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Influence of Forest Canopy Cover on Tree Species Diversity in Different Forest Reserves in Southwestern Nigeria

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Abstract

Akure Strict Nature Reserve (Akure SNR), Eda and Shasha forest reserves. Each forest was categorized into three forest canopy classes: open canopy, partial canopy cover and closed canopy. Overstory trees were inventoried in nine 625 m^2 main temporary sample plots in each canopy class, resulting in 27 plots for each forest reserve. Sapling and seedling species were enumerated in 25 m^2 and 4 m^2 quadrants and sub-quadrants, respectively laid at the center of each main plot and quadrant. Results revealed that tree growth characteristics and most biodiversity indices decreased along canopy classes, with closed and open canopy covers having the highest and lowest values, respectively. Overstory tree species richness of the closed canopy (34, 29 and 26 at Akure SNR, Eda and Shasha forests, respectively) was significantly higher than that of open canopy (11, 16 and 18 in the respective forests). Similar trend was observed in the understories of the three canopy cover classes of the forests. Shannon-Wiener diversity index varied from 2.98 - 3.11 and 2.22 - 2.72 in closed and open canopy covers, respectively of the three forests while species evenness was similar in all the canopy cover classes. Stand basal area under the closed canopy (17.06 - 79.15 m^2ha^{-1}) was significantly higher than under partial canopy cover (9.32 - 23.48 m^2ha^{-1}) and open canopy (5.61 - 6.41 m^2ha^{-1}). Since the degree of canopy openness is linked to forest degradation, the poor growth and biodiversity indices of the open canopy class is attributed to anthropogenic disturbances, which pose great risk to forest growth and biodiversity conservation. It is recommended that anthropogenic activities in the forests be reduced or halted to prevent further degradation, promote conservation and regeneration. Restoration in the partial and open canopy portions of the forests is also recommended

Keywords: Biodiversity indices, canopy cover species, conservation, forest disturbance, forest reserve, Nigeria

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INTRODUCTION

Tropical rainforests are among the most species rich ecosystems on earth (Carson and Schnitzer, 2008). They account for only seven percent of the earth's land area and harbour about 70% of global fauna and flora species (Onyekwelu *et al.*, 2008). There are between 100 and 300 tree species per hectare in tropical rainforests, which is much higher than the number of tree species in any other ecosystem on earth (Pitman *et al.*, 2005; Lasco, 2008; Rahayu *et al.*, 2022). This high species diversity and complexity of tropical forests make them to contribute significantly to climate change mitigation, especially through the enormous carbon they sequester (Wang *et al.*, 2021; Onyekwelu *et al.*, 2024). However, the high species diversity of tropical rainforests is also the reason they are being subjected to severe pressure (Onyekwelu *et al.*, 2008), which has resulted to forest degradation, deforestation, biodiversity loss, and decrease in productivity of the ecosystem.

The forest understory, which is an intrinsic part of the forest, plays important roles in its conservation (Bauhus *et al.*, 2001; Xiong *et al.*, 2024). Understory vegetation is very important for forest regeneration through its influence on the resources at the forest floor (Connell *et al.*, 1997). Although understory vegetation contributes very little to the total forest productivity (Gilliam, 2007), it contributes significantly to total floristic diversity of the forest ecosystem (Gilliam and Roborts, 2003; Onyekwelu *et al*., 2021), and its structure has direct implication for forest succession and management. On the other hand, some understory vegetation can affect germination of seed as well as survival and growth of tree seedlings through competition for forest resources (e.g. nutrients, water, and light) (Augusto *et al.*, 2003). Understory vegetation is influenced by forest canopy conditions.

Forest canopy is one of the major contributing factors of the microclimate within the forest ecosystem. It is the collection of all the crowns within the forest ecosystem, the aggregation of twigs, foliage, branches, epiphytes and the interstices in a forest (Parker, 1995). Nakamura *et al*. (2017) explained that forest canopy is the primary site of gas exchange between the atmosphere and vegetation that enriches many processes important for maintenance and diversity of the forest. Didham and Fagan (2004) observed that the forest canopy exhibits many properties and performs major role in the fluctuations of the forest atmosphere. It has controlling effect on understory microclimate. Forest canopy structure has great impact on entire forest environment and on the climate surrounding individual trees, by altering the microclimate through its layers. It greatly impacts the light and rainfall that gets to the forest understory by reducing the amount of light and intercepting the rainfall that reaches the forest floor, which could affect the diversity and composition of understory plants. Information on the assessment of the effect of canopy cover on understory plants composition in Nigeria is scanty. This research was therefore conceived to fill this information gap, it was undertaken to provide information on the influence of canopy cover on understory plant species in forest reserves in southwestern Nigeria.

METHODOLOGY

Study areas

This study was conducted in three forest reserves (Akure forest reserve, Eda forest reserve and Shasha forest reserve) in Southwestern Nigeria (Figure 1). The locations of the forest reserves are: Akure forest reserve (latitude 7^{o} 16' - 7^{o} 18' N and longitude 5^{o} 09'- 5^{0} 11' E); Eda forest reserve (latitude 7^{o} 23' - 7^{o} 46' N and longitude 4^{o} 45' - 5^{o} 47' E) and Shasha forest reserve (latitude 7^{o} 00' - 7^{o} 30' N and longitude 4^{o} 00' – 5^{o}). The three forest reserves are located in the tropical rainforest region of southwestern Nigeria. The climate is humid tropical, with two prominent seasons: rainy and dry seasons. The duration of rainy season is nine months annually (March to November) while that of dry season is three months (December and February). Mean annual temperature is about 26.5^{0}C (range: 19.5 ^{o}C and 32.5 ^{o}C); the average annual relative humidity is about 80%. The soils are mainly ferruginous tropical, typical of the type found in intensively weathered basement complex formation areas of the rainforest region of southwest Nigeria. The soils are mature, red, well drained, stony and gravely in upper parts of the sequence while the topsoils are mainly sandy loam (Onyekwelu *et al*., 2008).

