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TREE SPECIES DIVERSITY AND FOREST STAND DYNAMICS IN A TROPICAL RAINFOREST IN SOUTHERN NIGERIA

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ABSTRACT

Twenty temporary sample plots were laid in Onigambari Forest Reserve, one of the major rainforest reserves in Nigeria (latitude 7º 25' and 7º 55'N and longitude 3º 53' and 3º 9'E) in an attempt to study the tree species diversity and stand structure. The sample plots were laid using systematic line transects. In each sample plot, all trees with a diameter at breath height (dbh) above 10 cm were identified by species and measured. The results show that the mean tree basal area obtained ranged from 0.5824 m^2/ha to 0.8116 m^2/ha. The mean number of stems and species per hectare on the different transects varied from 85 – 89 and 36 – 40, respectively. The differences between the transect lines were not statistically significant indicating a uniform nature of distribution of species and individuals trees in the forest. A total of 335 stems comprising 63 species and belonging to 25 families were encountered. Family Ebenaceae had the highest representation (17.31%) and Diospyros dendo (Ebony) was the most common member of this plant family.

Key words: Transect lines, sample plots, species diversity, stand dynamics, uniformity, and rainforest

INTRODUCTION

Forests constitute one of the principal renewable natural resources of mankind. They are essential in maintaining environmental stability, provision of raw materials for wood-based industries and provision of food, livelihood and employment for millions of people, particularly in the rural areas (FAO, 2010). It is worthy to note that in recent times, the concern has been to concentrate conservation effort on the tropical rainforest because of its relative richness in biodiversity. This rainforest consists of the moist tropical, and the lowland semi-deciduous forests, which form a narrow strip of green belt, a few kilometers inland along the Nigerian coast and covers a total area of 133,000 km^2.

In forest management operations, inventories on biodiversity are used to determine the nature and distribution of biodiversity. Quantification of tree species diversity is an important aspect as it provides resources for many species. To protect forests from declining, it is essential to examine the current status of species diversity as it will provide guidance for the management of forest areas. Information from this quantitative inventory will provide a valuable reference for forest assessment and improve our knowledge in identification of ecologically useful species as well as species of special concern. Thus identify conservation efforts to assess the tree species diversity and stand structure of Onigambari Forest Reserve, one of the major rainforest reserves in Nigeria.

Onigambari forest reserve has been selected for this study mainly because it is one of the few natural reserve in Nigeria that has been intensively examined over the years (Oguntala, 1981; Akinyemi *et al.*, 2012; Ige and Erhabor, 2013 and Ige *et al.*, 2013). The present study will not only constitute a base material for the study area but will also be available for reference in future as the environment and ecology of the area degenerate as a result of its closeness to the urban city of Ibadan, South West, Nigeria. Ecological degradation is a gradual process as often silent changes in the ecology which may not be easily noticed cumulate into a big environmental degeneration with time. Hence, if the present study is compare with future studies, changes in the ecology will be easily recorded an

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causes and effect easily determined for appropriate remedial actions.

MATERIALS AND METHODS

The study area

This study was carried out in Onigambari Forest Reserve (Figure 1). It is located on latitude 7º 25' and 7º 55'N and longitude 3º 53' and 3º 9'E within the low land semi-deciduous rain forest belt of Nigeria and covers a total land area of 17,984 ha. The reserve is divided into two types of forest: natural and plantation forests. The natural rain forest is made up of indigenous species such as *Terminalia spp* K. Shum (Afara), *Triplochiton scleroxylon* K. Shum (Arere, Obeche), *Irvingia garbonensis* (Oro), *Treculia africana,* among others while the plantation forest is made up of mainly exotic species such as G*melina arborea* (Gmelina) and *Tectona grandis* (Teak). The topography of the study area is generally undulating, lying at altitude between 90m and 140m above sea level. The annual rainfall ranges between 1200mm to 1300mm spreading from March to November. The dry season (December-February) is severe and the relative humidity is over 80% at 9.00am and average annual temperature is about 26.4ºC (Larinde and Olasupo, 2011).

