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The Potential of Agroforestry Species Diversity and Abundance in a Disturbed Forest Reserve of Ogun State, Nigeria

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Abstract

Nigeria's deforestation rate is at an alarming level due to weak forest governance, losing about 80 kha of natural forest cover per annum every year to agricultural land expansion, conflicts, and illegal logging. The expansion of agricultural land over other land use is over 50% and it is increasing. Agroforestry, as an option, offers a dynamic, ecologically based, natural resource management system that integrates forest trees into the agricultural landscape for the benefit of land users at all levels. This research aimed to assess the diversity and abundance of agroforestry tree species between the forest and farm zones at Edun Forest Reserve to improve agrobiodiversity by identifying tree species richness around farms in the reserve. A systematic sampling technique was used to sample plots, and relative dominance and important value index were determined. Results showed a significant difference between the species richness between the forest zone and farm zone of Edun Forest Reserve. On the important value index, *Gmelina arborea* (25.04) has the highest in the forest zone, while *Cedrela odorata* (0.661) is the least, and *Tectona grandis* (39.37) is the species with the highest in the farm zone *Terminalia ivorensis* (2.91) recorded the least. *Combretaceae* was identified as the most dominant family across the two zones. This research showed that appraisal of tree stand structure on farmlands is crucial for sustainable agroforestry management decisions in the forest zones of Nigeria.

Keywords

Agroforestry, Species Diversity, Land Use, Gmelina

1. Introduction

Trees on Nigerian forest landscapes have undergone different levels of disturbance

due to the unprecedented increase in human population [1]. This is largely due to the continuous exploitation of forest resources, particularly trees for timber firewood, in an unsustainable manner over the years. Hence, the unsustainable exploitation of trees impacts indigenous knowledge of tree flora and conservation around farming communities in Nigeria [2]. A higher number of tree species increases the number of agroecological niches as well as the number of associated species [3] [4]. Nigeria continues to lose its forest at an unprecedented rate due to poor forest management and weak forest governance; the rapid rate of deforestation in the country is approximately 3.5% per annum, translating into an average loss of about 400,000 ha of forest cover every year to agricultural land expansion, urbanisation, conflicts, and illegal logging [5]. According to estimates by the Chatham House Resource Trade Database, charcoal trade in 2015 amounted to 2.6 million tonnes globally, and Nigeria is among the top 5 charcoal-exporting countries [6].

Agroforestry is simply a system of raising tree plants on the same land with food and cash crops and remains a viable alternative in mitigating conversion of forest land for agricultural purposes. Agroforestry can significantly increase food production and boost food security while sustaining biodiversity. Agroforestry offers cheaper options with a wide range of benefits to farmers including increasing agroecology, income and soil fertility [7]. To fully explore the potential of agroforestry, as a viable land management, it is important to know the occurrence of agroforestry trees in the community. To ensure that agroforestry continues to serve as a potent land use system it is important to understand the abundance of tree species used in agroforestry practices. It is also essential to examine the status of the species diversity and composition as it will provide guidance for their management and valuable reference for improvement of our knowledge in identification of agroecologically useful woody species. [8]. Hence, there is a need to know the difference between the species richness of agroforestry trees in the forest and farmed areas. To do this, this research aimed to determine the diversity and abundance of agroforestry tree species between the forest and farm zones at Edun Forest Reserve in Ogun State, Nigeria. The objectives are to enhance the agrobiodiversity through sustainable agroforestry farming systems by identifying tree species richness around farms in the reserve and to determine the status of agroforestry tree species in farms surrounding the reserve. The research findings would ascertain the status of the most preferred trees on farms in recent times based on the dynamic nature of human consumption. It will also help to reduce agriculture's production vulnerability to climate change while improving water quality and availability among other ecosystem services, including farmers' income diversification and access to more nutritious food. Due to time and financial constraints, this research is focused on only Edun Forest reserve and farms within a 100-meter radius of the studied community forest reserve.

2. Materials and Methods

2.1. Study Area

This study was conducted in Edun Forest Reserve located in Ilaro of Yewa South Local Government, Ogun State, South-West Nigeria. The reserve lies between 6˚47'30.08" latitude and 3˚2'3.01" longitude with an estimated terrain elevation of about 80 meters above sea level.