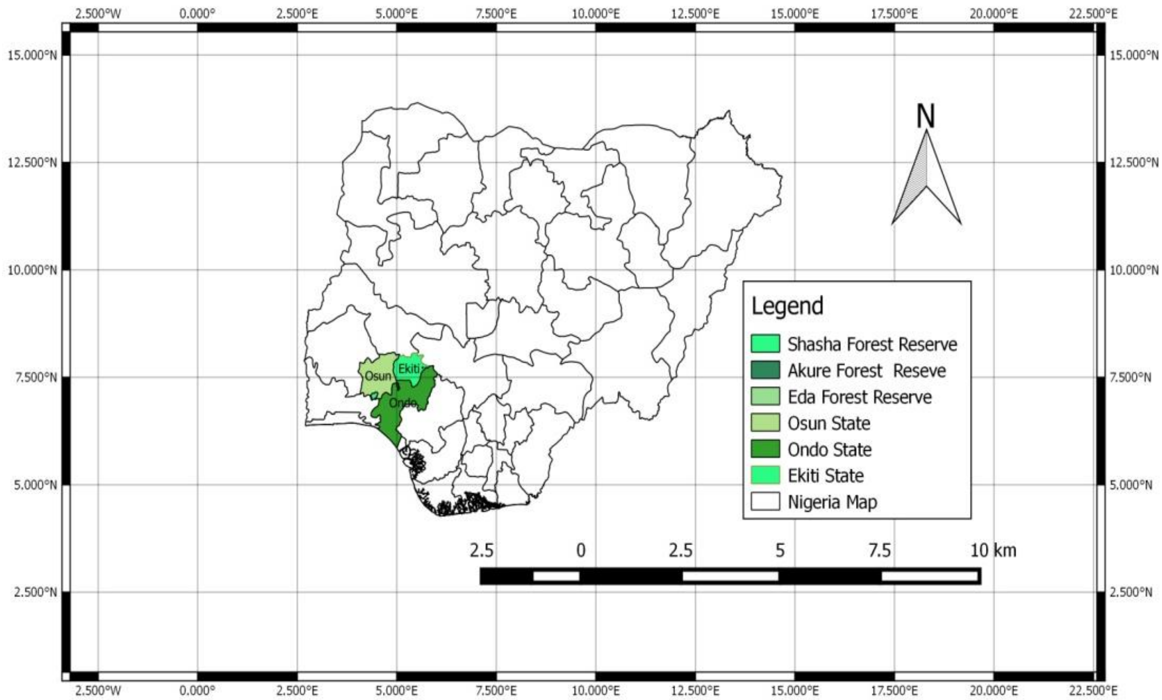

Figure 1. Map of Nigeria showing the selected States and forest reserves

Data Collection

Method of Data Collection

The three forest reserves purposively selected for this study represented states of different forest ecosystems in southwestern Nigeria. The Strict Nature Reserve (SNR) in Akure forest reserve is a primary forest, Shasha and Eda are moderately and highly degraded forest reserves, respectively. For the purpose of this study, each forest reserve was categorized into three canopy cover classes: open, partial and closed canopy covers. High resolution satellite imagery of each forest reserve was obtained, and their digitized maps produced. Sections of each forest reserve with the above canopy cover classes were identified and marked on the digitized map (Figures 2, 3 and 4). Three of each class were randomly selected from each forest reserve.

Data were obtained from 27 main temporary sample plots of 25m × 25m in the three forest reserves. Within each sample plot, trees with dbh of 10 cm and above (overstory trees) were identified and their dbh were measured. Also, data were collected from forest understory layer categorized into sapling layer (i.e. dbh ≥ 1 cm but < 10 cm) and seedling layer (dbh < 1 cm). For enumeration of the sapling layer, a 5 m × 5 m quadrant was laid at the centre of each main plot. All sapling species within the quadrant were identified and their dbh taken. For seedlings assessment, a 2 m × 2 m sub-quadrant was laid approximately at the centre of each quadrant. The seedling species were identified and their frequency of occurrence recorded. Keay (1989) was used as a guide for tree species nomenclature. Where a species could not be identified in the field, samples of the fruits, leaves, or back were taken to the laboratory for identification.