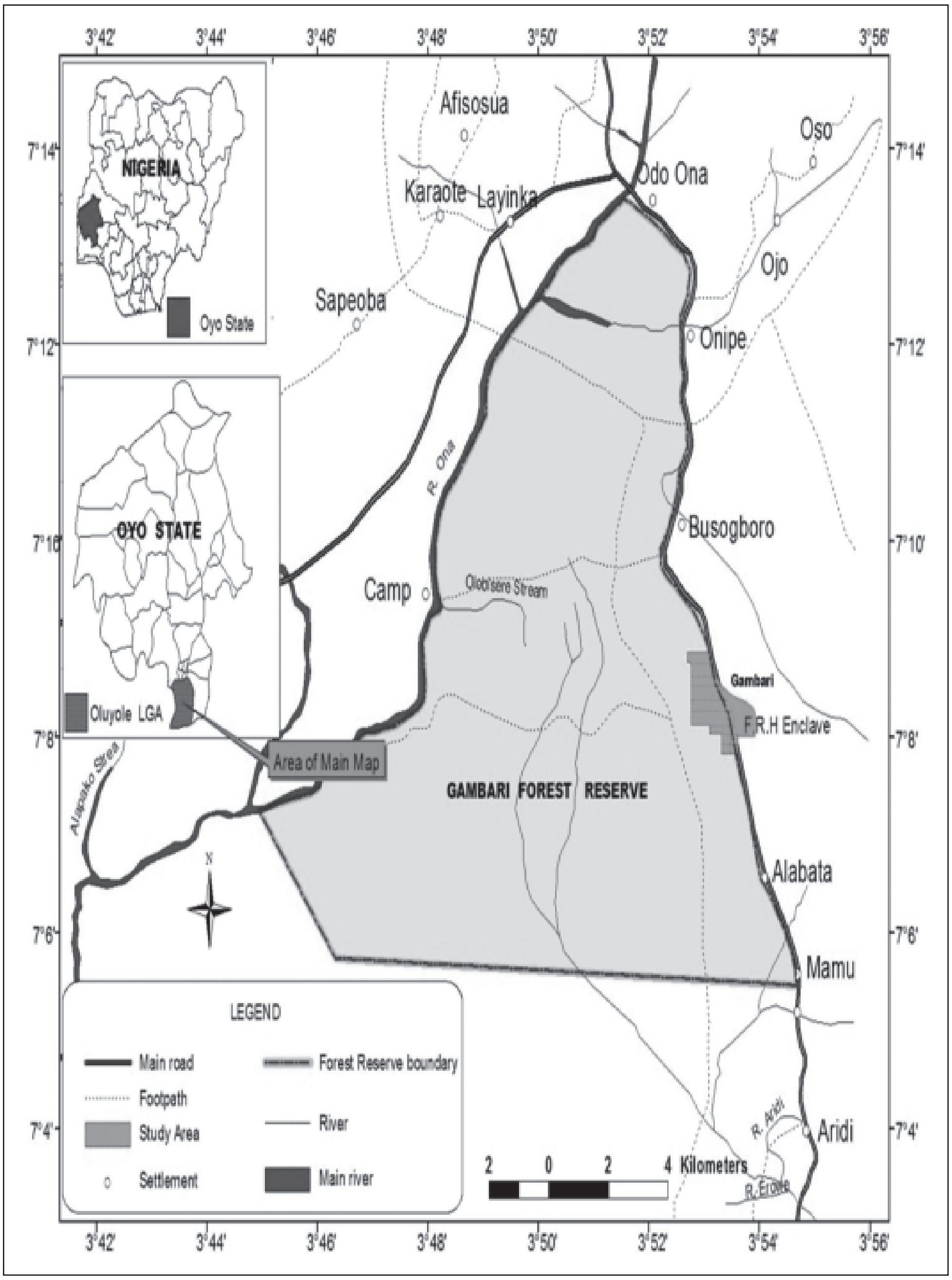

Fig. 1. Map of Onigambari forest reserve.

