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***E-mail:** jrfwe2019@gmail.com; jfewr@yahoo.com*
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EDGE-INTERIOR DISPARITIES IN TREE SPECIES DIVERSITY AND SOIL PHYSICOCHEMICAL PROPERTIES IN A NIGERIAN STRICT NATURE RESERVE

Lawal, A. and Ariyo, R. O.

Department of Forestry and Wood Technology, Federal University of Technology Akure, Ondo State, Nigeria.

Corresponding Author:alawal@futa.edu.ng; 07031641263

ABSTRACT

This study was designed to compare the variation in species richness, diversity of trees and soil physiochemical properties along the edge-interior gradient of a Nigerian Strict Nature Reserve located in Akure Forest Reserve, Ondo State. The forest was categorized into three habitats, namely: edge (0–100m), intermediate (100–200m), and interior (> 200m), depending on the distance from the forest margin. A total of five plots of 20m x 20m were laid in each habitat where data on mature trees, saplings and seedlings were collected. Soil samples were also collected for laboratory analysis. This study revealed that forest edge and intermediate were relatively similar but different from the forest interior in terms of tree species richness, diversity, evenness and structural composition respectively. The forest interior possessed higher species richness (25), diversity (2.93) and density of mature trees (89/ha), while the intermediate and edge possessed higher tree saplings (179/ha, 237/ha) and seedlings (611/ha, 358/ha). However, the soil physicochemical properties, except soil organic matter and organic carbon at 15-30cm, were uniform along the edge/interior gradient of the reserve. Since this forest edge and intermediate had higher regeneration potential than the forest interior, strict conservation measure should be put in place to protect the regenerated tree saplings and seedlings in this nature reserve.

Keyword: Forest edge, tree diversity, soil physiochemical properties, human impact

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Introduction

Forest edge is known to be unique because it combines the characteristic features of more than two forest types. Sulistyawati and Tihurua (2019) discovered that forest fragmentation creates forest edges that possess different biotic characteristic in comparison to its interior. According to them, a forest patch located in an open landscape forms forest parts with different characteristics; the interior and edge forest. Various studies done in tropical forests have reported negative impacts of forest fragmentation (Lawal and Adekunle 2013, Akindele *et al.* 2021, Fasalejo *et al.* 2021). the major impacts of forest fragmentation include, but not limited to reduction in recruitment rates of trees due to habitat desiccation and seedling damage by litter and tree falling near forest edges; many human activities at the edges include uprooting, stumbling on growing plants that may not survive and may put the edge at the risk of soil erosion and shallow landslides.

Herlin (2001) discovered that forest edges are the physical vegetation structures that form the transition zone between the forest and open land cover or other land uses. Thus they modify and affect multiple processes in the landscape as they

can work as filters, barriers, corridors, and habitats. This is strongly related to the vegetation structure and species composition of the forest itself. Forest edges are unique not only because they combine some of the characteristics of at least two adjacent vegetation types but they also consist of two or more different ecological features that are associated with variations in the convergence of plants species (Herlin, 2001).

Forest edges are generally made up of sun-tolerant species such as pioneer species with low wood density but species that grow inside forest interiors are those that are shade-tolerant, and in general, belong to climax species that have high wood density (Swaine and Whitmore 1988). No matter what the main factor behind the causes of decreasing biodiversity, most especially at the edges, the knowledge on edge-interior species could help to protect, maintain and use the forest in a sustainable manner. Turkisandelmas (2018) pointed out that the development of management plans focusing on the dynamics and biodiversity of forest ecosystem can only be possible if the processes of the ecosystems are learned and the information collected is institutionalised.

The Strict Nature Reserve (SNR), also known as queen plot, covers an area of 32 ha in Akure Forest Reserve and it is under the management of the forestry research institute of Nigeria (FRIN). Studies on tree species diversity and soil chemical properties had been carried in this plot by few researchers (Lawal and Adekunle 2013, Adekunke *et al.* 2013). However, information about tree species richness, abundance, diversity and soil characteristics along the edge-interior gradient of the plot is scarce. Murcia (1995) pointed out that the characteristics differences between interior and edge of forest highlight how important it is to consider the conservation area. Hence, the need for this study.

MATERIALS AND METHODS

Study Area

This study was carried out in a Nigerian Strict Nature Reserve. The Strict Nature Reserve (SNR) is located in Akure Forest Reserve, Ondo State, Nigeria (Fig. 1). It covers a total area of 32ha and it is under the management of the forestry research institute of Nigeria. The adjacent vegetation consists of farmlands and a buffer zone where some disgruntled elements have been carrying out illegal logging activities, fetching firewood and collecting other non-timber forest products (NTFPs). Akure forest reserve lies between Ondo–Akure road, beginning at about 20 km south of Akure, the capital city of Ondo State. The area is gently undulating and lies on a general altitude of 229 m above sea level (jones 1948). The climate is humid tropical with seasonal variation (Lawal and Adekunle 2013). The mean annual rainfall is about 4000 mm with double maxima in the months of July and September and a short relatively dry period in August. December through to February constitutes the major dry season (Ola-Adams and Hall 1987). The monthly mean temperature is about 27°c, a condition that is conducive to the development of tropical rainforest.