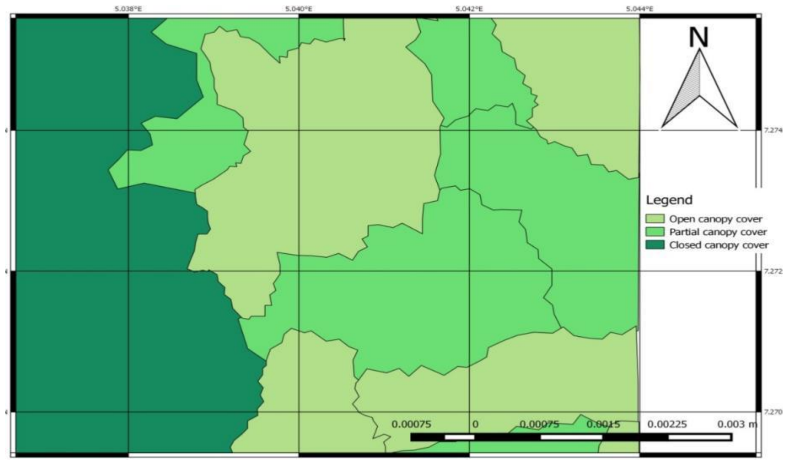

Figure 2: Digitized map of Akure forest reserve

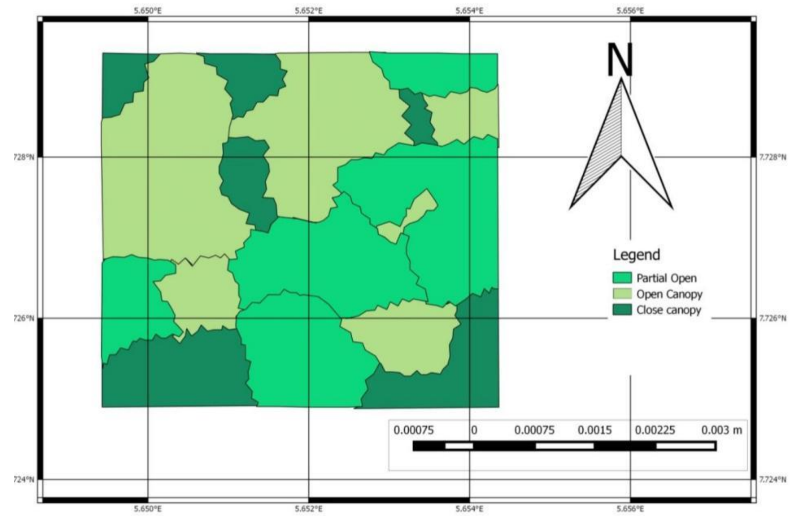

Figure 3: Digitized map of Eda forest reserves

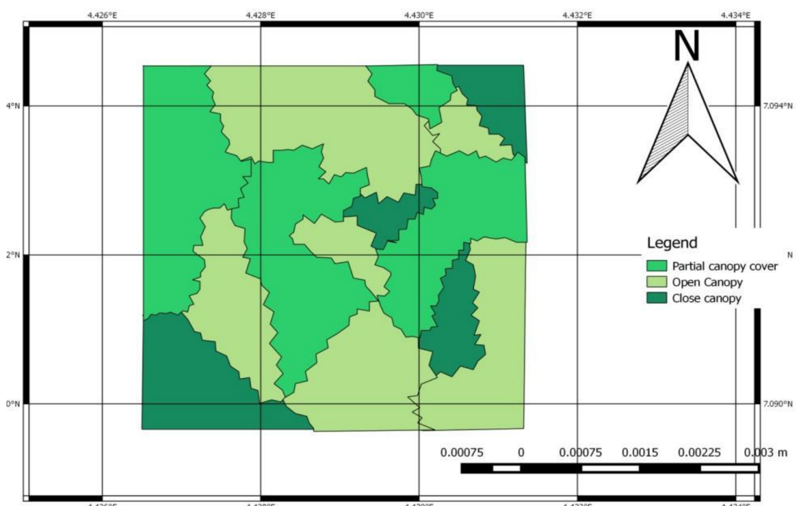

Figure 4: Digitized map of Shasha forest reserve

Data Computation and Analysis

Equation 1 was used to compute the basal area of each tree.

$$BA = \frac{\pi D^2}{4} \qquad \text{(eqn 1)}$$

Where BA = Basal area (m^2); D = Diameter at breast height (cm) and π = 3.142.

Total plot basal area was calculated as the summation of the basal areas of all trees in respective sample plot. Mean plot basal area for each site was obtained by first summing the total basal area of all plots and then dividing the value by the number of sample plots. The basal area per hectare was computed by multiplying mean plot basal area by 16, which is the number of 25 m x 25 m sample plots in one hectare.

The following biodiversity indices were calculated:

a. Species Relative Dominance (RDo (%): This was obtained using equation 2:

$$RDo = \frac{(\sum Ba_i * 100)}{\sum Ba_n} \qquad \text{(eqn 2)}$$

Where RD_o = Relative Dominance; Ba_i = Basal area of individual trees belonging to ith tree species: Ba_n = Stand basal area

b. Species Relative Density (RD): Species relative density (equation 3) was estimated as the number of individuals of a particular tree species divided by the total number of individual trees of all species.

$$RD = \frac{n_i}{N} * 100 \qquad (eqn. 3)$$

Where RD = relative density; n_i = number of the individual of species; N = total number of individual trees in the entire population.

c. Importance Value Index (IVI): This was estimated as the summation of Relative density and Relative dominance, divided 2 as presented in equation (4).

$$IVI = \frac{\mathrm{RD} + \mathrm{RD}_o}{2} \qquad (eqn. 4)$$

d. The Shannon–Wiener diversity index (H′): Shannon–Wiener diversity index (H′) was used to compute ecosystems' diversity index since it takes into consideration the richness and abundance of each species in the different ecosystems. The index was estimated using equation 5.

$$H' = \sum_{i=1}^{s} \text{pi ln(pi)} \qquad \text{(eqn. 5)}$$

H′ = Shannon diversity index; S = total number of species in the habitat; Pi = proportion S (species in the family) made up of the i^th^ species; ln = natural logarithm.

e. Species evenness (E): This was estimated using Shannon's equitability index (E_H) (eqn. 6):

$$E_H = \frac{\sum_{i=1}^{s} p_i \, ln(p_i)}{\ln(S)} \qquad \text{(eqn. 6)}$$

f. Shannon's maximum diversity index was estimated with equation (7);

$$H_{max} = \ln S \qquad \text{(eqn. 7)}$$

g. Sorensen's species similarity index (SI) was adopted in assessing species similarity between any two-forest reserve. The index was computed using equation (8):

$$SI = \left(\frac{2C}{a+b}\right) * 100 \qquad \text{(eqn. 8)}$$

Where: C = number of species in sites a & b; a, b = number of species at sites a and b

Two-way analysis of variance was employed to test for significant differences in growth characteristics and biodiversity indices (species diversity, evenness, richness, etc) in the three canopy cover classes of the three forest reserves. The analysis was undertaken with SPSS for Windows version 23.0. Means found to differ significantly were separated using Fisher's Least Square Difference (LSD).