Sampling techniques and data collection

Systematic line transect was used in the laying of the temporary sample plots. A total of four transect lines of 225 m (Figure 2) in length (abbreviated as L1, L2, L3 and L4) were established in east-west direction using a compass. Sample plots of 25m x 25m in size were established in alternate along each transect at 20m interval and thus summing up to 5 sample plots per 225m transect and a total of 20 sample plots in the study area. The topographic position, including the gradient was measured at each plot using a clinometer (Table 1). All trees were measured for diameter at breast height over bark (dbh-1.3 m above the ground) and trees above 10cm dbh were identified by species and measured. The dbh was measured using a diameter tape accurate to 0.1cm. In cases where identification of the trees was not possible, the botanical specimens were taken to the herbarium section of the Forestry Research Institute of Nigeria (FRIN) for identification.

Data analysis

The means of individual tree basal area, number of genera, number of species and number of stems per hectare were calculated for each transects line. One-way analysis of variance (ANOVA) was used to test the differences between the means of these parameters using Statistical Package for Social Sciences (SPSS) version 20. The relative dominance (abundance) of the species in each transect line was identified on the basis of relative basal area. The

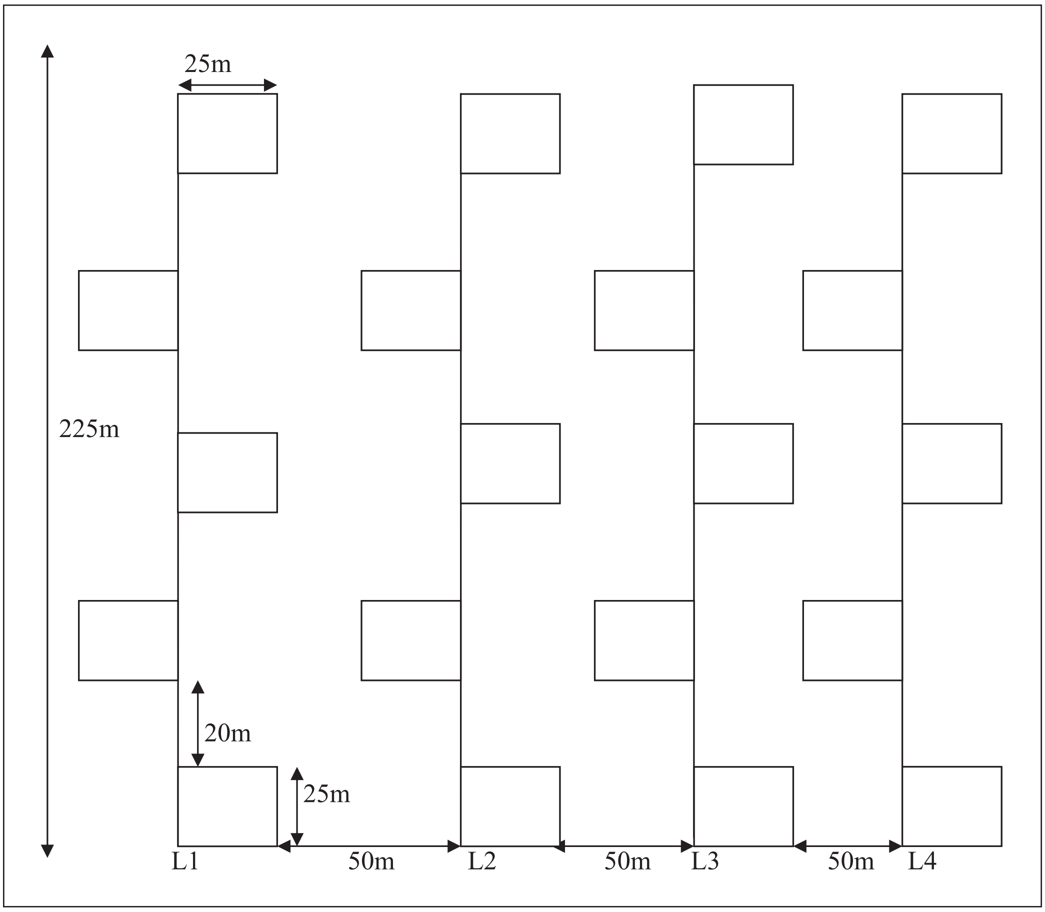

Fig. 2. Plot layout with systematic line transects sampling technique.