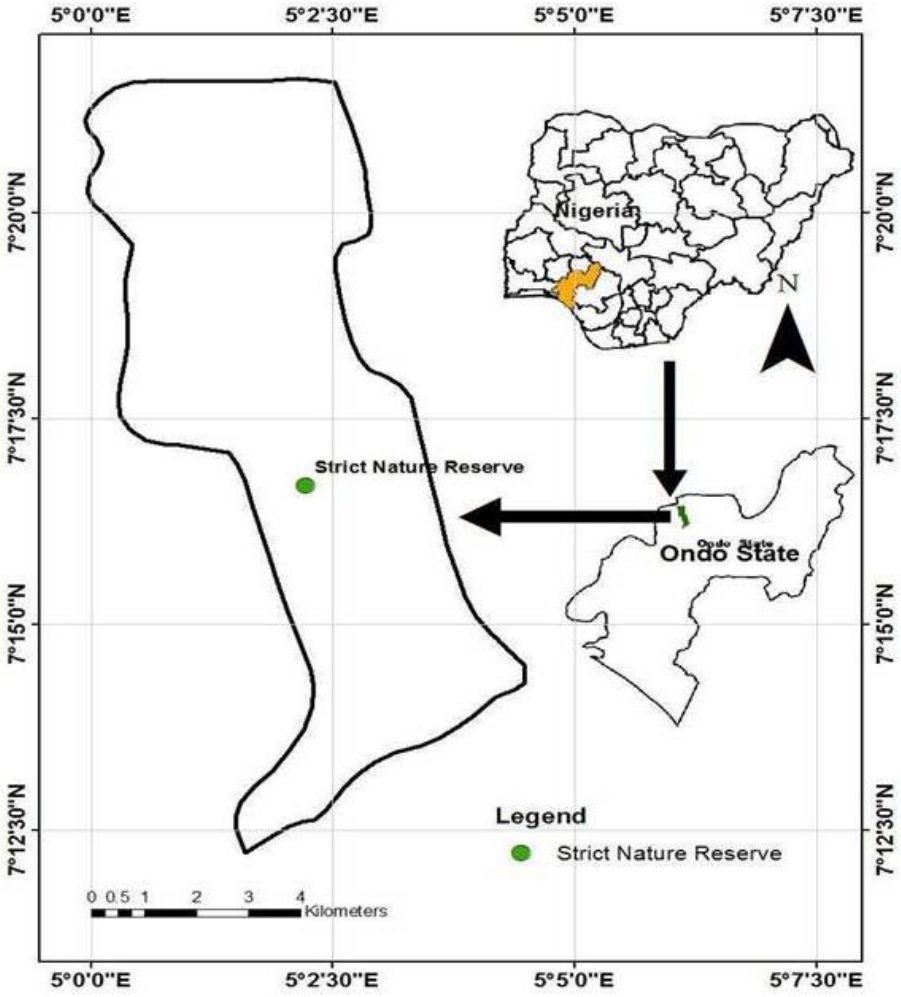

Fig. 1: Map of Akure Strict Nature Reserve

Sampling Procedure

Following Kacholi (2014), the forest was classified into three habitats, namely edge (0-100m), intermediate (100-200m) and interior (>200) depending on the distance from the forest margin. A total of five plots of 20m x 20m were laid in an alternate direction along a line transect in each of the forest habitats.

Data Collection

According to Onyekwelu *et al*. (2021), trees were classified as mature trees (DBH≥10cm), saplings (Dbh≥1cm and ≤10cm) and seedlings (Dbh ≤1cm). In each plot, all trees with DBH≥10cm were identified; their diameters at breast height (dbh), diameter at the base (D_b)were measured with girth diameter tape, diameter at the middle (D_m) diameter at the top (D_t) and height (H_t) were measured using Spiegel relaskop. Saplings, tree species with Dbh≥1cm and ≤10cm, were identified and their dbh were measured with vernier caliper. Also, all seedlings, species with Dbh ≤1cm, were counted**.** Soil samples were also collected diagonally, at 0–15 cm and 15–30 cm depths respectively, from three randomly selected plots in each habitat. Soil samples from the same depth and from the same plot were thoroughly mixed to form a composite sample, from which samples were collected for laboratory analysis.

Data Analysis

The basal area of individual tree was calculated using the formula:

$BA = \frac{\pi D^2}{4}$ ….. (1)

Where: BA = basal area (m^2), D = DBH (cm) and π = Pie (3.142).

Basal area per hectare was obtained by multiplying mean basal area per plot with the number of 20× 20 m plots in a hectare (25),

$BA_{ha} = \overline{BA} * 25$….. (2)

Where BA_{ha}= basal area per hectare.

The volume of individual trees was also estimated using the Newton's formula of Husch*et al*. (2003): $V = \frac{\pi h}{24}(D^2_b + 4D^2_m + D^2_t)$ …… (3)

Where: V= volume of tree (m^3), D_b= diameter at the base (m^3), D_m= diameter at the middle (m^3), D_t= diameter at the top (m^3) and H= height (m).