RESULTS

The data for this study were obtained from three canopy covers (closed canopy, partial canopy and open canopy covers) in three forest reserves (Akure Strict Nature Reserve, Eda and Shasha forest reserves). Pooling together the data from the overstory layers of the three forest canopy covers, the results indicated that Akure SNR had a significantly higher mean stand basal area and dbh than the other two forest reserves, which were not significantly different from each other (Table 1a). Except the number of tree families, Akure SNR had the highest biodiversity indices, some of which were statistically similar with those of Shasha forest reserve but significantly higher than those of Eda forest reserve (Table 1a). Species evenness and maximum diversity indices of the three forests were not significantly different.

In the overstory layer of the forests, results revealed that, except species evenness, the closed canopy cover had the significantly highest stand growth characteristics and biodiversity indices values compared to partial canopy cover and open canopy cover of the three forests (Table 1b). This was followed by partial canopy cover, which had significantly higher growth characteristics and biodiversity indices values than open canopy cover. Thus, the open canopy cover of the three forests exhibited the statistically lowest growth characteristics and biodiversity indices values. High Shannon-Wiener diversity index (H') values of 3.11, 3.06 and 2.98 were obtained in closed canopy portions of Akure-SNR, Eda and Shasha forests, respectively, followed by partial canopy cover with H' of 3.02, 2.88 and 2.85 for the three respective forests while the lowest H' values were obtained in open canopy portion of the three forests (Table 1b).

Results on Table 2 indicates that Shannon-Wiener diversity index, species richness and Shannon maximum diversity index of the understory layers (sapling and seedling layer) of the three forests followed the trend as the overstory layer. Akure SNR had significantly higher growth and biodiversity indices than Shasha forest reserve, which had significantly higher values than Eda forest reserve. The sapling and seedling layers of the three forests had statistically similar species evenness values (Table 2).

The results of the understory layer (sapling and seedling layers) of the three forests indicate that the growth characteristics and biodiversity indices of the sapling and seedling layers of the three canopy cover classes followed similar trend as those of the overstory layers (Tables 3a & b). Similar to the overstory layer, stand growth characteristics and biodiversity indices of the understory layer (sapling and seedling) of the closed canopy cover were significantly higher than those of the partial canopy and open canopy covers (Tables 3a & 3b). The partial canopy cover of the sapling and seedling layers of the three forests had significantly higher growth characteristics and biodiversity indices values than the open canopy class.

Tree species with high relative Dominance (RDo) in the three canopy cover classes of the overstory layer of Akure forest reserve were: *Triplochiton scleroxylon* (41.99 %), *Ricinodendron heudelotii* (7.85 %) and *Cola gigantea* (6.66 %) (Closed canopy cover), *Triplochiton scleroxylon* (28.94%), *Ricinodendron heudelotii* (27.40%), *Pycnanthus angolensis* (10.15 %) (Partial canopy cover) and *Triplochiton scleroxylon* (42.18 %), *Celtis zenkeri* (21.02 %) and *Pterygota macrocarpa* (11.61 %) (Open canopy) (Table 4). Judging from these results, *Triplochiton scleroxylon* appears to be the most dominant species in overstory layer of Akure forest reserve since the species had the highest RDo in the three canopy cover classes of this layer.

Table 1a: Summary of growth characteristics and tree species diversity indices of the overstory layer of the three forest reserves

Forest Reserves	Dbh (m)	Basal Area (m^2)	Shannon Diversity Index(H’)	Species Evenness (E_H)	Maximum Diversity Index (Hmax)	No of spp	No of families	Freq of individuals
Akure Forest Reserve	50.06 [a]	36.90 [a]	3.73 [a]	0.93 [a]	3.97 [a]	53 [a]	25[b]	163 [a]
Eda Forest Reserve	29.91 [b]	10.90 [b]	3.47[c]	0.89 [a]	3.89 [a]	49 [b]	21[b]	138[b]
Shasha Forest Reserve	32.68 [b]	13.13 [b]	3.65[bc]	0.92 [a]	3.95 [a]	52 [ab]	28[a]	151[ab]

Table 1b: Summary of overstory tree growth characteristics and species diversity indices of the three canopy covers of the forests

	Akure Forest Reserve			Eda Forest Reserve			Shasha Forest Reserve		
Tree parameters	CL	PC	OP	CL	PC	OP	CL	PC	OP
No of Species	34[a]	26[b]	11[c]	29[a]	24[b]	16[c]	26[a]	23[b]	18[c]
No of Families	20[a]	16[b]	5[c]	15[a]	12[b]	10[c]	18[a]	17[b]	11[c]
Freq of Individuals	90[a]	53[b]	20[c]	65[a]	48[b]	29[c]	70[a]	53[b]	26[c]
BA (m^2ha^{-1})	79.15[a]	23.48[b]	5.84[c]	17.06[a]	9.32[b]	6.41[c]	23.50[a]	9.45[b]	5.61[c]
Mean Dbh of all trees(cm)	34.14[a]	28.27[b]	26.53[c]	21.86[a]	21.52[b]	18.59[c]	21.34[a]	20.39[b]	19.59[c]
(H’)	3.11[a]	3.02[b]	2.22[c]	3.06[a]	2.88[b]	2.48[c]	2.98[a]	2.85[b]	2.72[c]
(E_H)	0.88[a]	0.93[a]	0.93[a]	0.91[a]	0.90[a]	0.89[a]	0.91[a]	0.91[a]	0.94[a]
Hmax	3.53[a]	3.26[b]	2.40[c]	3.37[a]	3.17 [b]	2.77[c]	3.26[a]	3.14[b]	2.89[c]