Table 1. General features of sample plot within the five transect lines of the study area

Transect	No of plots	Area (m^2)	Slop (°)	Topography
L1	5	25 x 25	7 – 45	Steep lower slope
L2	5	25 x 25	4 – 36	Gentle to mid slope
L3	5	25 x 25	5 – 25	Mid-slope with riverine areas
L4	5	25 x 25	0 – 10	Mainly flat and gentle slope

relative basal area of a species on transect lines was calculated as the basal area of a species divided by total basal area of the site and multiplied with 100. The dominant and co-dominant species in terms of occurrence in each line were identified based on this value. In addition, species with the highest relative high basal area was similarly defined as dominant and that with the second highest relative basal area was defined as co-dominant not in terms of position in the canopy but in terms of frequency of occurrence on the line transect. A variety of different diversity indices can be used as measures of some attributes of forest structure because they are often seen as ecological indicators (Magurran, 1988). Diversity indices provide important information about rarity and commonness of species in a tree community. These indices can be used to compare diversity between habitat types (Kent and Coker, 1992) over time. Different diversity, species richness, species evenness indices were calculated for each transect as well as pooled data for all transects. The methods used for assessing the studied parameters are described in Supplementary Table 1.

RESULTS AND DISCUSSION

Stand structure and characteristics of the studied site

Information on the basal area, stem, species and genera densities are efficient expression for revealing forest stand structure and spatial distribution of trees present in a forest (Akinnagbe, 2001 and Ige, 2011). The results of the parameters are presented on Table 2. From Table 2, it can be seen that the mean basal area of the four transects range from 0.5824m^2/ha to 0.8116m^3/ha, mean number of stem per ha, from 85 to 89, mean number of a species/ha 36-40 and mean number of genera 15-18. All these means were not statistically significantly different (P<0.5) for the lines suggesting a good uniformity of diversity in the study area (Table 2). This also conforms with Oguntala (1981)'s investigation in the study area.

In the present study, a range of 85 to 89 species ha^{-1} has been recorded in the lowland rainforest of Onigambari Forest Reserve near Ibadan, Nigeria (Table 2). In the very rich rainforests, the number of species in the rainforests could be as high as 400 species ha^{-1} (Nwoboshi, 1982). A much lower result was reported for some forests in Africa where the species richness is about 60 stems ha^{-1} (Oguntala 1981, Bernhard-Reversat *et al*., 2001 and Akinnagbe 2001). When compared to some rainforests around the world particularly in Africa, the low land rainforest of Onigambari could be considered to be species rich.

The mean numbers of genera per hectare varied from 15 (L1) to 18 (L3) genera ha^{-1}. This small difference though not statistically significant could be due to genetic and site differences.

On the basis of relative basal area, the four sites differed in the combination of dominant and co-dominant tree species. *Diospyros dendo* was more numerous in L1 and followed by L3 and L4. *Triplochiton scleroxylon* dominated at the L3 and L4. L3 had the highest number of species dominance with species such as *Triplochiton scleroxylon*, (*Brachystegia enrycoma*, *Ricinodendron heudelotii)* and *Cordia millenii* (Omo) among others. Meanwhile next more frequent species such as *Diospyros dendo Cleistopholis patens* (Agbalamo) and *Rinorea dentate* were encountered in L1.

The data from the four transect lines when combined yielded a total of 335 stems and 63 species of trees ≥ 10 cm dbh. These species represent 65 genera and 25 families. Table 3 shows the summary statistics for various indices of diversity, richness and evenness. It is generally recognized that the area and environmental heterogeneity have strong effects on species diversity (Rosenzweig, 1995; Whitmore, 1998; Waide *et al*., 1999). The Shannon-Weiner index (*H'*) was used to compare species diversitybetween transects. The *H'* for L1 – L4 were 2.98, 2.61, 2.99 and 2.52, respectively, indicating that among transects, L3 was the most complex in species diversity whereas L4 had the simplest forest cover in terms of species composition.