The forest reserve shares a boundary with a few native communities in the surrounding area. The communities are predominantly farmers practicing Taungya farming system. Crops cultivated in the reserve are major food crops by the nearby community farmers. Below is the map showing the location of the reserve in Yewa Local Government Area of Ogun State, Nigeria. (Figure 1)

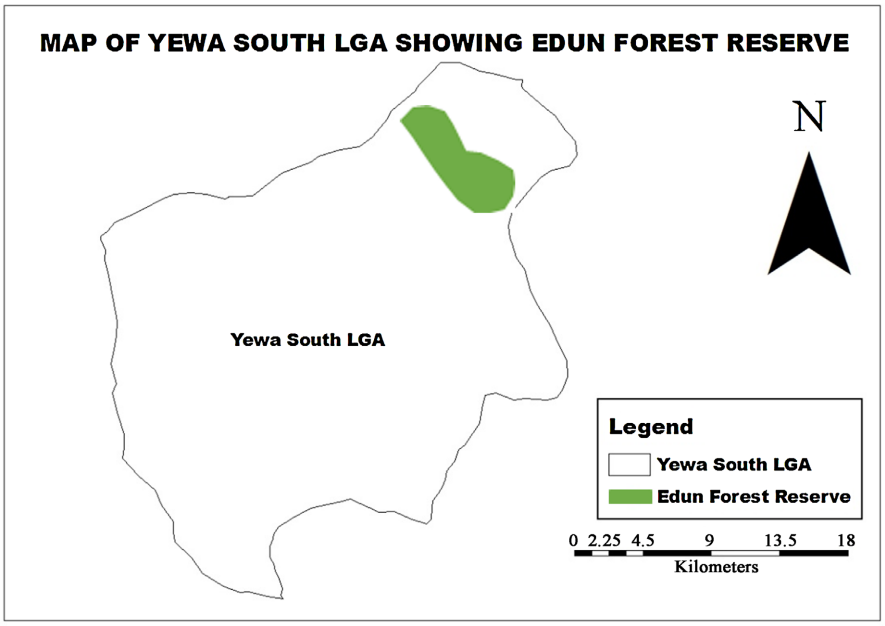

Figure 1. Map of Edun Forest reserve in Ogun state, Nigeria.

2.2. Data Collection

Systematic sampling technique was adopted in sample plot selection in line with [9]. Two (2) Transects were laid at an interval 500 m apart with each of the transects representing the Forest and Farm area of the reserve.

Along each transect 6 plots were laid at an interval of 100 m, making a total of 12 plots with every plot having an area of 50 m × 50 m. See Figure 2 for the schematic diagram of the line transects layout on the study site.

In every plot, tree plant data of all trees within the layout were collected. They include Diameter at Breast Height (DBH) at 1.37 m above ground, tree origin, tree height, tree species identification, tree population, taxonomic family and common usage, leaf type were collected. Tree Coordinates of sampled Trees were recorded using Garmin GPS version 73 also each tree's local names were recorded. Annual and biennial crops planted on the sampled plots were also identified. Only