Note: CL = Closed canopy class; PC = Partial canopy cover class; OP = Opened canopy class; H' = Shannon Wiener diversity Index; E_H = Species Evenness: Hmax = Shannon maximum diversity index.
Means in the same column and row with the same superscript are not significantly different (p≥0.05)

Table 2: Biodiversity indices of sapling and seedling tree species of the three forest reserves

Forest Reserves	Shannon-Wiener Diversity Index (H′)	Species Evenness (EH)	Species Richness	Hmax
Sapling Layer				
Akure SNR	2.89 ^{a}	0.96 ^{a}	20 ^{a}	3.00 ^{a}
Eda forest reserve	2.31 ^{c}	0.96 ^{a}	11 ^{c}	2.39 ^{c}
Shasha forest reserve	2.59 ^{b}	0.96 ^{a}	15 ^{b}	2.71 ^{b}
Seedling Layer				
Akure SNR	2.49 ^{a}	0.97 ^{a}	13 ^{a}	2.56 ^{a}
Eda forest reserve	2.16 ^{c}	0.94 ^{a}	10 ^{b}	2.30 ^{c}
Shasha forest reserve	2.34 ^{b}	0.96 ^{a}	11 ^{b}	2.39 ^{b}

Means in the same column with the same superscript are not significantly different (p≥0.05)

Tables 3a: Sapling layer diversity indices of the different canopy classes of the three forests

Forest Reserves	Akure SNR			Eda Forest reserve			Shasha Forest Reserve		
Diversity Indices	CL	PC	OP	CL	PC	OP	CL	PC	OP
Species richness	15 ^{a}	11 ^{b}	7 ^{c}	10 ^{a}	8 ^{b}	6 ^{c}	12 ^{a}	10 ^{b}	7 ^{c}
(H')	2.55 ^{a}	2.25 ^{b}	1.84 ^{c}	2.13 ^{a}	1.93 ^{b}	1.60 ^{c}	2.28 ^{a}	2.06 ^{b}	1.70 ^{c}
(E_H)	0.94 ^{a}	0.94 ^{a}	0.95 ^{a}	0.93 ^{a}	0.93 ^{a}	0.90 ^{a}	0.92 ^{a}	0.90 ^{a}	0.87 ^{a}
Hmax	2.71 ^{a}	2.40 ^{b}	1.95 ^{c}	2.30 ^{a}	2.08 ^{b}	1.79 ^{c}	2.48 ^{a}	2.30 ^{b}	1.95 ^{c}

Tables 3b: Seedling layer diversity indices of the different canopy classes of the three forests

	Akure SNR			Eda Forest reserve			Shasha Forest Reserve		
Diversity Indices	CL	PC	OP	CL	PC	OP	CL	PC	OP
Species richness	13 ^{a}	9 ^{b}	3 ^{c}	10 ^{a}	7 ^{b}	4 ^{c}	10 ^{a}	9 ^{b}	4 ^{c}
H'	2.49 ^{a}	2.14 ^{b}	1.08 ^{c}	2.22 ^{a}	1.93 ^{b}	1.27 ^{c}	2.15 ^{a}	2.09 ^{b}	1.26 ^{c}
E	0.90 ^{a}	0.97 ^{a}	0.98 ^{a}	0.96 ^{a}	0.99 ^{a}	0.92 ^{a}	0.93 ^{a}	0.95 ^{a}	0.91 ^{a}
Hmax	2.56 ^{a}	2.20 ^{b}	1.10 ^{c}	2.30 ^{a}	1.95 ^{b}	1.39 ^{c}	2.30 ^{a}	2.20 ^{b}	1.39 ^{c}

Note: CL = Closed canopy; PC = Partial canopy; OP = Opened canopy; H' = Shannon Wiener diversity Index; E_H = Species Evenness: Hmax = Shannon maximum diversity index.

Table 4: Summary of growth characteristics and diversity indices of six dominant tree species in the three canopy cover classes of the overstory layers of Akure Strict Nature Reserve

