

Tree Species and Size Diversity of Akure Strict Nature Reserve, Nigeria

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Abstract: Size and species structures control the natural mechanisms maintaining high structural diversity. Use of size inequality and species diversity measures singly for conservation decisions brings about inconsistent results. Therefore, most conservation efforts fail due to lack of understanding of mechanisms promoting coexistence of tree species. However, relationship between size inequality and species diversity indicates the natural mechanism promoting coexistence of high species diversity. Therefore, this study investigated the relationship between tree size inequality and species diversity in Akure Strict Nature Reserve. Eighteen and twelve plots (30m × 30m) were laid on parallel transects of 3.60km long and 50m width in Old-growth and Riparian forests, respectively. Trees with diameter-at-breast-height (dbh) ≥ 10cm were counted and identified to species level. Tree diameter at base, middle and top and total height were measured using girth tape and Relaskop. Tree species diversity (Shannon-Weiner; Simpson; Margalef indices) and dbh inequality measures (Gini coefficient, Gini; Coefficient of Variation, CV; Skewness Coefficient, Skewness) were computed and compared. Stem biomass were computed and converted to carbon stock. Data were analysed using descriptive, and correlation analysis at $\alpha_{0.05}$. Fifty-five (56) tree species representing 17 families were found in the forest. Species diversity indices were higher in Riparian while size inequalities in Old-growth forests. GC correlate with Shannon-Weiner ($r=0.54$; $n=18$, $p\leq 0.018$) and Margalef ($r=0.473$; $n=18$, $p\leq 0.04$) in Old-growth while GC correlate with CV ($r=0.716$; $n=12$, $p\leq 0.09$) in Riparian forests. The size inequality measures were strongly related with each other in Riparian while species and size inequality measures were strongly related with each other in Old-growth forests. The carbon stocks of Old-growth and Riparian forests were 117.21Mg/ha and 43.47Mg/ha, respectively. *Triplochiton scleroxylon* and *Bridelia micrantha* contained highest carbon stock in Old-growth and Riparian forests, respectively. Asymmetric mode of interaction in the absence of competition shows competition for below-ground resource, especially presence of moisture and nutrient gradient. Size inequality among different and within the same species determined coexistence tree communities in Old-growth and Riparian forests of Akure Strict Nature Reserve, respectively.

Keywords: Tree Species Diversity, Stem Size Hierarchy, Tree Size Inequality, Stem Carbon Stock

1. Introduction

Forest spatial structure regulates the coexistence of tree species diversity in tree communities [16]. Tropical forest comprise of trees of different species and sizes, mixed in different patterns. Conspecific indicates group of trees of the same species surrounding a reference tree while heterospecific indicates group of trees of different species surrounding a reference tree. Keren, S. et al. [5] stated that forest spatial structure is controlled by competitive

interactions among trees of different species and sizes. Conversely, size structure and species structure do not have the same effects on ecosystem functions and services. According to the authors [12, 18], species mingling is estimated by the number of different or same tree species surrounding a particular reference tree species. Although size may be used to characterize species diversity [6]. The identification of weakness and strength of species diversity and size inequality measures singly bring about the use of correlation between species diversity and sizes. Li, Y. et al. [6] identified decrease in species richness, abundance and spatial

diversity indices with increasing diameter class in inverted J-shaped diameter distribution. Therefore, there are relationships between tree species and size in tropical forests. Wang, H. et al. [17] emphasized that relationship between spatial arrangement of species and stem sizes identifies the natural mechanisms maintaining high structural diversity. The authors [17, 18] demonstrated that mechanisms for coexistence of high tree species diversity in a community can be determined by using relationship between spatial species diversity and size inequality. Therefore, investigation of natural mechanisms that promote high species diversity and tree growth should be the focus of conservation efforts and decisions on tree populations [12]. These suitable natural mechanisms can be mimic through structure-based silvicultural treatments. Keren, S. et al. [5] reiterated that it is necessary to understand the mechanisms regulating coexistence of high tree species and sizes diversities because it is required for decision making on tree species conservation and climate change issues. Hence maintenance of high species mingling and size diversity is important because it controls major ecosystem functions and services. Also, coexistence of high tree species and size diversities is critical to climate change mitigation and carbon sequestration because tree species and size differ in the carbon storage capacity. Furthermore, growth and survival of tree species dependent on above- and below-ground resources. Moreover, the contribution of water gradient to forest spatial structure is difficult to clarify. Moisture regimes can cause change in

forest tree size and species diversity. Hence, understanding the effect of different moisture regimes on tree species and size inequality can improve tree species conservation efforts and decisions. Therefore, this study investigated the relationship between tree species diversity and size inequality in Old-growth and Riparian forests of Akure Strict Nature Reserve with a view of optimizing conservation efforts and carbon stock optimization.