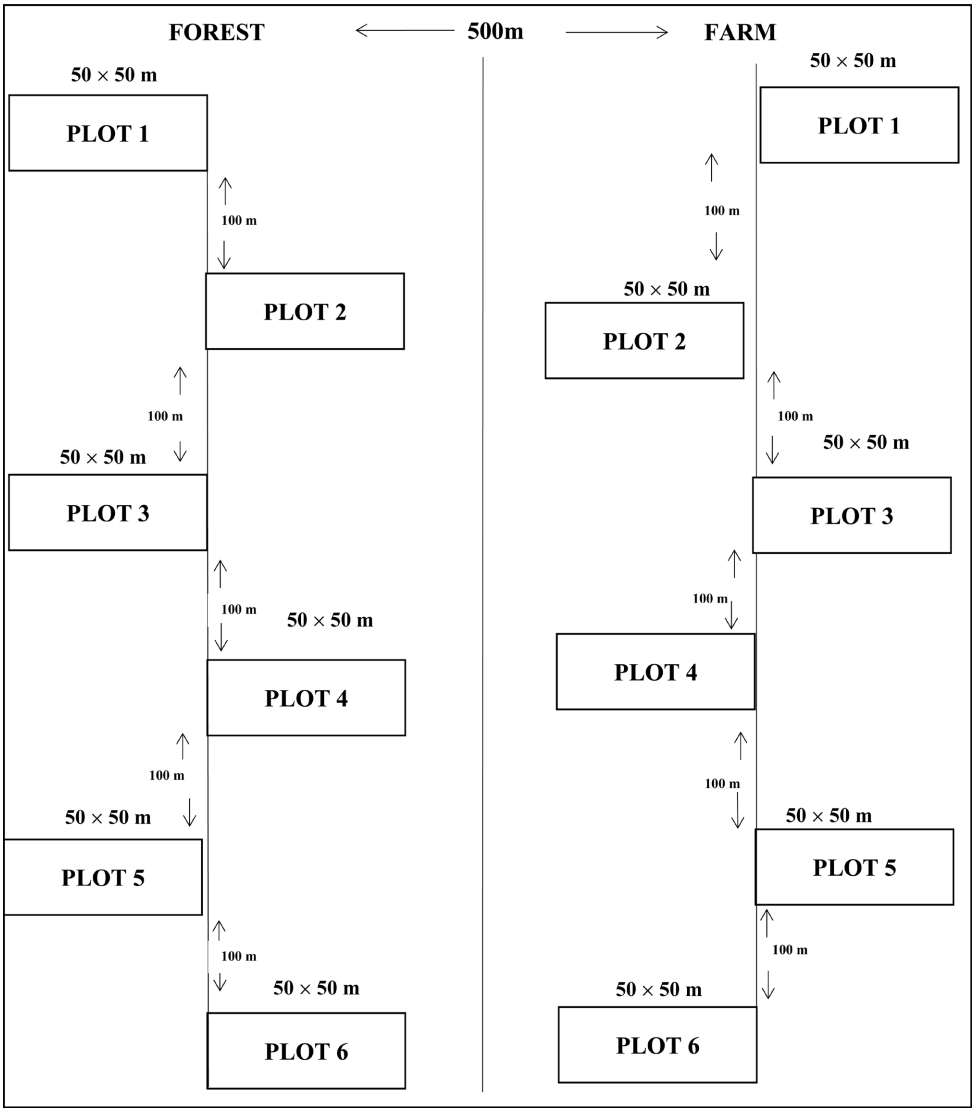

Figure 2. Line-transects of the plot layout in a vertical orientation for each area sampled.

trees with a DBH ≥ 10 cm were sampled. Trees with under DBH ≥ 10 cm were considered as shrubs.

Data were collected using a well-designed Google Form, an Open-Source data gathering tool developed by Google where needed data were inputted.

2.3. Data Analysis

Based on collected data, Basal Area, Relative Density, Relative Frequency, Relative Dominance of the trees were analysed. The importance value index (IVI) of tree species was also determined as follows:

$$\frac{t = d\sqrt{n}}{sd}$$

t = Paired T-test

d = Mean of the differences

n = Number of Blocks

sd = Standard Deviation

2.3.1. Basal Area

This is the diameter of the tree at 1.37 m above ground level. The Basal Area of trees in the two areas were calculated using the formula.

$$\frac{\pi dbh^2}{4} \tag{1}$$

BA = basal area (m^2), DBH = diameter at breast height (cm), and π = 3.142.

The total BA for each area was computed by adding all trees BA in the sampled area.

2.3.2. Relative Density (RD)

The relative density represents the index for relative distribution, assessment. It is calculated as follows:

$$\mathrm{RD} = \frac{t_1}{T} \times 100 \tag{2}$$

RD (%) = species relative density

where t_1 = is the number of individuals of species. T is the total number of all individual trees of all species in the entire community. The tree species are classified based on the relative densities (RD) using the methods in [10] and [9] as follows:

Abundant = RD ≥ 5.00;

Frequent = 4.00 ≤ RD ≤ 4.99;

Occasional = 3.00 ≤ RD ≤ 3.99;

Rare = 1.00 ≤ RD ≤ 2.99 and;

Threatened/Endangered = RD < 1.00.

2.3.3. Relative Dominance

Species Relative Dominance RD_0 represents the assessment of relative space occupancy of a tree in a particular area. It is calculated by the formula below:

$$\mathrm{RD}_0 = \frac{Ba_i}{Ba_n} \times 100 \tag{3}$$

Ba_i = sum of basal area of all specific trees in each zone, Ba_n = Total sum of basal area of all trees for each zone.