S/N	Tree Species	Family	Freq (ha^{-1})	Mdbh (cm)	BA (m^2)	BA (m^2ha^{-1})	RDo (%)	RD (%)	IVI (%)
Closed canopy									
1	*Triplochiton scleroxylon*	Sterculiaceae	21	125.75	6.23	33.24	41.99	4.44	23.22
2	*Ricinodendron heudelotii*	Euphorbiaceae	21	58.18	1.17	6.22	7.85	4.44	6.15
3	*Cola gigantea*	Sterculiaceae	11	77.05	0.99	5.27	6.66	2.22	4.44
4	*Celtis zenkeri*	Ulmaceae	69	26.79	0.88	4.70	5.94	14.44	10.19
5	*Mansonia altissima*	Sterculiaceae	64	29.77	0.88	4.70	5.94	13.33	9.64
6	*Sterculia rhinopetala*	Sterculiaceae	43	29.89	0.65	3.45	4.36	8.89	6.63
Total						***57.58***	***72.74***	***47.76***	***60.27***
Partial canopy									
1	*Triplochiton scleroxylon*	Sterculiaceae	21	53.08	0.98	5.20	28.94	7.55	18.25
2	*Ricinodendron heudelotii*	Euphorbiaceae	32	35.87	0.92	4.92	27.40	11.32	19.36
3	*Pycnanthus angolensis*	Myristicaceae	5	66.00	0.34	1.82	10.15	1.89	6.02
4	*Celtis zenkeri*	Ulmaceae	27	21.66	0.24	1.26	7.01	9.43	8.22
5	*Sterculia rhinopetala*	Sterculiaceae	16	23.40	0.18	0.97	5.39	5.66	5.53
6	*Celtis philippensis*	Ulmaceae	32	12.90	0.08	0.43	2.41	11.32	6.86
Total						***14.60***	***81.30***	***47.17***	***64.24***
Open canopy									
1	*Triplochiton scleroxylon*	Sterculiaceae	27	46.26	1.07	3.44	42.18	25.00	33.59
2	*Celtis zenkeri*	Ulmaceae	16	38.27	0.54	2.85	21.01	15.00	18.01
3	*Pterygota macrocarpa*	Sterculiaceae	11	43.1	0.3	2.37	11.61	10.00	10.81
4	*Cordia millenii*	Boraginaceae	5	46.5	0.17	2.72	6.67	5.00	5.83
5	*Sterculia rhinopetala*	Sterculiaceae	11	25.85	0.14	1.15	5.63	10.00	7.82
6	*Celtis philippensis*	Ulmaceae	11	25.1	0.13	1.01	4.94	10.00	7.47
Total						***13.54***	***92.04***	***75.00***	***83.53***

Bosqueia angolensis (19.34%), *Ricinodendron heudelotii* (13.12%) and *Lonchocarpus cyanescens* (11.66%) (Closed canopy), *Celtis zenkeri* (27.82%), *Cola gigantea* (11.48%) and *Cleistopholis patens* (8.55%) (Partial canopy cover), *Sterculia rhinopetala* (21.70%), *Trichilia monadelpha* (15.91%) and *Celtis zenkeri* (12.58%) (Open canopy) were among the dominant tree species in the overstory layer of Eda forest reserve (Table 5). For Shasha forest reserve, the dominant tree species in the overstory layer were *Sterculia rhinopetala* (20.68%), *Ricinodendron heudelotii* (16.95%) and *Cola gigantea* (10.66%) (closed canopy), *Cola acuminata* (17.64%), *Ficus exasperata* (15.75%) and *Mansonia altissima* (9.41%) (partial canopy cover) *Cola gigantea* (22.12%), *Gmelina arborea* (13.51%) and *Croton penduliflorus* (10.34%) (open canopy) (Table 6).

There are indications that only few tree species accounted for the floristic compositions of the three forest reserves as revealed by the results of the six dominant and important overstory tree species of the three canopy cover classes of our forests (Table 4 - 6). Depending on the canopy cover, the six species accounted for between 72.74 % - 92.04 % of the Relative Dominance (RDo) and 60.27 % and 83.53% of the Importance Value Index (IVI) of all tree species in Akure forest reserve (Table 4). At Eda forest reserve, the six species accounted for 64.8 - 75.07 % and 56.07 - 66.85 % of RDo and IVI, respectively of all trees at Eda forest reserve (Table 5). The same trend was observed at Shasha forest reserve where the six species accounted for 62.57 - 70.68 % of RDo and 55.38 - 58.42 % of IVI of all tree species in this forest reserve. (Table 6).

Table 5: Summary of growth characteristics and diversity indices of six dominant tree species in the three canopy cover classes of the overstory layer of Eda forest Reserve

S/N	**Tree Species**	**Family**	**Freq (ha^{-1})**	**Mdbh (cm)**	**BA (m^2)**	BA (m^2ha^{-1})	RDo (%)	**RD (%)**	**IVI (%)**
Closed canopy									
1	*Bosqueia angolensis*	Moraceae	27	37.04	0.62	3.29	19.34	7.69	13.51
2	*Ricinodendron heudelotii*	Euphorbiaceae	53	21.35	0.42	2.23	13.12	15.38	14.25
3	*Lonchocarpus cyanescens*	Papilionaceae	21	33.13	0.37	1.98	11.66	6.15	8.91
4	*Celtis zenkeri*	Ulmaceae	32	24.98	0.34	1.82	10.72	9.23	9.97
5	*Entandrophragma cylindricum*	Meliaceae	5	48.00	0.18	0.97	5.67	1.54	3.60
6	*Funtumia elastica*	Apocynaceae	27	17.20	0.13	0.68	3.97	7.69	5.83
Total						***10.97***	**64.48**	**47.68**	**56.07**
Partial canopy									
1	***Celtis zenkeri***	**Ulmaceae**	**43**	**25.13**	**0.47**	**2.49**	**26.73**	**16.67**	**21.70**
2	*Cola gigantea*	Sterculiaceae	11	34.90	0.19	1.03	11.03	4.17	7.60
3	*Cleistopholis patens*	Annonaceae	21	20.40	0.14	0.77	8.21	8.33	8.27
4	*Albizia ferruginea*	Mimosaceae	11	26.50	0.13	0.70	7.50	4.17	5.83
5	*Mansonia altissima*	Sterculiaceae	37	11.76	0.13	0.69	7.45	14.58	11.02
6	*Funtumia elastica*	Apocynaceae	16	16.37	0.07	0.38	4.12	6.25	5.18
Total						***6.06***	**65.04**	**54.17**	**59.60**
Open canopy									
1	***Sterculia rhinopetala***	**Sterculiaceae**	**43**	**19.09**	**0.26**	**1.39**	**21.70**	**27.59**	**24.64**
2	*Zanthoxylum zanthoxyloides*	Rutaceae	11	31.00	0.19	1.02	15.91	6.90	11.41
3	*Celtis zenkeri*	Ulmaceae	11	29.00	0.15	0.81	12.58	6.90	9.74
4	*Musanga cecropioides*	Moraceae	5	39.50	0.12	0.65	10.20	3.45	6.82
5	*Cola gigantea*	Sterculiaceae	11	24.50	0.10	0.53	8.24	6.90	7.57
6	*Trichilia monadelpha*	Meliaceae	11	20.50	0.08	0.41	6.44	6.90	6.67
Total						***4.81***	**75.07**	**58.64**	**66.85**