Volume per hectare was obtained by multiplying mean volume per plot $\overline{V}_P$ with the number of 20 x 20m plots in a hectare.

$V_{ha} = \overline{V}_P$ x 25 ……. (4)

The following biodiversity indices were computed:

(i) Shannon-Weiner diversity index (Kent and Coker, 1992):

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \quad \text{…… (5)}$$

Where: H' = Shannon-Weiner diversity index, S = Total number of species in the community,

P_i = proportion of S made up of the i^{th} species, ln = natural logarithm

(v) Species evenness in each community was determined using Shannon's equitability (E_H):

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)} \quad \text{…. (6)}$$

(vi) Mangalef's index was calculated as:

$$D = \frac{S-1}{\ln N} \quad \text{…. (7)}$$

Where: S = number of species

N = number of individual

(vii) Simpson's index

$$D = 1 - \sum \left(\frac{n_i}{N}\right)^2 \quad \text{…… (8)}$$

Where:

n_i = number of individual of species i

N = total number of all tree species in the entire community

The soil organic carbon and matter were determined using Walkley and Black method (Walkley and Black 1934). Soil pH was determined in water suspension, using electronic method (pH meter). Five grams (5g) of soil sample was measured into a cup and 10ml of distilled water was then added. It was stirred severally and left for 30minutes after which the pH meter was set on to stabilize and adjusted to a neutral level in order to get the actual reading of the sample. The pH of the soil was measured by immersing a glass electrode deeply into the partly-settled suspension and the reading was taken. Soil salinity was also determined in water suspension, using an electronic method (salinity meter). 5g of soil measured into a cup after which 10ml of distilled water was added. The salinity of the soil was measured by immersing an electrode into the measured soil sample and the reading was taken. Particle size analysis was determined using hydrometer method with calgon (sodiumhexametaphosphate) as a dispersing agent (Black *et al*. 1965).

The USDA particle size classification was adopted in expressing soil particle size fractions (soil survey staff 2003). 51g of air dried sample was weighed into a cup, 100ml of calgon solution was added to the soil, mixed and allowed to soak for 24hours. The soil solution was then transferred into a measuring cylinder and filled to a 1000ml mark with a hydrometer suspended in the cylinder. The hydrometer was removed and a plunger was inserted to move up and down in order to mix the content thoroughly for 40 seconds after which the hydrometer was carefully lowered into the measuring cylinder, reading was taken and temperature was recorded using hydrometer. Another hydrometer and temperature reading was taken after two hours.

The particle size distribution was calculated using the formula:

$$\%\text{Silt} + \%\text{Clay} = R40secs + \frac{(T1 - 20℃ \times 0.36)}{Weight\ of\ soil} \times 100 \quad \text{… (9)}$$

$$\%\text{Sand} = 100 - (\%Silt + \%Clay) \quad \text{…(10)}$$

$$\%\ \text{Clay} = R2hrs + \frac{(T2 - 20℃ \times 0.36)}{Weight\ of\ soil} \times 100 \quad \text{…(11)}$$

$$\%\text{Silt} = 100 - (\%Sand + \%Clay) \quad \text{…. (12)}$$

Where: $R40secs$ = hydrometer reading after 40 seconds

T_1=temperature after 40 seconds

$R2hrs$ = hydrometer reading after 2 hours
T_2 = temperature reading after 2 hours
Bulk density was determined by using core samplers to get soil from the three selected habitats (Edge, intermediate and interior of the forest reserve) and the weight, height, diameter and radius of the samplers were taken before going to the field. The core samplers were inserted deeply into the soil, removed gently and wrapped in a foil paper tightly after which the weight was taken. It was oven dried for 3 days and the final weight was taken.
The bulk density was calculated using the formula:
Bulk density = $Db = \frac{W_3 - W_1}{V}$ …. (13)
Where: W_3 = weight of oven dried soil with can, W_1 = weight of can,
V = $\frac{22}{7} \times r^2 \times h$…. (14)
Where: R = radius of the can and V = height of the can
Moisture content was calculated from the weight taken and recorded from bulk density.
The moisture content was calculated as:
$\%M.C = (\frac{W_2 - W_3}{W_3 - W_1}) \times 100$ …… (15)
Where: W_2 = weight of the can with soil
W_3 = weight of oven dried soil with can
W_1 = weight of can.
One-way analysis of variance (ANOVA) was carried to test the significant difference among means and where significant difference exist, Duncan New Multiple range test was used for mean separation.

RESULTS

Floristic and abundance of mature trees

Mature tree species distribution and abundance at the edge, intermediate, and interior of the forest reserve is presented in Table 1. *Mansonia altissima* had the highest relative abundance (16.0), followed by *Celtis zenkeri* (11.6) and *Sterculia rhinopetala* (11.6) respectively. The distribution of *Mansonia altissima* was uniform among the three forest classes. More so, the population of *Sterculia rhinopetala* (a non-pioneer light demander) was conspicuously higher in the forest interior than other species in this forest reserve. The edge had a total of 67 individual trees and the interior had 89 individual trees, indicating an increase in the species density from the edge to the interior part of the Forest Reserve.

Table 1: Mature tree species distribution and abundance at the edge, intermediate and interior of the forest reserve.