2.3.4. Importance Value Index

Importance Value Index measures the dominance of a species in a specified area. The tree species Importance Value Index (IVI) was calculated for each area using the following equation:

$$\mathrm{IVI} = \frac{\mathrm{RD}_0 + \mathrm{RD}}{2} \tag{4}$$

RD = Relative density,

RD_0 = Relative dominance

3. Results

3.1. Agroforestry Species Diversity with Crops

The different studied forest and farm plots had food crops cultivated at different growth rates. Table 1 shows the food crops planted in each sampled plots owned by community farmers around the reserve. Tuber crops (*Dioscorea rotundata* and *Manihot esculentum*) are the most common species cultivated on the farmlands.

Table 1. Food and cash crops cultivated on the sampled plots.

Plot	Forest zone	Farm zone
1	*Dioscorea rotundata*	*Manihot spp*; *Capsicum spp*
2	No crop	*Dioscorea rotundata*
3	No crop	*Capsicum spp*; *Ananas comosus*
4	*Dioscorea rotundata*	*Manihot spp*
5	*Dioscorea rotundata*	*Manihot spp*
6	No crop	*Manihot spp*

In Table 3, the tree population in each of the forest and farm areas was sampled. A total of 168 trees belonging to 11 families were identified across the studied area. The number of tree species identified in each area differs. A total of 110 trees species belonging to 8 families namely, Fabaceae, Meliaceae, Anacardiaceae, Combretaceae, Lamiaceae, Rubiaceae, Apocynaceae, Malvaceae were recorded in the Forest Area. However, the Farm Area had 58 tree species recorded and belonging to 8 families namely, Anacardiaceae, Meliaceae Caricaceae, Arecaceae, Fabaceae, Lamiaceae, Myrtaceae, Combretaceae. The forest area had more species presence. They include Rubiaceae, Apocynaceae, and Malvaceae were present in Forest Area and not present in the Farm Area of the Reserve while the following species Caricaceae, Arecaceae and Myrtaceae were only present in the Farm Area of the Reserve.

All the identified trees across the Forest and the Farm Area were classified based on their origin. It was discovered that out of the 168 plants identified in the reserve 122 tree species which represent 72.61% of the sampled trees are exotic while 46 tree species which 27.38% of the entire tree sampled are indigenous.

3.2. Tree Species Relative Density

The Species Relative Density (RD) of the trees in the studied area for both the forest area and the farm area ranged from 0.91% to 30% and 1.72% to 34.48% respectively. *Gmelina arborea* had the highest (RD) among tree species in the forest area accounting for 30% followed by *Tectona grandis* and *Terminalia ivorensis* with RD of 18.18% and 15.45% respectively. *Cedrela odorata*, *Gliricidia sepium*

and *Triplochiton scleroxylon* all recorded the least relative density in the forest area, having 0.91% relative density each. In the farm area, *Tectona grandis* with a relative density of 34.48% had the highest followed by *Gmelina arborea* with a RD of 29.31%. The following species *Caricapa papaya*, *Elaeis guineensis*, *Gliricidia sepium* and *Mangifera indica* recorded about 5.17% relative density each. *Terminalia ivorensis* with a RD of 1.72% recorded the least relative density.

3.3. Tree Species Relative Dominance

On the variability in the species, relative dominance between the two studied areas that the farm area had the highest variability ranging from 3.70% (*Caricapa papaya*) to 44.3% (*Tectona grandis*) as against the forest area ranging 0.41% (*Cedrela odorata*) to 20.07% (*Gmelina arborea*). Thus, highlighting the unevenness of the species present in both areas. *Gmelina arborea* (20.07%) is the most dominant tree species in the forest area while *Tectona grandis* (44.3%) is the most dominant species in the farm area. The choice of *Tectona grandis* by farmers in the farm area is directly proportional to its leaf harvest for organic food packaging among the communities. The leaf is mainly used for packing "Eko," which is prepared from ground maize. This means that most preferred tree species by the communities are densely populated in the two studied areas. However, it was observed that *Triplochiton scleroxylon* had a low RD_0 of 0.72% in the forest area despite the species' potential to thrive. The dominant families in the studied area include Combretaceae, Lamiaceae and Fabaceae.