Table 6: Summary of growth characteristics and diversity indices for six dominant tree species in the three canopy cover classes in the overstory layer of Shasha forest Reserve

S/N	Tree Species	Family	Freq (ha^{-1})	Mdbh (cm)	BA (m^2)	BA (m^2ha^{-1})	RDo (%)	RD (%)	IVI
Closed canopy									
1	*Sterculia rhinopetala*	Sterculiaceae	21	44.83	0.91	4.86	20.68	5.71	13.2
2	*Ricinodendron heudelotii*	Euphorbiaceae	27	35.78	0.75	3.98	16.95	7.14	12.05
3	*Cola gigantea*	Sterculiaceae	43	21.04	0.47	2.5	10.65	11.43	11.04
4	*Celtis zenkerii*	Ulmaceae	37	21.23	0.29	1.56	6.63	10	8.32
5	*Sterculia tragacantha*	Sterculiaceae	16	32.73	0.29	1.56	6.63	4.29	5.46
6	*Trilepisium madagascariense*	Moraceae	21	22.25	0.22	1.15	4.91	5.71	5.31
Total						***15.61***	***66.45***	***44.28***	***55.38***
Partial canopy									
1	*Cola acuminata*	Sterculiaceae	32	24.47	0.31	1.67	17.64	11.32	14.48
2	*Ficus exasperate*	Moraceae	48	18.96	0.28	1.49	15.75	16.98	16.36
3	*Mansonia altissima*	Sterculiaceae	21	22.3	0.17	0.89	9.41	7.55	8.48
4	*Celtis philippensis*	Ulmaceae	5	39.9	0.13	0.67	7.05	1.89	4.47
5	*Tectona grandis*	Verbenaceae	27	16.1	0.12	0.63	6.72	9.43	8.07
6	*Ficus mucuso*	Moraceae	11	23.2	0.11	0.57	6	3.77	4.89
Total						***5.92***	***62.57***	***50.94***	***56.75***
Open canopy									
1	*Cola gigantea*	Sterculiaceae	11	38.15	0.23	1.24	22.12	7.69	14.91
2	*Gmelina arborea*	Verbenaceae	11	30.05	0.14	0.76	13.51	7.69	10.6
3	*Croton penduliflorus*	Euphorbiaceae	5	37.2	0.11	0.58	10.34	3.85	7.09
4	*Terminalia superba*	Combretaceae	16	18.4	0.1	0.51	9.18	11.54	10.36
5	*Trema orientalis*	Ulmaceae	5	33.7	0.09	0.48	8.48	3.85	6.16
6	*Ricinodendron heudelotii*	Euphorbiaceae	16	17.7	0.07	0.4	7.05	11.54	9.3
Total						***3.97***	***70.68***	***46.16***	***58.42***

DISCUSSION

Tropical rainforests are the richest forest communities on earth (Pillay *et al.*, 2022; Rahayu *et al.*, 2022). However, they are vulnerable to many anthropogenic activities, particularly deforestation, forest degradation and farming, probably due to the high species diversity they habour. Onyekwelu *et al.* (2008) opined that the high species diversity of tropical rainforests is partly responsible for the high degradation pressure to which they have been and are still being subjected. The higher number of families recorded in closed canopy portions of the three forest reserves compared to the other two canopy cover classes could be as a result of the little or no anthropogenic disturbances in the closed canopy portions of the forests. The lower number of families enumerated within the open canopy class is attributed to anthropogenic activities like illegal logging, farming, animal grazing, etc. When farmers encroach into the forest, they usually open up the canopy to allow light reach the forest floor to promote growth of their crops.

Biodiversity indices are usually generated to bring the floristic diversity and abundance in different habitats to similar scale for comparison, which is important for conservation Onyekwelu, 2021). Tree species richness is an important measure of forest biodiversity. Our results indicated that there were 34, 26 and 11; 29, 24 and 16 as well as 26, 23 and 18 tree species under the closed canopy, partial canopy and open canopy classes of Akure SNR, Eda and Shasha forest reserves, respectively. The higher species richness in the closed canopy, especially in Akure SNR could be the result of minimal human activities in this part of the forest and an indication of its dense vegetation cover. Akure SNR is a protected inviolate tropical rainforest ecosystem with no history of human intervention for almost a century, which could explain its higher species richness compared to the other forest reserves in this study. Our results are in tandem with those of Rahman *et al*. (2009) who reported higher tree species richness in a slightly disturbed site compared with medium and highly disturbed sites in Sal forest, Bangladesh.