S/N	Scientific Name	Family	Edge	Intermediate	Interior	Total	Relative Abundance
1	*Amphimas pterocarpoides*	Leguminosae	2	0	0	2	0.9
2	*Anonidium mannii*	Annonaceae	0	4	2	6	2.7
3	*Antidesma acidum*	Phyllanthaceae	0	2	2	4	1.8
4	*Blighia sapida*	Sapindaceae	2	0	0	2	0.9
5	*Brachystegia eurycoma*	Fabaceae	1	1	0	2	0.9
6	*Brachystegia nigerica*	Fabaceae	0	1	0	1	0.4
7	*Buchholzia coriacea*	Capparaceae	2	0	0	2	0.9
8	*Celtis philipensis*	Ulmaceae	0	6	3	9	4.0
9	*Celtis zenkeri*	Ulmaceae	11	10	5	26	11.6
10	*Chrysophyllum albidium*	Sapotaceae	3	0	3	6	2.7
11	*Chrysophyllum purpulchrum*	Sapotaceae	0	2	2	4	1.8
12	*Cola acuminata*	Sterculiaceae	1	2	1	4	1.8
13	*Cola gigantea*	Sterculiaceae	1	1	0	2	0.9
14	*Cola heterophylla*	Sterculiaceae	1	0	0	1	0.4
15	*Cordia millenii*	Boraginaceae	3	0	1	4	1.8
16	*Desplatsia subericarpa*	Tiliaceae	0	0	3	3	1.3
17	*Drypetes acuminata*	Putranjivaceae	4	0	1	5	2.2
18	*Entandrophragma angolense*	Meliaceae	0	1	0	1	0.4

19	*Entandrophragma utile*	Meliaceae	3	3	2	8	3.6
20	*Funtumia elastic*	Apocynaceae	3	4	5	12	5.3
21	*Khaya grandifoliola*	Meliaceae	0	1	0	1	0.4
22	*Licania tomentosa*	Chrysobalanaceae	0	1	0	1	0.4
23	*Mansonia altissima*	Malvaceae	11	13	12	36	16.0
24	*Melancantha alnifolia*	Asphodelaceae	0	1	4	5	2.2
25	*Monodora myristica*	Annonaceae	0	1	0	1	0.4
26	*Nesogordonia papaverifera*	Malvaceae	5	1	1	7	3.1
27	*Picralimanitida*	Apocynaceae	0	0	1	1	0.4
28	*Pterocarpus osun*	Fabaceae	0	0	5	5	2.2
29	*Pterygota macrocarpa*	Malvaceae	0	0	2	2	0.9
30	*Pycnanthus angolensis*	Myristicaceae	0	0	1	1	0.4
31	*Spathodea campanulata*	Bignoniaceae	0	0	2	2	0.9
32	*Sterculia rhinopetala*	Malvaceae	2	7	16	25	11.2
33	*Strombosia postulate*	Olacaceae	0	1	2	3	1.3
34	*Terminalia ivorensis*	Combretaceae	1	0	0	1	0.4
35	*Terminalia superb*	Combretaceae	2	0	0	2	0.9
36	*Trichilia welwitschii*	Meliaceae	0	0	3	3	1.3
37	*Trichilia heudelotii*	Meliaceae	1	1	5	7	3.1
38	*Trilepisium madagascariense*	Moraceae	1	0	0	1	0.4
39	*Triplochiton scleroxylon*	Malvaceae	7	6	5	18	8.0
40	*Vitex altissima*	Lamiaceae	0	1	0	1	0.4
	Total		**67**	**71**	**89**	**227**	**100**

Sapling's Composition and Abundance in the Study Area

Saplings distribution and abundance along the edge-interior gradients of the study area is presented in Table 2. This study revealed a gradual decline in the sapling abundance along the edge-interior gradient. At the edge, a total of 237 individual saplings were recorded. At the intermediate, a total of 179 individual saplings were found and 172 individual saplings at the interior respectively. Some important tree species such as *Baphia nitida*, *Celtis zenkeri*,*Dospyros dendo*, *Sterculia rhinopetala*, *Strombosia postulata* were found in all the forest classes. However, *Chrysophyllum abidum* was only recorded in the forest edge.

Table 2: Saplings distribution and abundance at the edge, intermediate and interior of the forest reserve

S/N	**Scientific Name**	**Family**	**Edge**	**Intermediate**	**Interior**	**Total**	**Relative Abundance**
1	*Albizia ferruginea*	Fabaceae	1	0	0	1	0.2
2	*Albizia zygia*	Mimosoideae	0	5	0	5	0.9
3	*Afzelia africana*	Fabaceae	1	0	0	1	0.2
4	*Amphimas pterocarpoides*	Leguminosae	1	0	0	1	0.2
5	*Anthonotha macrophylla*	Leguminosae	3	0	0	3	0.5
6	*Antiaris africana*	Moraceae	1	0	0	1	0.2
7	*Antidesma acidum*	Phyllanthaceae	3	3	0	3	0.5
8	*Baphia nitida*	Leguminosae	7	10	10	27	4.7
9	*Baphia obanensis*	Leguminosae	1	0	10	11	281
10	*Blihia sapida*	Sapindaceae	1	0	0	1	
11	*Brachystigia nigerica*	Fabaceae	7	3	0	10	1.7
12	*Buchholzia coriacea*	Capparaceae	1	0	0	1	0.2
13	*Carpolobia lutea*	Polygalaceae	7	9	6	22	3.8

