) was recorded in the *I. gaboneensis* sites.

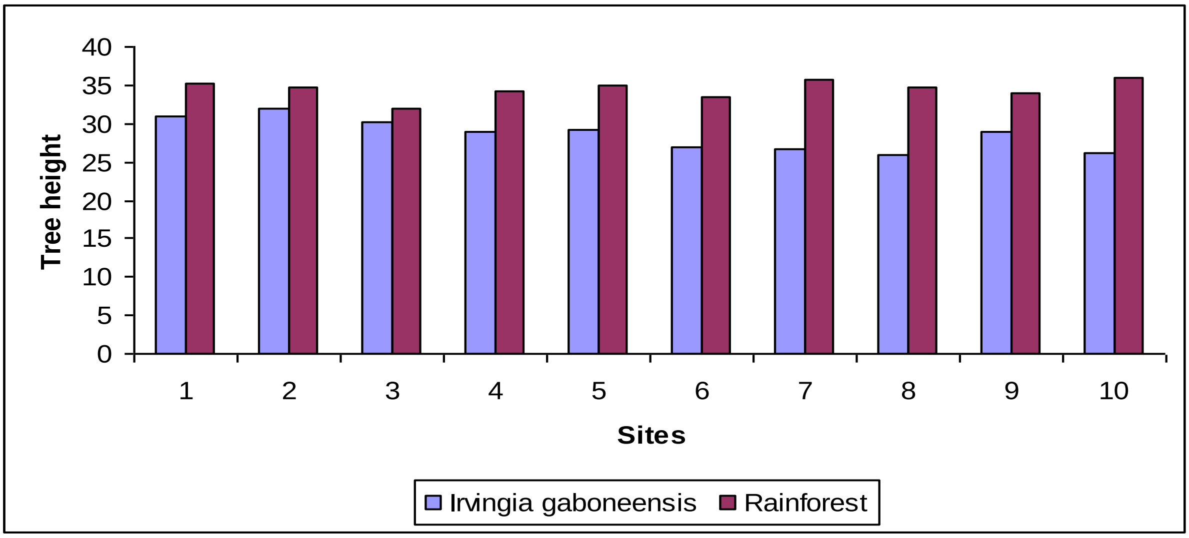

Fig. 2. Mean tree heights (M) for *Irvingia gaboneesis* and rainforest

From Fig. 3, trees within RF control sites have larger DBH than the experimental *I. gaboneensis.* Trees in the RF were bigger with respect to DBH than that of *I. gaboneensis.* This shows that, within the typical and natural rainforest, trees are bigger in terms of DBH. This is as to be expected because rainforest ecosystems have been known for the supply of timber and other valuable wood products as resources [2]. The smaller size of *I. gaboneensis* with respect to DBH accounts for its reduced ability to supply more wood resources like the other trees within the RF.

T-test statistics was used to test the difference in the measures of aboveground biomass parameters between *I. gaboneensis* and the ART at 95% alpha level.

Table 2. Tree diameters at breast height per sample site (m)

Sample sites	***Irvingia gaboneensis* (Bush mango)**	**Rainforest control**
1	0.48	0.69
2	0.44	0.74
3	0.39	0.73
4	0.37	0.78
5	0.40	0.75
6	0.47	0.79
7	0.51	0.68
8	0.42	0.78
9	0.46	0.66
10	0.37	0.69
Mean	0.43	0.73
SD	0.02	0.01
CV (%)	4.65	1.37

Source: Field work, 2023

Table 3 presents t-test results for the statistical differences in the measures of aboveground biomass between *I. gaboneensis* and ART. With t-value and p-value of 6.9810 and 0.0000 for TH; 11.9940 and 0.0000 for DBH, the differences in the aboveground biomass parameters between *I. gaboneensis* and ART are significant at 95% alpha level. This confirms that there is a significant difference between the measures of aboveground biomass parameters (TH and DBH) of stands of *I. gaboneensis* and ART. Although, *Irvingia gaboneensis* is an indigenous tree of the RF origin, its height and DBH are less that that of the rainforest species that were investigated in this study. This finding is similar to results reported by Ndakara [8] where trees within mature rainforest showed high TH and DBH; while Ndakara [1] showed that the biomass parameters of trees were higher in the mature RF than those of exotic trees.

3.3 Relationship Between TH and DBH in *I. gaboneensis* and RF Trees

Since aboveground biomass of standing trees contribute to soil nutrient elements and soil productivities, the assessment of the measures of biomass parameters and the possible relationship and level of correlation that exist between sets of the measures of the biomass parameters will make it easy to understand the essential usefulness of trees within RF environment. Certain trees are capable of growing tall without corresponding increase in their girth thus, bearing smaller DBH. Such trees tend to spread their litter far away from their base, thereby reducing the level of nutrient input to the soil (Londe, et al., [11]. With respect to resource importance of such trees, they are capable of supplying required length of trees than shorter trees. Conversely, shorter trees with increased DBH tend to concentrate litter directly underneath tree stands thus, directly contributing to soil nutrients and productivity.

Table 4 presents the regression output for the relationship and correlation between TH and DBH of *I. gaboneensis* stands. The regression values showed that the relationship between TH and DBH are not significant at 95% alpha level.