Similar patterns were found for species richness, which was computed using Margalef index of species richness (*SR*) and the number of equally common species (N_1). The *SR* ranged from 10.40 to 13.77 and the N_1 ranged from 27.89 to 38.36. Whittaker index of evenness (*Ew*) ranged from 19.08 to 21.36, the highest value was recorded at L3 and the lowest at L4. In thepresent study,

Table 2. The Stand Structure of a Tropical Rainforest Onigambari Forest Reserve, at Southwest, Nigeria

Variables	L1	L2	L3	L4	Sig (p≤0.05)
Mean basal area (m^2/ha)	0.7352	0.5824	0.8116	0.6317	Not significant
Mean no. of stems/ha	86	85	89	88	Not significant
Mean no. of species/ha	36	37	40	38	Not significant
Mean no. of genera/ha	15	16	18	16	Not significant

Table 3. Pattern of Tree Species Diversity in a Tropical Rainforest Onigambari Forest Reserve

Variables	L1	L2	L3	L4
Shannon-Weiner index *(H')*	2.98	2.61	2.99	2.52
Margalef index of species richness *(SR)*	12.56	12.72	13.77	10.40
Whittaker index of evenness (E_w)	19.92	20.11	21.36	19.08
The number of equally common species (N_1)	27.89	30.14	38.36	29.10
Simpson's diversity *(D)*	0.97	0.98	0.98	0.93
Whittaker index of β-diversity (βw)	2.55	3.67	4.17	3.21

Simpson's diversity (*D*) was not a very sensitive indicator of diversity as three of four sites (L1–L3) had somewhat similar values. Whittaker index of β-diversity (β_W) was used to compare habitat heterogeneity within transect. The β_W value was the highest for L3 (4.17) and the lowest for L1 (2.55). Further analysis indicated that the number of species per individual had a direct positive influence on β-diversity (Table 3). According to Condit *et al*. (1998), species richness is positively associated with species abundance. This relationship suggests that large population is less prone to extinction than small ones. Based on the relationship between abundance and diversity, habitats supporting large numbers of individuals can support more populations and more species than habitat supporting small number of individuals.

Species distribution

The similarity between lines (L1–L4) based on Bray-Curtis index (C_N) was calculated between the pair of transects and abundance similarity matrix (Table 4). The Bray-Curtis similarity index was used because it often yields satisfactory coefficients for biological data on community structure. Comparison of C_N values among the four transects data indicates that the species composition of L1 was fairly different though not statistically significant from those of the other three sites. L3 had a high species similarity to L2 and L4, and L4 had a high species similarity to L2.

A total of 25 tree families were encountered in the forest (Table 5). The maximum number of tree species belongs to Ebenaceae which accounts for 17.31% of Ebony, the total individuals encountered in the study site. *Diospyros dendo* is the most widely occurring species from this family. Other trees from this family such as *Diospyros cauliflor, Diospyros monbutensis* and *Diospyros suaveoleus* are among the important part of floristic composition in the study area. The other dominant families are Malvaceae, Putranjivaceae and Steculiaceae, which account for 12.54%, 10.75% and 8.06% respectively, of the total individual encountered in the study site, respectively. Earlier study also indicates that Ebenaceae was the dominant family in Shasha forest about 200km from the present study site with 21% of tree species belonging to this family (Ige, 2011).