3.4. Tree Species Importance Value Index

The Importance Value Index (IVI) indicates how significantly dominant a species is in a specified area. Thus, tree species with the highest IVI represent the dominant tree in such an area. When the two-study areas are compared in **Table 2**, *Gmelina arborea* (25.04) has the highest IVI in the forest area while the species with the least IVI is *Cedrela odorata* (0.661). For the farm area, *Tectona grandis* (39.37) is the species with the highest IVI while the least IVI is reco RD_0ed on *Terminalia ivorensis* (2.91).

3.5. Tree Species Relative Status

Out of the 14 tree species identified in the forest area, five of the species (*Anogeissus leiocarpus*, *Gmelina arborea*, *Tectona grandis*, *Terminalia ivorensis*, *Terminalia superba*) observed were under abundant category while *Albizzia lebbeck* and *Khaya ivorensis* were classified as under the frequent category. The rare category had *Acacia nilotica*, *Anacardium occidentale* and *Morinda lucida* in the forest area. The endangered species are *Cedrela odorata*, *Gliricidia sepium*, *Rauvolfia vomitoria* and *Triplochiton scleroxylon* respectively. However, for the Farm Area of the 11 tree species observed only *Terminalia ivorensis* was rare while species such as *Caricapa papaya*, *Elaeis guineensis*, *Gliricidia sepium*, *Gmelina arborea*, *Mangifera indica*, *Tectona grandis* were all observed to be abundant. Species

identified as occasional are *Anacardium occidentale*, *Azadirachta indica*, *Guajava psidium* and *Terminalia superba*. No species was observed to be frequent or endangered in the farm area of the studied area.

3.6. Species Richness

The means of the all trees for each of the 6 blocks sampled and compared using paired student T-test showed that calculated value (3.21) is higher than the tabulated value (2.57) as seen in Table 2 below. This indicates the rejection of the null hypothesis (H_0) that there is no significant difference between the species richness of agroforestry trees in the forest and farm area. Hence, this study clearly shows there is a difference between the species richness of agroforestry trees in the forest area and farm area of Edun Forest Reserve. The difference in species richness is expected to improve the agrobiodiversity potentials of farm communities around forest reserves.

Table 2. Means of sampled trees using student t-test.

Forest area	Farm area	Mean diff.	SD	No. of blocks (degree of freedom)	T-test (calculated)	T-test (tabulated)	Decision
22	6	16	6.24	6 (5)	3.21	2.57	Reject
24	11	13	1.97				
27	9	18					
14	12	2					
12	9	3					
11	11	0					

Student t-test results; t-calculated = 3.21; t-tabulated (df-5) = 2.57.

Table 3. Tree species distribution, relative status in the sampled plots.

Area	Tree species	Family	Species frquency	RD	RD_0	IVI	Status	Total No. trees
Forest area	*Acacia nilotica*	Fabaceae	3	2.73	1.377	2.052	Rare	110
	Albizzia lebbeck	Fabaceae	5	4.55	3.22	3.883	Frequent	
	Anacardium occidentale	Anacardiaceae	2	1.82	0.723	1.271	Rare	
	Anogeissus leiocarpus	Combretaceae	8	7.27	4.527	5.900	Abundant	
	Cedrela odorata	Meliaceae	1	0.91	0.413	0.661	Endangered	
	Gliricidia sepium	Fabaceae	1	0.91	0.465	0.687	Endangered	
	Gmelina arborea	Lamiaceae	33	30.00	20.069	25.035	Abundant	
	Khaya ivorensis	Meliaceae	5	4.55	4.561	4.553	Frequent	
	Morinda lucida	Rubiaceae	3	2.73	1.205	1.966	Rare	
	Rauvolfia Vomitoria	Apocynaceae	1	0.91	0.43	0.670	Endangered	