2. Materials and Methods

2.1. Study Area

The study was carried out in Akure Strict Nature Reserve. The Akure Strict Nature Reserve is on Latitude $07^{\circ} 61' 00''$ to $07^{\circ} 18' 00''$ N of the Equator and Longitude $05^{\circ} 09' 00''$ to $05^{\circ} 12' 48''$ E of the Greenwich Meridian at an altitude of 150m above sea level (asl) in Southwestern, Nigeria. Akure Strict Nature Reserve covers approximately 32,000ha. It has a tropical climate with pronounced rainy and dry seasons [1]. The soil is on basement complex with gneisses quartzitic rock and disintegrated to ferruginous brown soil with gravel content of approximately 40%. Strict Nature Reserve supposed to be strictly protected area and referenced area for scientific and educative research but Akure Strict Nature Reserve is facing problem of evasive tree species (such as *Gmelina arborea*) and mild encroachment.

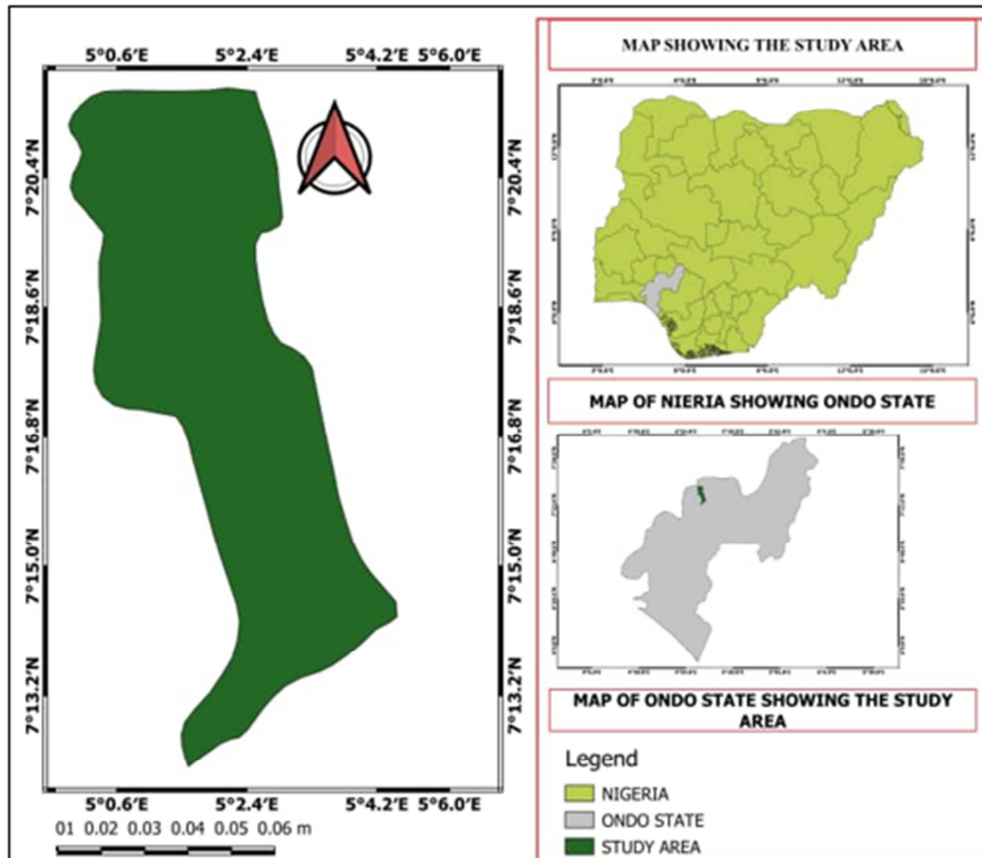


Figure 1. The spatial map of Akure Strict Nature Reserve (Queen's plot).

2.2. Data Collection Procedure

Eighteen (18) and twelve (12) sample plots of size (30m × 30m) were systematically demarcated at interval of 30m along parallel transects of 3.60km long with 50m widths in Old-growth and Riparian forests, respectively. Six sample plots were demarcated on a transect. Three and two parallel transects were used for sampling in Old-growth and Re-growth forests, respectively. Tree stems with diameter-at-breast height (dbh) ≥ 10cm were counted and identified to species level in each plot. Tree diameter at base, middle and top and total height were measured using Spiegel Relaskop. Tree species diversity was measured using Shannon-Weiner, Simpson and Margalef indices of diversity while size inequality based on dbh was measured using Gini-Coefficient, GC; Skewness Coefficient, Skewness and Coefficient of Variation, CV. The measures of tree species diversity and size inequality of each forest were computed and compared.