The stand structure of Onigambari forest was studied based on the distribution of tree diameter class. In this study, the distribution of trees clearly displays the characteristic of De iocourt's factor

Table 4. Similarity coefficient among the four transects of examined in a tropical rainforest Onigambari Forest Reserve

Transect	L1	L2	L3
L2	0.16		
L3	0.15	0.21	
L4	0.14	0.14	0.39

Table 5. Distributions of Families of Trees Species Showing the Names of the Families, Frequency and Percentage of Occurrence

Family	No of Species	%
Achariaceae	1	0.30
Anacardiaceae	1	0.30
Annonaceae	6	1.79
Apocynaceae	17	5.07
Bombacaceae	2	0.60
Boraginaceae	7	2.09
Cannabaceae	14	4.18
Capparaceae	11	3.28
Clusiaceae	2	0.60
Cyperaceae	4	1.19
Ebenaceae	58	17.31
Euphorbiaceae	11	3.28
Fabaceae	15	4.48
Malvaceae	42	12.54
Meliaceae	24	7.16
Moraceae	16	4.78
Olacaceae	25	7.46
Passifloraceae	1	0.30
Putranjivaceae	36	10.75
Rhamnaceae	1	0.30
Rubiaceae	9	2.69
Rutaceae	2	0.60
Steculiaceae	27	8.06
Ulmaceae	2	0.60
Violaceae	1	0.30

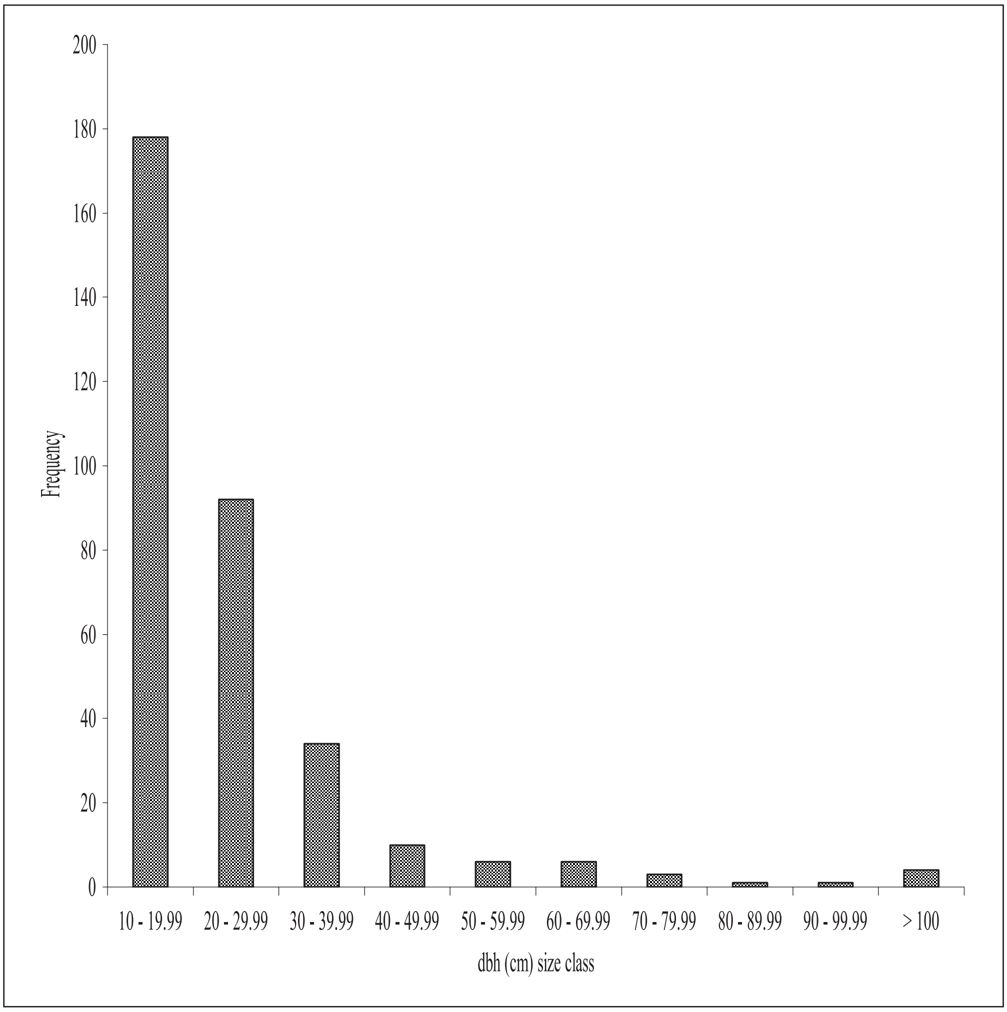

Fig. 3. dbh distribution of tree species at Onigambari forest reserve.