Continued

	Tectona grandis	Lamiaceae	20	18.18	10.15	14.166	Abundant	
	Terminalia ivorensis	Combretaceae	17	15.45	12.014	13.734	Abundant	
	Terminalia superba	Combretaceae	10	9.09	11.773	10.432	Abundant	
	Triplochiton scleroxylon	Malvaceae	1	0.91	0.723	0.816	Endangered	
	Anacardium occidentale	Anacardiaceae	2	3.45	5.397	4.423	Occasional	58
	Azadirachta indica	Meliaceae	2	3.45	6.554	5.001	Occasional	
	Caricapa papaya	Caricaceae	3	5.17	3.701	4.437	Abundant	
	Elaeis guineensis	Arecaceae	3	5.17	4.241	4.706	Abundant	
	Gliricidia sepium	Fabaceae	3	5.17	7.325	6.249	Abundant	
Farm area	*Gmelina arborea*	Lamiaceae	17	29.31	41.712	35.511	Abundant	
	Guajava psidium	Myrtaceae	2	3.45	3.932	3.690	Occasional	
	Mangifera indica	Anacardiaceae	3	5.17	8.481	6.827	Abundant	
	Tectona grandis	Lamiaceae	20	34.48	44.256	39.369	Abundant	
	Terminalia ivorensis	Combretaceae	1	1.72	4.086	2.905	Rare	
	Terminalia superba	Combretaceae	2	3.45	8.096	5.772	Occasional	

The DBH of major trees present in the reserve, as demonstrated in a graph in Figure 3, showed that trees in forest area had higher DBH in comparison with trees in the farm area except for *Anacardium occidentale* (Cashew). This could be attributed to the ability of the tree to provide fruits, thereby improving farmers nutrition and income level. Cashew nut is widely exported from Nigeria to South-Eastern Asian countries.

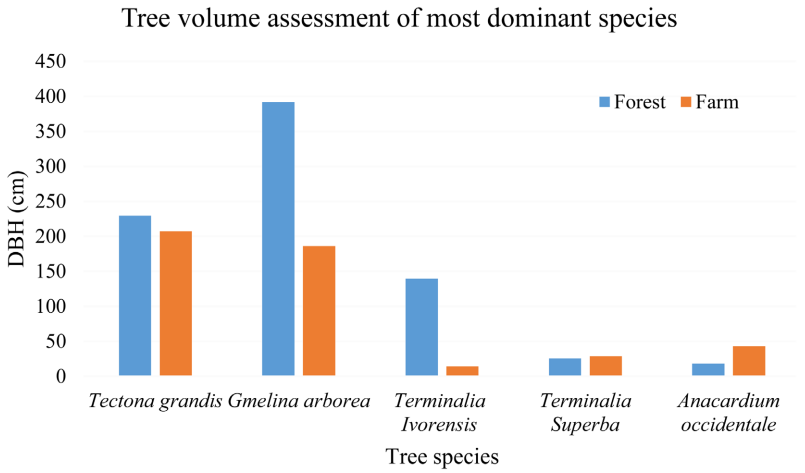

Figure 3. Diameter at Breast Height of most common tree species.

4. Discussion

4.1. Species Diversity

A total of 168 tree species belonging to 11 families were identified during this

study which depicts rich ecosystem in terms of species quality in biodiversity (see Table 3). Tree species identified in the research is quite higher when compared with similar research conducted to determine species biodiversity within similar ecosystems in southwestern part of Nigeria. [11] obtained 71 species for Abeku sector of Omo Forest reserve in Ogun State. [12] recorded 99 tree species in bitumen-producing area of Ondo State. The results of this study confirmed that Edun Forest Reserve is a repository of both indigenous tropical hardwood and exotic tree species in different families, judging by the tree species richness of the reserve.

Species such as *Acacia nilotica*, *Morinda lucida*, and *Terminalia ivorensis* were identified as Rare while *Cedrela odorata*, *Gliricidia sepium*, *Rauvolfia Vomitoria*, *Triplochiton scleroxylon* were identified as Endangered or Threatened during this research. This could be attributed to the effects of a series of human activities on the growth and distribution of tree species which could have played a role in the status of these species in the ecosystem, threatening the occurrence and development of certain species while favouring others.

4.2. Tree Species Diameter at Breast Height

Diameter at Breast Height (DBH) shows the population structure of trees in the forest [13] [14]. Tree distribution across different DBHs revealed how well the growing forest is utilizing functional and structural resources, and it is often used to represent the population structure of forests [15].