Also, stem volume of individual tree species was calculated using Newton wood volume expressed in equation 1, which was derived from [1, 3]. The volume was converted to species stem biomass. Biomass is the product of wood volume and wood density of each species. Information on wood density of tropical tree species was extracted from Wood Density Database [21]. Furthermore, species stem biomass was converted to biomass carbon by multiplying species stem biomass with 0.5, as indicated in equation 2 [8]. Data collected were analysed using descriptive, correlation analysis at $\alpha_{0.05}$.

$$\text{Newton wood volume equation} = \left(\frac{D_b + D_m + D_t}{6} \right) \times h \quad (1)$$

Hence, D_b is the diameter of tree at the base, D_m is the diameter of the tree at the middle, D_t is the diameter of tree at the top and h is the total height of the tree.

$$\text{Carbon stock of tree species} = \frac{\text{Stem Volume}}{\text{Wood density}} \times 0.50 \quad (2)$$

2.3. Data Analysis

Tree dbh data were divided into equal diameter classes using 10.0 cm dbh interval to described each forest type. Three diversity indices were used to calculate tree species diversity and three inequality measures were used to calculate tree size inequality of dbh. Tree size inequality based on dbh was quantified using Gini coefficient (Gini), Coefficient of Variation (CV) and Skewness Coefficient (Skewness) [20, 2] while tree species diversity was quantified using Shannon-Weiner, Simpson and Margalef indices [4]. The size inequality measures and tree species diversity indices were computed for each plot. Species richness is number of tree species encounter in each sampled plot [7, 4]. The relationship between tree size inequality measures and tree species diversity indices for each forest were computed using Spearman correlation analysis at $\alpha_{0.05}$.

Three Species diversity indices were calculated for each forest type using Shannon-Weiner, Simpson and Margalef

indices in equation 1, 2 and 3 below, respectively.

Shannon-Weiner species diversity index was calculated using:

$$H' = - \sum p_i \ln(p_i) \quad (3)$$

Given:

H' is Shannon-Weiner index; P_i is the ratio of abundance of a particular tree species encountered (n) in a plot, N is total number of individuals encountered in a plot and \ln is natural logarithm of value.

Simpson species diversity index (I-D)

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right) \quad (4)$$

Given:

n is abundance of individual tree species, N is total number of individuals of all tree species.

Margalef index of species richness (M)

$$M = \frac{(S-1)}{\ln N} \quad (5)$$

Given

S is total number of species in the community, N is total number of all individual trees and

\ln is natural logarithm of value

Species Evenness (E)

$$E = \frac{H'}{\ln S} \quad (6)$$

Also, tree size inequality based on dbh was quantified using Gini-coefficient, Coefficient of variation and skewness coefficient as expressed in equation 7, 8 and 9:

$$\text{Gini Coefficient} = \frac{\sum (2j-n-1)ba_j}{\sum ba_j(n-1)} \quad (7)$$

$$\text{Coefficient of Variation} = \frac{\text{Standard deviation}}{\text{Sample mean}} \times 100 \quad (8)$$

$$\text{Skewness Coefficient} = \frac{\sum (x_i - \bar{x})^3}{(N-1)\sigma^3} \quad (9)$$

X_i = i^{th} Random Variable, \bar{X} = Mean of the Distribution, N = Number of Variables in the Distribution, σ = Standard Distribution.

3. Result

Fifty-five (56) tree species representing 17 families were encountered in Akure Strict Nature Reserve (Table 6). Thirty-eight (38) and thirty-six (36) tree species were identified in Old-growth and Riparian forests, respectively (Table 1 and Table 6). Twenty tree species were common to Old-growth and Riparian forests. Tree density ranged from 175.0 stems/ha (Re-growth forest) to 199.0 stems/ha (Old-growth forest). The tree stem carbon stock of Old-growth forest and Riparian forest were 117.21Mg/ha and 43.47Mg/ha, respectively (Table 1). *Triplochiton scleroxylon*,

Celtis zenkeri and *Pterygota macrocarpa* contributed highest carbon stock density in Old-growth while *Bridelia micrantha*, *Mansonia altissima* and *Drypetes afzelli* contributed highest carbon stock density in Riparian forests, respectively (Table

6). Therefore, the values of tree species richness, tree stem density and tree stem carbon for Old-growth forest were higher than Riparian forest.

Table 1. Structural attributes of Old-growth and Riparian forests of Akure Strict Nature Reserve.