procedure (inverse J distribution) where stems frequencies decrease with the increase in dbh (Figure 2). This generally indicates that stands are developing and regeneration in the forest is ongoing. Natural regeneration is dependent on the availability of mother trees, fruiting pattern and favourable conditions. As shown in Figure 3, the presence of growth of the forest is indicated by the upward movement of trees in various diameter classes. There were a higher number of stems for smaller diameter classes, with 53.13% of trees falling between 10 – 19.99 cm, 27.46% falling between 20 – 29.99 cm and 10.15% falling between 30 – 39.99 cm. The bar chart (Figure 3) shows less number of stems in diameter classes 70 cm and above. This reason for this is that under natural conditions, an old, big emergent tree may fall down and encourage gap regeneration via natural succession if the area is not too far away from mature primary forest trees serving as source for the recalcitrant seeds.

CONCLUSIONS

Onigambari Forests Reserve comprises of natural vegetation and is dictated by a combination of biotic and biotic factors like topography, altitude, geology, climatic etc. as well as historical conditions of geology and climate. Thedensity and size distribution of trees contribute to the structural pattern characteristics of the forest. The study indicates that the forests are characterized by a uniform distribution of individuals with mixed species composition and the sites arerepresented by different combinations of the dominants and co-dominant species. The distribution of trees displays the characteristic of De iocourt's factor procedure (inverse J-distribution) where stems frequencies decrease with the increase in dbh, indicating growing stable populations in which regeneration of the forest in this area is present.

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Supplementary Table 1. Methods used for assessing the diversity parameters.

Method	Formula	References
The Basal Area (BA) of individual trees	$BA = \frac{\pi}{4} D^2$ Where: BA = Basal area (m^2), D = dbh (cm). Π = 22/7 i.e. 3.14	Husch *et al*, 2003
Shannon-Weiner Diversity Index (*H'*)	$H' = \sum_{i=1}^{s} p_i \, lnp_i$ Where *H'*= the Shannon-Wiener index *pi*= the proportion of individuals belonging to species *i* inp=the natural log (i.e., 2.718)	Shannon and Weaver, 1949
The Species Richness (No. of species per unit area)	$SR = \frac{S-1}{ln(N)}$ Where *SR*=the Margalef index of species richness *S*=the number of species *N* =the total number of individuals In= the natural log (i.e, 2.718)	Margalef, 1958
The Whittaker's Index of Species Evenness	$E_w = \frac{S}{lnN_i - lnN_s}$ Where *Ew*=the Whittaker's index of evenness *Ni*=the abundance of most important species *Ns*=the abundance of the least important species In= Natural log (i.e. 2.718) S= Species No	Whittaker, 1972

α-Diversity	a. $N_1 = exp^{H'}$ Where *Ni*=the number of equally common species *H'*=the Shannon-Weiner index	This Index was measured based on unified indices (exponential Shannon-Weiner index and Simpson's diversity) index
Simpson's Diversity (*D*) Index	$D = 1 - \lambda$ Where D=the Simpson diversity index *λ*= the Simpson's concentration of dominance index calculated as $\sum p_i^2$	Simpson, 1949
The Whittaker's Index of β-diversity	$\beta w = \frac{S_c}{\bar{S}}$ Where *βw*= the Whittaker's index of β-diversity *S*c = the total number of species $\bar{S}$ = the average number of species per line	Whittaker, 1972
Bray-Curtis index (*CN*)	$C_N = \frac{2jN}{(aN+bN)}$ Where *CN*=the Bray-Curtis index *aN*=individual numbers of species A *bN*=individual numbers of species B *jN*= the sum of individual numbers of each species common in plots A and B	Bray and Curtis, 1947