14	*Celtis phillipensis*	Ulmaceae	3	2	0	5	0.9
15	*Celtis zenkeri*	Ulmaceae	3	8	2	13	2.2
16	*Chrysophyllum abidum*	Sapotaceae	15	0	0	15	2.6
17	*Chrysophyllum purpulchrum*	Sapotaceae	0	0	6	6	1.0
18	*Cleistopholis patens*	Annonaceae	2	0	0	2	0.3
19	*Cola acuminate*	Sterculiaceae	0	3	3	6	1.0
20	*Cola gigantean*	Sterculiaceae	0	6	0	6	1.0
21	*Cola heterophylla*	Sterculiaceae	7	0	2	9	1.5
22	*Cola hispida*	Sterculiaceae	6	1	2	9	1.6
23	*Cola nigerica*	Sterculiaceae	1	1	0	2	0.3
24	*Deinbollia pinnata*	Sapindaceae	1	0	0	1	0.2
25	*Dialiumguineense*	Fabaceae	0	0	4	4	0.7
26	*Diospyrosdendo*	Ebenaceae	14	6	8	28	4.8
27	*Diospyros monbuttensis*	Ebenaceae	1	0	0	1	0.2
28	*Drypetes gilgiana*	Putranjivaceae	3	3	0	6	1.0
29	*Entandrophragma angolense*	Meliaceae	0	2	0	2	0.3
30	*Entandrophragma utile*	Meliaceae	1	1	0	2	0.3
31	*Funtumia elastic*	Apocynaceae	33	8	10	51	8.8
32	*Keetia gueinzii*	Rubiaceae	2	0	0	2	0.3
33	*Mallotus oppositifolius*	Euphotbiaceae	10	4	11	25	4.3
34	*Monodora tenuifolia*	Annonaceae	1	0	0	1	0.2
35	*Mansonia altissima*	Malvaceae	3	1	0	4	0.7
36	*Melancantha alnifolia*	Asphodelaceae	0	4	14	18	3.1
37	*Microdesmis puberula*	Pandaceae	15	12	9	36	6.2
38	*Milicia excels*	Moraceae	1	0	0	1	0.2
39	*Napoleonaea imperialis*	Lecythidaceae	3	3	11	14	2.4
40	*Newbouldia leawis*	Bignoniaceae	2	0	0	2	0.3
41	*Nauclea longiflora*	Cactaceae	1	0	0	1	0.2
42	*Paullinia tomentosa*	Paulowniaceae	0	3	0	3	0.5
43	*Picralima nitida*	Apocynaceae	4	8	0	12	2.1
44	*Pterygota macrocarpa*	Malvaceae	1	2	4	7	1.2
45	*Pycnanthus angolensis*	Myristicaceae	2	9	0	11	1.9
46	*Rhinorea dentata*	Violaceae	7	17	15	39	6.7
47	*Rhinorea melanodonta*	Violaceae	2	0	0	2	0.3
48	*Rinorea brachypetala*	Violaceae	1	15	0	16	2.8
49	*Rinorea oblongifolia*	Violaceae	7	0	15	22	3.8
50	*Rothmannia longiflora*	Rubiaceae	0	3	0	3	0.5
51	*Rothmannia whitfieldii*	Rubiaceae	2	0	0	1	0.2
52	*Spathodea camponulata*	Bignoniaceae	0	1	0	1	0.2
53	*Sphenocentrum jollyanum*	Menispermaceae	1	0	0	1	0.2
54	*Spilanthes bratiolata*	Asteraceae	7	0	0	7	1.2
55	*Sterculia oblonga*	Malvaceae	1	0	0	1	0.2
56	*Sterculia rhinopetala*	Malvaceae	3	2	3	8	1.4
57	*Sterculia tragacantha*	Malvaceae	1	0	0	1	0.2

58	*Strombosia postulata*	Olacaceae	10	11	25	46	8.0
59	*Synsepalum brevipes*	Sapotaceae	0	2	0	2	0.3
60	*Tabernaemontana divaricata*	Apocynaceae	2	0	0	2	0.3
61	*Trichilia welwitschii*	Meliaceae	0	1	0	1	0.2
62	*Trichilia heudelotii*	Meliaceae	14	4	0	18	3.1
63	*Trilepisium madagascariensis*	Moraceae	10	3	2	15	2.6
64	*Triplochiton scleroxylon*	Malvaceae	0	1	0	1	0.2
65	*Zanthoxylum zanthoxyloides*	Rutaceae	0	2	0	2	0.3
	Total		**237**	**179**	**172**	**581**	**100**

Seedlings Composition and Abundance in The Study Area

This study recorded 1,201 seedlings belonging to 59 species (Table 3). *Albizia zygia* in the family of Mimosoideae has the highest number of individuals (235) and a relative abundance of 19.7%, followed by *Triplochiton scleroxylon* (176) in Malvaceae family with a relative abundance of 14.7%. The intermediate part of the forest had the highest number of tree seedlings (611), followed by the forest edge (358) and forest interior (285) respectively.