Attributes	Old-growth forest	Riparian forest
Tree species richness	38.0	36.0
Tree family	11.0	13.0
Tree density (stems/ha)	199.0	175.0
Tree stem carbon (Mg/ha)	117.21	43.47
Dominant tree species	<i>Celtis zenkeri</i> , <i>Mansonia altissima</i> , <i>Nesogordonia papaverifera</i>	<i>Celtis zenkeri</i> , <i>Annona manni</i> , <i>Cola gigantea</i>

Table 2. The value of tree species indices of diversity for Old-growth forest and Riparian forest of Akure Strict Nature Reserve.

Variables	Old-growth forest	Riparian forest
Shannon-weiner (H')	2.87	3.18
Simpson diversity index	0.90	0.94
Species evenness	0.42	0.67
Margalef index	7.09	6.67

The value of Shannon-Weininger index of tree species diversity ranged from 2.87 (Old-growth forest) to 3.18 (Riparian forest). Also, the values of Simpson diversity index ranged from 0.90 (Old-growth forest) to 0.94 (Riparian forest). Margalef index of tree richness ranged from 6.67 (Riparian forest) to 7.09 (Old-growth forest). Therefore, the values of tree species diversity indices of Riparian forest were higher than Old-growth forest (Table 2). Conversely, Margalef index of species richness was higher in Old-growth

than Riparian forests.

The Gini-coefficient (0.26), Coefficient of variation (96.60%) and Skewness coefficient (3.45) of Old-growth forest were higher than Gini-coefficient (0.25), Coefficient of variation (91.98%) and Skewness coefficient (2.95) of Riparian forest. There was only small difference in the CV and Gini of size density distribution of Old-growth and Riparian forests (Table 3).

Table 3. The characteristics of tree size distribution for Old-growth forest and Riparian forest of Akure Strict Nature Reserve.

Forest	Minimum	Maximum	Mean±std	Gini	CV (%)	skewness	Kurtosis
Old-growth	15.92	557.32	70.98±8.63	0.26	96.60	3.45	16.95
Re-growth	12.73	399.68	60.59±5.74	0.25	91.98	2.95	11.32

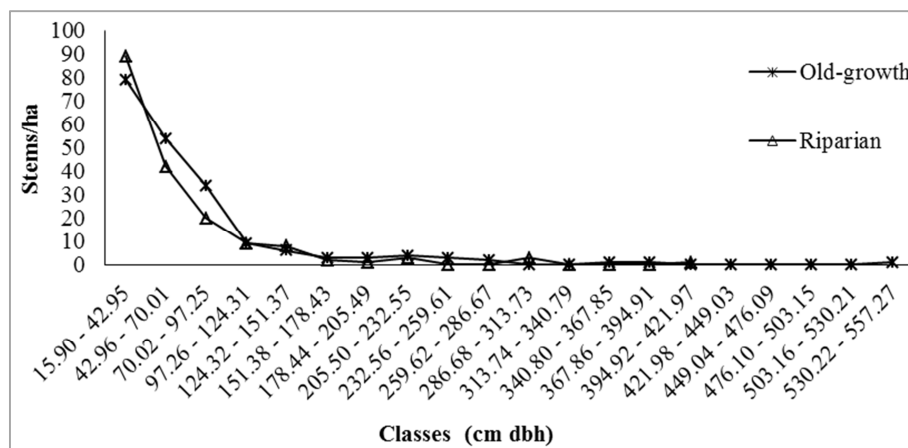


Figure 2. Diameter distribution of Old-growth and Riparian forests of Akure Forest Reserve.

The tree size distribution of Old-growth and Riparian forests were positively skewed. The tree dbh distribution for Old-growth forest expressed higher stem density at 15.90-42.95cm dbh (79 stems/ha) followed by 54 stems/ha at 42.96-70.01cm dbh and followed by a steep decline to 34 stems/ha at 70.02-97.25cm dbh and 9 stems/ha at 97.26-124.31 cm dbh. The stem dbh distribution for Old-growth

forest was truncated at 530.27-557.27cm dbh (Figure 2). Also. Tree dbh distribution of Riparian forest contained highest stem density at 15.90-42.95cm dbh (89 stems/ha) followed by 42 stems/ha at 42.96-70.01cm dbh and followed by a gentle reduction to 20 stems/ha at 70.02-97.25cm dbh and 9 stems/ha at 97.26-124.31 cm dbh. The stem dbh distribution of Riparian forest was truncated at 394.92-

421.92cm dbh (Figure 2). Conversely, there was no stem representation between 286.68 to 340.79 and 394.92 to 530.21 cm dbh classes of Old-growth forest and between 232.56 to 286.67 and 313.74 to 394.91cm dbh of Riparian forest.