The lower tree species richness enumerated in the open canopies of the three forests is an indication of the adverse effect of the exposure of forests to human activities like logging, farming, grazing, among others. This agrees with the findings of Bargali *et al*., (2014) for dry deciduous forest of Barnawapara wildlife Sanctuary, India. Kung'u *et al.* (2023) showed that *human* presence and *activities* at both the plot and landscape level explained variations in vegetation structure in a Kenyan biodiversity hotspot. Tree species richness followed the trend: closed canopy > partial canopy cover > open canopy, which implies that species richness decreased as canopy openness increased, in other words tree species richness decreases as degradation activities increases. In a study in tropical forest ecosystems of south western Nigeria, Onyekwelu *et al*., (2008) observed that species richness decreased as the intensity of forest disturbance and degradation increased, which is in agreement with the results of current study. The low species richness under open canopy could be an indication of increased exploitation through activities such as cutting of trees for timber and fuelwood, gathering of fruits and other non-timber forest products that might have effect on tree species composition, which was also the view of Nath *et al*. (2005). The densities obtained under open canopies of our three forests are similar to the results of Olajuyigbe and Adaja (2014) as well as Iyagin and Adekunle (2017) for similarly disturbed ecosystems. This confirms the widely held opinion that disturbances are among the major causes of reduction in tree density and species richness in forest ecosystems.

Higher basal areas were recorded under the closed canopy portion of the three forests. The higher basal area of the closed canopy cover could be an indication of higher productivity at this portion of the forests. The basal areas of the closed canopies of three forests in this study (range: 17.06 m^2ha^{-1} - 79.15 m^2ha^{-1}) are higher and/or comparable with the 22.54 m^2ha^{-1} reported for a strict nature reserve (Adekunle *et al*., 2013) and the 41.59 m^2ha^{-1} reported for a primary forest in Cross River National Park (Jimoh *et al*., 2012). The basal area range for partial canopy cover in our forests (range: 9.32 m^2ha^{-1} - 20.4 8m^2ha^{-1}) is similar to the 10.29 m^2ha^{-1} reported by Olajuyigbe and Adaja (2014) and the 16.84 m^2ha^{-1} by Adekunle and Olagoke (2008). This result can be explained by moderate exposure/disturbance of this portion of the forests, coupled with the tree stocking level that has been reduced by human impact. The basal area range of 5.48 m^2/ha - 6.41 m^2/ha for open canopy sections of our forests agrees with the range of 1.31 m^2/ha - 13.78 m^2/ha estimated by Sagar and Singh (2006) for a disturbed forest in northern India. The very low basal area production under the open canopy is an indication that this portion of the forest has been highly degraded, probably due to human induced disturbances.

The Shannon-Wiener index value range of 2.85 to 3.11 obtained for the closed and partial canopy cover classes of our three forest reserves are similar to the range of 3.34 to 3.66 and 2.82 to 3.32 recorded for some rainforest ecosystems in Nigeria (Adekunle *et al*., 2013; Onyekwelu *et al*., 2008; Onyekwelu *et al*., 2021; 2022) but less than the 3.76 to 3.96 obtained by Adekunle *et al*. (2013). The value obtained is also lower than 3.83 recorded by Aigbe e*t al*. (2014); the 3.55 obtained by Sarkar and Devi (2014) but higher than 2.20 recorded by Bargali *et al*. (2014) for less disturbed and moderately disturbed forests. The Shannon-Wiener diversity index range of 2.22 - 2.79 obtained for open canopy in the three forests are comparable to 2.20 - 2.65 recorded by Sundarapandian and Swamy (2000) but higher than 0.63 obtained by Bargali *et al*. (2014) in open canopy of dry deciduous forest in India. The higher H′ value in the closed canopy, compared to partial and open canopy cover classes of our three forests implies higher species diversity under the closed canopy, which could be attributed to the fact that this canopy layer is less disturbed. This was corroborated by the findings of Nath (2005) who obtained higher species diversity in undisturbed forest than moderately and highly disturbed forests in India.

The higher species richness recorded under the closed canopy of the three forests compared to other canopy cover classes can be attributed to factors such as intactness of the forest structure, litter quality available to understory plants (Gregory, 2006), absence of anthropogenic disturbance activities (Bobo *et al*., 2006), among others. Thus, the higher richness and diversity of tree species and families recorded under closed canopies of the three forests was as a result of little or no disturbance under the closed canopy layers. Contrary to our results, Zubair *et al*. (2021) observed that site with partial canopy exhibited the highest diversity, dominance, and abundance of medicinal plants in moist temperate forests in Northern Pakistan compared to open spaces and closed canopy. It has been demonstrated that population density of plant species can be reduced by natural or anthropogenic disturbance and this can further lead to extinction of endangered species (Bargali *et al*., 2014).

In addition, the higher basal area, which was recorded under the closed canopy of the three forests in this study compared to other canopy types, could be attributed to the presence of more large trees under the closed canopies. The presence of large trees in the closed canopy is further confirmation that the closed canopy site experienced little or no disturbance. High mean dbh were recorded in the closed canopy layers of the three forest reserves, which shows that the sites provide more nutrient for the plants to thrive.

CONCLUSION AND RECOMMENDATIONS

The overstory layer of the closed canopy portion of three forests in this forest had the highest biodiversity indices, which was attributed to the little or no human interference in this portion of the forests. The higher diversity indices under the closed forest canopy is an indication of better biodiversity conservation in intact or less disturbed forests and that intactness (conservation) of a forest promotes regeneration of tree seedlings and offer favorable condition for understory plants to thrive. Following the trend of our results, it can be concluded that richness and composition of understory tree species could a result of their different responses to biotic and abiotic factors. The generally poor results under the open canopy portions of the three forests further strengthens the conclusion that canopy openness, occasioned by forest disturbances, negatively affects productivity and biodiversity conservation status of tropical forests. There should be policy and sensitization aimed towards preventing further degradation activities and deforestation of forest ecosystems. Tree species with low RDo and IVI should be considered as endangered and efforts on their conservation should be intensified to prevent them from going into extinction. Restoration of the open canopy portion of the forests is necessary using silvicultural interventions such as enrichment planting.

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