Table 3: Seedlings distribution and abundance at the edge, intermediate and interior of the forest reserve

S/N	Scientific Name	Family	Edge	Intermediate	Interior	Total	Relative Abundance
1	*Albizia zygia*	Leguminonaceae	1	235	0	236	19.7
2	*Alstonia boonei*	Apocynaceae	0	0	3	3	0.2
3	*Amphimas pterocarpoides*	Leguminonaceae	4	0	0	4	0.3
4	*Anthonotha macrophylla*	Leguminosae	0	1	0	1	0.1
5	*Anthonotha obanensis*	Leguminosae	6	0	0	6	0.5
6	*Antidesma acidum*	Phyllanthaceae	5	0	0	5	0.4
7	*Baphia nitida*	Leguminosae	8	8	10	26	2.2
8	*Blighia sapida*	Leguminosae	3	3	15	21	1.7
9	*Blighia unijugata*	Leguminosae	0	4	0	4	0.3
10	*Barteria fistulosa*	Passifloraceae	0	2	2	4	0.3
11	*Brachystegia nigerica*	Fabaceae	11	4	0	15	1.2
12	*Carpolobia lutea*	Polygalaceae	2	2	12	16	1.3
13	*Celtis philippensis*	Ulmaceae	8	0	0	8	0.7
14	*Celtis zenkeri*	Ulmaceae	1	6	1	8	0.7
15	*Chrysophyllum albidum*	Sapotaceae	0	1	0	1	0.1
16	*Chytrathus macrobotryx*	Sapindaceae	0	0	1	1	0.1
17	*Cnestis ferruginea*	Connaraceae	0	1	1	2	0.2
18	*Coffeae bratiolata*	Rubiaceae	1	1	0	2	0.2
19	*Cola heterophylla*	Sterculiaceae	4	0	0	4	0.3
20	*Cola hispida*	Sterculiaceae	1	2	2	5	0.4
21	*Cola nigerica*	Sterculiaceae	2	0	0	2	0.2
22	*Diospyros dendo*	Ebenaceae	8	4	12	24	2.0
23	*Diospyros lotus*	Ebenaceae	8	3	4	15	1.2
24	*Diospyros mobutensis*	Ebenaceae	1	0	0	1	0.1
25	*Diospyros suaveolens*	Ebenaceae	0	1	0	1	0.1
26	*Drypetes gossweileri*	Euphorbiaceae	2	0	0	2	0.2
27	*Drypetis gilgiana*	Putranjivaceae	3	4	91	98	8.2
28	*Entandrophragma angolense*	Meliaceae	0	2	0	2	0.2
29	*Entandrophragma utile*	Meliaceae	5	0	3	8	0.7
30	*Euclinia longiflora*	Rubiaceae	1	0	0	1	0.1
31	*Futumia elastic*	Apocynaceae	11	19	34	11	0.9

32	*Lannea welwitchii*	Meliaceae	1	4	0	5	0.4
33	*Lecanodiscus cupanoides*	Meliaceae	0	1	0	1	0.1
34	*Mallotus oppositifolia*	Euphorbiaceae	17	6	5	28	2.3
35	*Mansonia altissima*	Malvaceae	5	0	0	5	0.4
36	*Markhamia lutia*	Bignoniaceae	0	2	0	2	0.2
37	*Melancantha alnifolia*	Asphodelaceae	0	3	0	3	0.2
38	*Microdesmis puberula*	Pandaceae	5	2	10	17	1.4
39	*Milicia excels*	Moraceae	1	0	0	1	0.1
40	*Monodora myristica*	Anonacea	0	1	0	1	0.1
41	*Monodoria tenufolia*	Annonaceae	4	1	2	7	0.6
42	*Nepenthes holdenii*	Nepenthaceae	0	0	1	1	0.1
43	*Nepenthes purpurea*	Sarraceniaceae	0	0	3	3	0.2
44	*Oxyanthus pyriformis*	Rubiaceae	0	0	1	1	0.1
45	*Paullinia pinnata*	Sapindaceae	0	2	0	2	0.2
46	*Picralima nitida*	Apocynaceae	1	0	1	2	0.2
47	*Pterygota macrocarpa*	Malvaceae	0	0	1	1	0.1
48	*Pycnanthus angolensis*	Myristicaceae	0	2	1	3	0.2
49	*Rinorea brachypetala*	Violaceae	3	10	0	13	1.1
50	*Rinorea dentate*	Violaceae	40	124	1	165	13.7
51	*Rothmannia longiflora*	Rubiaceae	0	3	0	3	0.2
52	*Sphenocentrum jollyanum*	Menispermaceae	77	22	40	139	11.6
53	*Sterculia guttata*	Malvaceae	1	0	0	1	0.1
54	*Sterculia rhinopetala*	Sterculiaceae	3	2	7	12	1.0
55	*Strombosia postulate*	Olacaceae	7	14	21	42	3.5
56	*Strombosia pustulata*	Olacaceae	0	2	0	2	0.2
57	*Trichilia heudelotii*	Meliaceae	20	7	0	27	2.2
58	*Trilepisium madagascariensis*	Moraceae	0	1	0	1	0.1
59	*Triplochiton scleroxylon*	Malvaceae	77	99	0	176	14.7
	Total		**358**	**611**	**285**	**1201**	100