The values of Gini coefficient were significantly correlated to Shannon-weinner index of tree species diversity ($r=0.549$; $n=18$, $p\leq 0.018$) and Margalef ($r=0.473$; $n=18$, $p\leq 0.047$) in Old-growth forest. Also, the values of Coefficient of Variation were

significantly correlated to Evenness. Skewness coefficient were significant positive correlated to Simpson index of tree species diversity (Table 4) in Old-growth forest. Therefore, there was correlation between measures of tree size and inequality species diversity in Old-growth forest. Conversely, the values of Coefficient of variation were correlated with Gini coefficient ($r=0.716$; $p\leq 0.009$) and Skewness coefficient (0.699; $p\leq 0.011$) in Riparian forest (Table 5). The measures of dbh inequality were correlated to each other in Riparian forest.

Table 4. The relationship between tree diameter inequality and tree species diversity measures for Old-growth forest of Akure Strict Nature Reserve.

Index 1	Index 2	r	p ≤ 0.05
Gini Coefficient	Shannon-Weinner	0.549	0.018
Gini Coefficient	Margalef index	0.473	0.047
Coefficient of Variation	Evenness index	0.530	0.002
Skewness coefficient	Simpson index	0.495	0.037

Table 5. The relationship between tree diameter inequality and tree species diversity measures for Riparian forest of Akure Strict Nature Reserve.

Index 1	Index 2	r	p ≤ 0.05
Coefficient of Variation	Gini coefficient	0.716	0.009
Coefficient of Variation	Skewness	0.699	0.011

4. Discussion

4.1. Tree Species Diversity of Old-Growth and Riparian Forests

Fifty-five (56) tree species representing 17 families were encountered in Akure Strict Nature Reserve. Thirty-eight (38) and thirty-six (36) tree species were identified in Old-growth and Riparian forests, respectively. Five (5) tree species were common to Old-growth forest and Riparian forest. Old-growth forest comprise more tree species than Riparian forest. Old-growth forest contained more favourable micro-sites for growth and survival of many tree species. However, proximity to source of water provide favourable conditions for some tree species that are not present in Old-growth forest. Old-growth had higher number of tree species but least values of species diversity indices when compare to Riparian forest. This is because there was a distinct difference in the abundance of stems among tree species in Old-growth forest. Shannon-Weiner diversity indices take species richness and relative abundance into consideration. Tree stem density of Old-growth forest was greater than Riparian forest. Therefore, size asymmetric inter-tree competition may be more pronounced in Old-growth forest than Riparian forest due to higher skewness. Also, stem carbon stocks of Old-growth forest (117.21 Mg/ha) was greater than Riparian forest (143.47 Mg/ha). Therefore, Old-growth forest of Akure Strict Nature Reserve provides good biomass carbon sequestration potential in Nigeria. *Triplochiton scleroxylon*, *Celtis zenkeri* and *Pterygota macrocarpa* contributed highest carbon stock density in Old-growth forest while *Bridelia micrantha*, *Mansonia altissima* and *Drypetes afzelli* contributed highest carbon stock density in Riparian forest. Therefore, the values of most structural characteristics of Old-growth forest were higher than

Riparian forest. Hence, high structural diversity of Old-growth forest would improve biodiversity of Akure Strict Nature Reserve because structural diversity is attributed of biodiversity value.

4.2. Tree Size Distribution of Old-Growth and Riparian Forests in Akure Strict Nature Reserve

Tree size distribution of Old-growth and Riparian forests showed extended reverse J-shape curve. Hence, the diameter class distribution of both forests represented positively skewed distributions with many small and intermediate stem size as well as a few very large stem size. This indicated that most stems were smaller than the mean tree size. This showed good reproductive and regeneration with capacity for replacement of emergent trees in both Old-growth and Riparian forests of Akure Strict Nature Reserve. Also, this showed that large canopy tree size can be easily replaced by presence of abundant intermediate tree sizes. Old-growth and Riparian forests showed rotated sigmoid dbh distribution because the distribution presented a plateau in the intermediate dbh size range. Rotated sigmoid is typical of a forest with many canopy strata [11]. Old-growth forest showed extended tree size distribution because of the presence of few big trees. Large tree stems contribute more valuable biomass ecosystem services such as wood productivity and carbon sequestration [20].