Table 3. Paired Samples T-Test Output for the differences in measures of aboveground biomass parameters between Stands of *Irvingia gaboneensis* and ART

Measures of Aboveground Biomass Parameters	Paired Samples	Paired S.E.M	Paired Differences (95% Confidence Interval)		t-value	df	Sig. (2-tailed)
			Lower Differences	Upper Differences			
Tree Height	*I. gaboneensis* Rainforest	0.8497	7.8542	4.0098	6.9810	9	0.0000
Diameter at Breast Height	*I. gaboneensis* Rainforest	0.0249	0.3542	0.2418	11.9940	9	0.0000

TH correlated weakly with tree DBH. This implies that the height of *I. gaboneensis* does not totally determine its DBH. It is possible for shorter stands of *I. gaboneensis* to be smaller in DBH than several taller stands. Therefore, the extent to which *I. gaboneensis* grow tall does not necessarily influence the ability of the trees to increase in DBH, but a function of several other functions which include soil nutrient status capacity to support the growth and productivity of trees within the ecosystem. This result is in line with findings reported by Kazumichi, et al. [16]

Table 5 presents the regression output for the relationship and correlation between TH and DBH of rainforest tree stands. The TH is negatively correlated with the DBH, while the regression values showed that the relationship between TH and DBH are not significant at the 0.05 confidence level. The height of trees within the rainforest does not influence and determine their DBH. Therefore, the extent to which rainforest trees grow tall do not mainly influence the ability of the trees to increase in DBH, but a function of several other functions which include soil nutrient status capacity to support the growth and productivity of trees within the ecosystem. This result is in line with findings reported by Kazumichi, et al. [16].

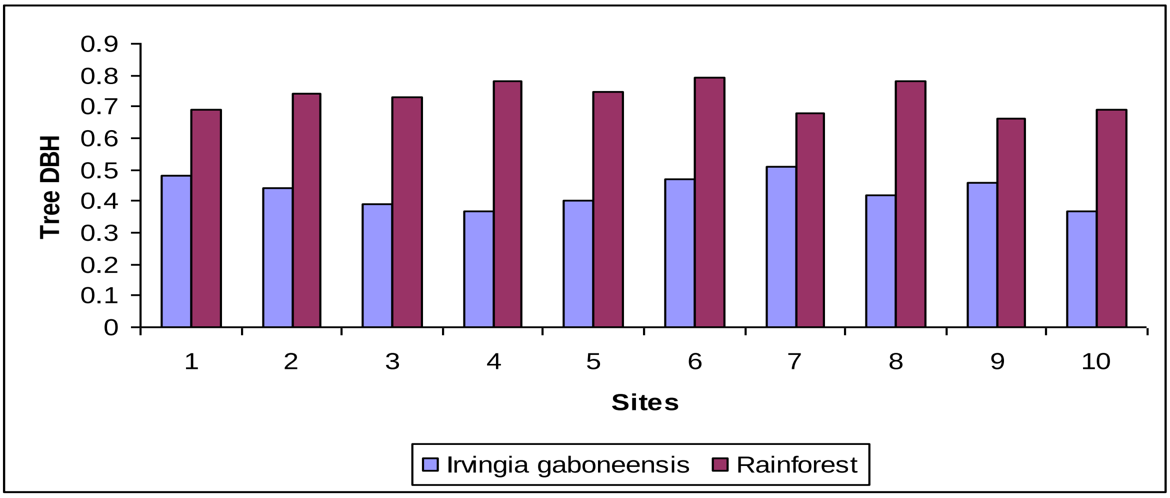

Fig. 3. Mean tree diameters at breast height per sample site (m)

Table 4. Regression output for the relationship between TH and DBH in *Irvingia gaboneensis*

Model Summary

Mode	R	R Square	Adjusted R Square	Std. Error o he Estimate	Change Statistics R Square Change	F Change	df1	df2	ig. F Chang
1	.023[a]	.001	-.124	2.20523	.001	.004	1	8	.949

a. Predictors: (Constant), DBH

Coefficients[a]

Mode		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Partial	Part
1	(Constar	28.141	6.551		4.296	.003			
	DBH	.996	15.114	.023	.066	.949	.023	.023	.023

a. Dependent Variable: TreeHeight

Table 5. Regression output for the telationship between TH and DBH in rainforest

Model Summary

Mode	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.352[a]	.124	.014	1.16260	.124	1.131	1	8	.319

a. Predictors: (Constant), DBH

Coefficients[a]

Mode		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	40.925	6.051		6.763	.000			
	DBH	-8.811	8.285	-.352	-1.063	.319	-.352	-.352	-.352

a. Dependent Variable: TreeHeight

4. CONCLUSION AND RECOMMENDATIONS

This research characterised measures of aboveground biomass of isolated *Irvingia gaboneensis* stands within Isoko South Local Government Area's rainforest, Nigeria. Findings showed that TH and DBH varied between stands of *I. gaboneensis* and RF. The differences in the aboveground biomass parameters between *I. gaboneensis* and ART are significant at 95% alpha level. For stands of *I. gaboneensis,* TH correlated weakly with tree DBH, while the relationship between them is not significant at 95% alpha level. This implies that the height of *I. gaboneensis* does not totally determine its DBH. For RF trees, TH negatively correlated with DBH, while the relationship between them is not significant at 95% alpha level. The height of trees within the rainforest does not influence and determine their DBH. The aboveground parameters of the standing *I. gaboneensis* shows that it supports effective productivity and functioning of the RF ecosystem thus, its conservation is necessary.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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