Trees and sapling growth characteristics along the Edge-Interior Gradient of the Forest

The growth characteristics of the mature trees and saplings along the edge-interior gradient of the forest are presented in Table 4. Forest edge had the highest mean DBH of 38cm, followed by the intermediate (36cm) and then the interior (28cm). The highest basal area per hectare was recorded at the intermediate ($7.39m^2$), the edge ($6.65m^2$) and the interior ($1.8m^2$). Also, the highest volume per hectare was recorded at the intermediate ($17.96m^3$), followed by the edge ($6.86m^3$) and then the interior ($2.25m^3$) as presented in Table 4. Tree saplings were found to have the same mean DBH (3cm) at the edge, intermediate and interior of the forest reserve. Also, Tree saplings had the same basal area per hectare along the edge-interior gradient of the forest as presented in Table 4.

Table 4: Growth characteristics of the mature trees and saplings along the edge-interior gradient of the forest

Growth characteristics (m)	Forest classes		
Mature trees	**Edge**	**Intermediate**	**Interior**
Mean DBH (m)	0.38	0.36	0.28
Max DBH (m)	1.86	3.01	1.64
Mean Ht (m)	18.78	14.86	11.87
BA/ha (m^2)	6.65	7.39	1.8
Vol/ha (m^3)	6.86	17.96	2.25
Saplings			
Mean DBH (m)	0.03	0.03	0.03
Max DBH (m)	0.09	0.09	0.08
BA/ha (m^2)	0.02	0.02	0.02

Species Richness and Diversity Indices of Mature Trees along the Edge-Interior Gradient of the Forest

Species richness and diversity indices for mature trees along the edge-interior gradient of SNR are presented in Table 5. Twenty-four (25) species were found in the interior, 23 in the intermediate and 21 at the edge of the forest. Shannon diversity index was higher in the interior (2.93), followed by the intermediate (2.71) and edge (2.65). Species evenness was higher in the interior (0.78) than inthe edge (0.67) and the intermediate (0.65) respectively. The Simpson index was found to be slightly higher at the interior (0.93) than the intermediate (0.91) and then the edge (0.90).

Table 5: Species richness and diversity indices of mature trees along the edge-interior gradient of the forest

Parameter	Edge	Intermediate	Interior
Number of species	21	23	25
Number of individuals	67	71	89
Simpson_1-D	0.90	0.91	0.93
Shannon_H	2.65	2.71	2.93
Evenness_e^H/S	0.67	0.65	0.78
Margalef	4.85	5.21	5.26

In this study, 51 species of tree saplings were recorded in the edge of the forest, 37 in the intermediate and 21 in the interior. The Shannon diversity index was higher in the edge (3.36), followed by intermediate (3.34) and interior (2.26) respectively. The Simpson index was slightly higher in the intermediate (0.96), followed by the edge (0.95) and then the interior (0.92). Species evenness in the interior (0.78) was higher than in the intermediate (0.74) and in the edge (0.59) of the forest respectively (Table 6).

Table 6: Species richness and diversity indices for saplings along the edge-interior gradient of the forest

Biodiversity indices	Edge	Intermediate	Interior
Number of species	51	37	21
Number of individuals	237	179	172
Simpson_1-D	0.95	0.96	0.92
Shannon_H	3.36	3.34	2.69
Evenness_e^H/S	0.59	0.74	0.78
Margalef	8.84	7.14	3.59

Species richness and diversity indices for seedlings along the edge-interior of the forest are presented in Table 7. A total of 37 species were recorded in the edge of the forest, 39 in the intermediate and 27 in the interior. The Shannon diversity index was higher in the edge (2.74), followed by the interior (2.30) and then the intermediate (2.02). The Simpson index was slightly higher in the edge (0.88), followed by the interior (0.84), and then the intermediate (0.77). Species evenness in the edge (0.39) was higher than the evenness in interior (0.38) and intermediate (0.20) respectively.

Table 7: Species richness and diversity indices for seedlings along the edge- interior of the forest

Biodiversity indices	Edge	Intermediate	Interior
Number of species	37	39	27
Number of individuals	358	611	285
Simpson_1-D	0.88	0.77	0.84
Shannon_H	2.74	2.02	2.30
Evenness_e^H/S	0.39	0.20	0.38
Margalef	6.63	5.79	4.46

An analysis of variance (ANOVA) for comparing soil physicochemical properties along the edge-interior gradient of the forest reserve is presented in Table 8. At 0–15 cm, soil chemical properties were the same along the edge-interior gradient of the forest. However, at 15-30cm, soil organic matter and organic carbon were significantly higher in the edge of the forest. in this study, all the soil physical properties were the same along edge-interior gradients regardless of the soil depth.