The stem size inequality measures of Old-growth forest were higher than Riparian forest. Gini coefficient allows comparison of diameter structure of different forests [11]. [9] stated that high size inequality is caused by the presence of dominant and suppressed trees due to limited supply of plant growth resource. The authors [10, 14] reiterated that high skewness of diameter distribution of stand may be due to exponential growth rate of some stem sizes and may not be due to dominance and suppression of individual stems. This

suggests asymmetric in the absence of inter-tree competition. Stem size distribution may become asymmetric in the absence of inter-tree competition due to variance in exponential growth rates of some individual stems [14]. Old-growth forest showed higher dbh structural diversity than Riparian forest of Akure Strict Nature Reserve.

4.3. Tree Size Inequality of Old-Growth and Riparian Forests

Correlation between Gini coefficient and Shannon-Weiner values were positively significant with highest correlation in Old-growth forest. Therefore, positive correlation between spatial species diversity and size inequality was more pronounced in Old-growth forest. This indicated that there was high tree species mingling with different tree stem sizes in Old-growth forest but size variation within same species do not differ [12, 17]. This implied that stem size differ among species but similar within each species. Hence, high size inequality among different species determined the mechanisms regulating coexistence of trees in Old-growth forest. Spatial size inequality is largely caused by species mingling [12]. [17] stated that large trees tend to have high species mingling. Probably a few large trees in Old-growth forest facilitated high species mingling. Species mingling suggested an attraction of different species with different sizes within tree communities of Old-growth forest.

Correlation between Gini coefficient and Coefficient of variation values were significant with highest correlation in Riparian forest. This indicated that strong positive correlation among tree size inequality measures was more pronounced in Riparian forest. Therefore, high size diversity within the same tree species determined the mechanisms regulating

coexistence of trees [17] in Riparian forest. This implied that many tree species populations in Riparian forest have similar size distributions. Spatial size inequality suggested an attraction of different tree sizes in Riparian forest. The interaction between conspecific and hetero-specific size structure facilitates these correlations [16]. These relationships were site-specific and they are the basis for the natural mechanisms for maintaining of plant diversity in a forest ecosystem. Correlation of spatial species and size diversity show different spatial patterns in the same forest ecosystem. However, the dominant correlation will determine the functional mechanism in the forest ecosystem.

5. Conclusion

Presence of similar shape but difference tree size structures in Old-growth and Riparian forests indicates different coexistence mechanisms among the tree communities. Also, asymmetric mode of interaction in the absence of interference shows competition for below-ground plant growth resource, especially presence of moisture and nutrient gradient. Therefore, below-ground plant growth resource is the major factor controlling the tree size structure in Akure Strict Nature Reserve and moisture gradient could be a factor causing delineation into Old-growth and Riparian forests. High size inequality among different tree species and size inequality within the same tree species determined the mechanisms regulating coexistence of trees in Old-growth forest and Riparian forest, respectively. Overall, there was more of different tree species with different sizes at short distances in Old-growth than Riparian forests and more of different tree sizes at short distances in Riparian than Old-growth forests.

Appendix

Table 6. The composition and stem biomass carbon of tree species in Old-growth and Riparian forests in Akure Strict Nature Reserve.

Old-growth forest			Riparian forest		
Tree Species in Old-growth forest	Family	stem Carbon stock	Tree Species in Riparian forest	Family	stem carbon stock
<i>Alstonia boonei</i>	Apocynaceae	1090.375	<i>Anona manni</i>	Annonaceae	6.481529
<i>Anona manni</i>	Annonaceae	4300.531	<i>Antiaris toxicaria</i>	Moraceae	92.77452
<i>Branchystegia laurentii</i>	Fabaceae	183.1547	<i>Brachystegia boehmii</i>	Fabaceae	102.9701
<i>Cassia occidentalis</i>	Fabaceae	467.5619	<i>Bridelia micrantha</i>	Phyllanthaceae	28295.41
<i>Ceiba pentandra</i>	Malvaceae	190.1694	<i>Celtis occidentalis</i>	Ulmaceae	51.54936
<i>Celtis mildbraedii</i>	Ulmaceae	64.6608	<i>Celtis philippensis</i>	Ulmaceae	31.39524
<i>Celtis philippensis</i>	Ulmaceae	40.3061	<i>Celtis zenkeri</i>	Ulmaceae	965.6347
<i>Celtis zenkeri</i>	Ulmaceae	12782.14	<i>Chrysophyllum albidum</i>	Sapotaceae	291.6132
<i>Chrysophyllum albidum</i>	Sapotaceae	1571.764	<i>Cleistopholis patens</i>	Annonaceae	39.49156
<i>Chrysophyllum cainito</i>	Sapotaceae	321.4428	<i>Cola gigantea</i>	Malvaceae	947.1239
<i>Cleistopholis patens</i>	Annonaceae	579.6895	<i>Cola hispida</i>	Malvaceae	76.69347
<i>Cola gigantea</i>	Malvaceae	3427.291	<i>Cola nitida</i>	Malvaceae	163.5713
<i>Cola milleni</i>	Malvaceae	68.12713	<i>Cordia millenii</i>	Boraginaceae	495.1562
<i>Cola nitida</i>	Malvaceae	109.1121	<i>Dacryodes edulis</i>	Burseraceae	27.14226
<i>Cola millenii</i>	Boraginaceae	415.5392	<i>Daubentonia madagascariensis</i>		489.7882
<i>Daubentonia madagascariensis</i>		3545.63	<i>Diospyros abyssinica</i>	Ebenaceae	194.3472
<i>Diospyros ebenum</i>	Ebenaceae	63.14274	<i>Drypetes afzelii</i>	Euphorbiaceae	1241.534
<i>Diospyros lotus</i>	Ebenaceae	236.2364	<i>Entandrophragma cylindricum</i>	Meliaceae	243.5515
<i>Drypetes afzelii</i>	Euphorbiaceae	617.7183	<i>Funtumia elastica</i>	Apocynaceae	378.2876

Old-growth forest			Riparian forest		
Tree Species in Old-growth forest	Family	stem Carbon stock	Tree Species in Riparian forest	Family	stem carbon stock
<i>Entandrophragma cylindricum</i>	Meliaceae	3395.84	<i>Gmelina arborea</i>	Verbanaceae	325.1861
<i>Epomophorus angolensis</i>		17.72293	<i>Irvingia wombolu</i>	Irvingiaceae	175.5727
<i>Funtumia elastica</i>	Apocynaceae	820.1616	<i>Khaya senegalensis</i>	Meliaceae	730.9527
<i>Gmelina arborea</i>	Verbanaceae	2802.563	<i>Lecaniodiscus cupanioides</i>	Sapotaceae	53.65605
<i>Hunteria unbellata</i>	Apocynaceae	39.33917	<i>Mansonia attisima</i>	Malvaceae	1713.977
<i>Irvingia gabonensis</i>	Irvingiaceae	1410.899	<i>Milicia excelsa</i>	Moraceae	225.5613
<i>Khaya senegalensis</i>	Meliaceae	229.1998	<i>Monodora myristica</i>	Annonaceae	7.584076
<i>Lecaniodiscus cupanioides</i>	Sapotaceae	69.08503	<i>Myrianthus arboreus</i>	Moraceae	6.108499
<i>Mansonia attisima</i>	Malvaceae	1926.097	<i>Nesogordonia papaverifera</i>	Malvaceae	943.9619
<i>Nesogordonia papaverifera</i>	Malvaceae	5188.512	<i>Pterocarpus osun</i>	Malvaceae	36.11178
<i>Pterygota maerocarpa</i>	Fabaceae	4569.453	<i>Pterygota macrocarpa</i>	Malvaceae	485.2459
<i>Pycnanthus angolensis</i>	Myristicaceae	201.6851	<i>Steculia oblong</i>	Malvaceae	237.5852
<i>Ricinodendron heudelotii</i>	Euphorbiaceae	357.6987	<i>Sterculia foetida</i>	Malvaceae	793.2581
<i>Senna siamea</i>	Fabaceae	345.0064	<i>Terminalia superba</i>	Combretaceae	1902.441
<i>Sterculia foetida</i>	Malvaceae	1298.36	<i>Trichilia catigua</i>	Meliaceae	599.8927
<i>Terminalia superba</i>	Combretaceae	1848.949	<i>Trichilia monadelpha</i>	Meliaceae	27.19517
<i>Thespesia populnea</i>	Malvaceae	151.4818	<i>Triplochiton scleroxylon</i>	Malvaceae	1078.157
<i>Trichilia catigua</i>	Meliaceae	239.0773			
<i>Triplochiton scleroxylon</i>	Malvaceae	62227.74			