Table 8: Comparison of soil physico-chemical properties along the edge- interior of the forest

	Soil properties	Edge	Intermediate	Interior
Chemical properties (0-15)	Organic carbon (%)	1.34[a]	1.28[a]	1.36[a]
	Organic matter (%)	2.32[a]	2.20[a]	2.34[a]
	Soil salinity	120.40[a]	125.17[a]	152.67[a]
	Soil pH	7.48[a]	6.64[a]	6.76[a]
Chemical properties (15-30)	Organic carbon (%)	1.26[a]	0.51[b]	0.51[b]
	Organic matter (%)	2.18[a]	0.87[b]	0.88[b]
	Soil salinity	80.53[a]	62.63[a]	83.20[a]
	Soil pH	7.64[a]	6.59[a]	6.76[a]
Physical properties (0-15)	Particle size (% of sand)	40.07[a]	38.73[a]	42.07[a]
	Particle size (% of silt)	6.33[a]	7.33[a]	3.00[a]
	Particle size (% of clay)	53.60[a]	53.93[a]	54.93[a]
Physical properties (15-30)	Particle size (% of sand)	41.40[a]	38.40[a]	40.07[a]
	Particle size (% of silt)	1.67[a]	4.67[a]	4.33[a]
	Particle size (% of clay)	59.93[a]	56.93[a]	55.6[a]
	Bulk density (g/cm^3)	1.26[a]	1.25[a]	1.35[a]
	Moisture content	18.30[a]	17.55[a]	14.66[a]

Note: means with the same superscript along the row are not significantly difference.

DISCUSSION

The tropical rainforest ecosystem of Southwest Nigeria is noted to be high in species diversity, genetic materials and ecological processes compared to other ecosystems (Adekunle*et al*. 2013). Fragmentation consequentially causes the creation of additional edge habitats. This may cause a reduction in species richness and abundance in comparison to that of the interior (Kacholi 2014). By reducing the size of

undisturbed areas, the number of species that can persist declines (Klyza and Trombulak 2014). Fragmentation also changes conditions in the fragment as a result of its proximity to disturbance. These edge effects occur due to the alteration of physical conditions, such as changes in wind and temperature, as well as changes in the biological characteristics near the border of the patch (Klyza and Trombulak 2014). The effects of fragmentation on a forest ecosystem are numerous. Extensive fragmentation will result in a less stable habitat for nesting birds, which are responsible for one means of seed dispersal for trees and also help control tree parasites (Fagan *et al.* 1999).

This study revealed that species richness and the number of individuals for mature trees were higher in the interior than in the intermediate and edge of the forest. However, species richness for saplings and seedlings was higher in the edge than in the forest intermediate and interior. The higher species richness of mature trees in the forest interior is an indication that the forest interior suffers fewer disturbances than the forest edge, as illegal logging was the main disturbance occurring on the forest edge. This finding supports Kacholi (2014) observation. According to him, the tree richness was higher in the forest interior than the forest edge of Kilengwe Forest in the Morogoro Region, Tanzania. The presence of more saplings and seedlings in the forest edge in comparison to the forest interior suggests that the forest edge has greater regeneration potential.

In this forest, disturbance experienced in the forest interior is generally lighter than at the forest edge. Light disturbances are caused by naturally occurring factors such as lightning, wind storms, and tree mortality, which usually create gaps for sunlight to reach forest floors and stimulate the growth of tree seedlings. This is responsible for the lower diversity of tree saplings and seedlings in the forest interior. The conspicuously higher population of *Triplochiton scleroxylon* at the forest edge and intermediate could be attributed to the ecological group that this species belongs, pioneer species (Damptey *et al.* 2021). According to Salami *et al.* (2016), the key features are that pioneer species germinate or establish seedling and survive under full light.

Healthy soil is an important component of the forest ecosystem. It is a strong foundation for trees and plants to grow on, a habitat for numerous insects, fungi, and algae, and a lab where old organic matter is recycled back into the ecosystem (FAO 2000). Generally, soil physical properties were found to be statistically the same for the edge-interior gradient of this forest. This result agrees with Onyekwelu *et al.* (2008) who revealed no significant difference for soil physical property at depth 0-15 in the same forest reserve. Similarly, it was discovered that soil chemical properties were similar except for soil organic matter and organic carbon at 15-30cm depth. The similarity in most of the soil physico-chemical properties, regardless of the soil depths, could be attributed to the paltry anthropogenic pressure on the forest as the reserve is still enjoys slight protection from the Forestry Research Institute of Nigeria (FRIN) and that the current level of anthropogenic disturbance has not impacted the soil physico-chemical properties. More so, higher organic matter and organic carbon at 15-30cm depth in the forest edge could be attributed to anthropogenic disturbances which had led the removal of organic materials from the surface of the soil in the forest edge.

CONCLUSION AND RECOMMENDATIONS

This study revealed that forest edge and intermediate habitats were different from the forest interior in terms of tree species richness and diversity. The forest interior possessed higher species richness, diversity and tree density of mature trees while the intermediate and forest edge possessed more tree saplings and seedlings. This study also established uniform soil physical and some soil chemical properties along the edge-interior gradient of this forest. Since this forest edge and intermediate had higher regeneration potential than the forest interior, strict conservation measure should be put in place to protect the regenerated tree saplings and seedlings.

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