References

- Adekunle, V. A. J., Olagoke A. O. and Akindele S. O. 2013. Tree species diversity and structure of a Nigerian Strict Nature Reserve. *International Society of Tropical Ecology* 54 (3): 275-289. [www.tropecol.com; http://216.10.241.130/pdf/open/PDF_54_3/01-Adekunle,%20Olagoke%20&%20Akindele.pdf](http://216.10.241.130/pdf/open/PDF_54_3/01-Adekunle,%20Olagoke%20&%20Akindele.pdf)
- Bendel, R. B., Higgins, S. S., Teberg, J. E. and Pyke, D. A. 1989. Comparison of skewness coefficient, Coefficient of Variation and Gini coefficient as inequality measures within populations. *Oecologia* 78: 394-400. doi.10.1007/BF00379115.
- Fonwebau, J. N. 1997. Effect of log formular, log length and method of measurement on the accuracy of volume estimate for three tropical timber species in Cameroon. *Commonwealth Forestry Review* 76 (2): 114-120.
- Heip, C. and Engels, P. 1974. Comparing species diversity and evenness indices. *Journal of Mash Biology Association of Uk* 54: 559-569. doi.10.1017/S002531540022748.
- Keren, S., Svoboda, M., Janda, P. and Nagel, T. A. 2020. Relationships between structural indices and conventional stand attributes in an Old-growth forest in Southeast Europe. *Forests* 11 (1): 4. doi.10.3390/fl1010004.
- Li, Y., Ye, S., Luo, Y., Yu, S., and Zhang, G. 2023. Relationship between species diversity and tree size in natural forests around the tropic of Cancer. *Journal of Forest Research*.
- Magurran, A. E. 1988. *Ecological diversity and measurement*. First ed. Pp. 81-101. Princeton University Press, Princeton.
- Malhi, y., Baker, T. A., Phillips, O. O., Almeida, S., Alvarez, E., Chave, J. et al. 2004. The above-ground coarse woody productivity of 104 Naotropical forest plots. *Global Change Biology* 10: 563-591.
- Metsaranta, J. and Lieffers, V. J. 2008. Inequality of size and size increment in *Pinus banksiana* in relation to stand dynamics and annual growth rate. *Annals o Botany* 101: 561-571. doi.10.1093/aob/mcm320.
- Mohler, C. L., Marks, P. L. and Sprugel, D. G. 1978. Stand structure and allometry of trees during self-thinning of pure stands. *Journal of Ecology* 66: 599-614. <http://www.jstor.org/stable/2259153>
- Pach, M. and Podlaski, R. 2014. Tree diameter structural diversity in Central European forests with *Abies alba* and *Fagus sylvatica*: managed versus unmanaged forest stands. *Ecological Research*. doi.10.1007/s11284-014-1232-4.
- Pommerening, A., Zhang, R. and Zhang, X. 2021. Unravelling the mechanisms of spatial correlation between species and size diversity in forest ecosystem. *Ecological Indicator* 121: 106995. doi.10.1016/j.ecolind.2020.106995.
- Sharma, K. P., Bhatta, S. P. and Lamsal, S. K. 2020. Species diversity and regeneraton of community-managed hill sal (*Shorea robusta*) forest in Central Nepal. *Current Science* 119 (1): 81-92. doi.10.18520/cs/v119/j1/83-92.
- Turner, M. D. and Rabinowitz, D. 1983. Factors affecting frequency distributions of plant mass: the absence of dominance and suppression in competing monocultures of *Festuca paradoxa*. *Ecology* 64 (3): 469-475. doi.10.2307/1939966.
- Uria-Diez, J., Gazol, A. and Ibanez, R. 2014. Driver of a riparian forest specialist *Carex remota*, Cyperaceae): It is not only a matter of soil moisture. *American Journal of Botany* 101 (8): 1286-1292. doi.10.3732/ajb.1300443.
- Wang, H., Zhao, Z., Myllymaki, M. and Pommerening, A. 2020. Spatial size diversity in natural and planted forest ecosystems and extending the concept of spatial size inequality. *Ecological Informatics* 57: 101054. doi.10.1016/j.ecoinf.2020.101054.
- Wang, H., Zhang, X., Hu, Y. and Pommerening, A. 2021a. Spatial patterns of correlation between conspecific species and size diversity in forest ecosystems. *Ecological Modelling* 457: 109678. doi. Org/10.1016/j.ecolmodel.2021.109678.

- [18] Wang, H. X, Huang, S. X, Zhang, S. S., Peng, H. and Cao, K. 2021b. Localized neighborhood species mingling is correlated with individual tree size inequality in natural forests in south China. *Annals of Forest Science* 78: 102. Doi 10.1007/s13595-021-01111-x.
- [19] Weiner, J. and Solbrig, O. T. 1984. The meaning and measurement of size hierarchies in plant population. *Oecologia* 61: 334-336. doi. 10.1007/BF00379630.
- [20] Weiner, J. and Thomas, S. C. 1986. Size variability and competition in plant monocultures. *Oikos* 47 (2): 211-222. doi.10.2307/3566048.
- [21] Zanne, A. E. 2009. Global wood density database. Available at: <http://hdl.handle.net/10255/dryad.235>. Accessed on 16 April, 2015.