Trees in forest areas have higher DBH values when compared with the farm area *Gmelina arborea* (391,633) and *Tectona grandis* (229.21) recorded the highest DBH value in the forest area as against *Gmelina arborea* (186.10) and *Tectona grandis* (270.36) recorded in the farm area. The only tree in farm area with higher the DBH compared with the forest area is *Anacardium occidentale* (Cashew) with DBH of 42.89 as against 18.05 DBH in farm area. The DBH value is lower than the value reported by [16]. The variation in the DBH identified trees in the farm and forest area is in line with the proposed structure by [17] on tropical forest tree species growth structure

4.3. Species Relative Density

The Relative Density of identified tree species was determined to be in line with [9] and [10] methodologies. About 20% of the tree species that had a relative density of $1.00 \leq RD \leq 2.99$ are categorized as Rare, while those with a relative density $RD < 1.00$ are categorized as threatened/endangered. In the forest area tree species such as *Acacia nilotica*, *Morinda lucida* and *Terminalia ivorensis* with their relative density ranging from 2.73 %, 1.82% and 2.73 respectively are observed to be rare in the Forest Area while *Terminalia ivorensis* with a relative density of 1.72% was detected to be rare in the farm area of the reserve. The endangered tree species in the farm area are *Cedrela odorata*, *Gliricidia sepium*, *Rauvolfia Vomitoria* and *Triplochiton scleroxylon* all had a Relative Density of 0.91% each. No species was observed to be endangered in farm Area.

There is every likelihood that the endangered species may soon be vanishing from the reserve unless sustainable management, such as intensive replanting exercise practices, is adopted. The disappearance such plant species can be attributed to anthropogenic activities resulting in the depletion of genetic resources and increasing threat to Africa's biodiversity. There is an urgent need to preserve genetic diversity including plant resources of known and unknown economic importance to guarantee the availability of their potential in the interest of human prosperity [18]. This is due to the overexploitation and fast replacement of forest ecosystems with human amenities, which has resulted in the decimation of over 70% of tree species in West African landscapes [19].

4.4. Species Relative Dominance

Combretaceae was identified as to be the most dominant family across the two sampled areas. This may be due to their fast regeneration ability, which is associated with symbiotic properties, which may have enabled the species to easily establish within habitat types. This is in contrast to the findings of [20], who stated that trees of legumes were the most prominent species recorded in Takamanda forest and [21] report the Fabaceae family is the most family in Ehor Forest Reserve, Edo State despite the fact these forests share some ecosystem characteristics, and geographical boundaries. The dominance *Combretaceae* could also be a result of habitat adaptation and relatively favourable environmental conditions, which encourage pollination, dispersal and eventual establishment of species. Similar situations were reported by [22] on species richness in relation to environment. [23] found that edaphic parameters (soil nutrients) played a major role in species richness and establishment in an ecosystem. The effect of climate change-induced anthropogenic activities on regeneration and distribution of tree species in forests could have affected the dominant status of individual species in the agroecosystem, thereby favouring few species over other equally significant species [24] [25]. However, when the study area was accessed independently *Gmelina arborea* (20.07%) had the highest Relative Dominance followed by *Terminalia ivorensis* (12.01%), *Terminalia superba* (11.78%) and *Tectona grandis* (10.15%), the least dominant tree species is *Cedrela odorata* (0.41%). For the farm area, the highest relative dominance is Tectona grandis (44.26%) and Gmelina arborea (41.71), both belonging to the Lamiaceae family. This could be because of the adaptation strategy that relatively favors environmental factors such as dispersal of seeds, pollination of flowers for fruits and establishment of wildlings that eventually become protected and managed species [26] [27].

4.5. Species Importance Value Index (IVI)

On the Importance Value Index (IVI), economic value was not considered while calculating the average between relative dominance and diversity of species in each area, but similar findings were reported in the species importance value in [28] assessment of *Fagus orientali* species in Iran. [29] Their research confirmed

wild mango and Cashew as some of the species among 2227 trees sampled with high IVI in the dry tropical landscapes of India. This important index is useful in forest management and biodiversity preservation. As it can be used to improve tree regeneration potential and the adoption of agroforestry on farmlands in dry landscapes using the available resources.

From the results, the reserve is populated by both indigenous and exotic tree species. However, a recent study by [30] agreed that the most dominant exotic species, *Gmelina arborea* and *Tectona grandis* are leading the exotic tree species frequency while *Terminalia ivorensis* and T*erminalia superba* are the native tree species dominating the reserve. The research found out that the most common trees present in the reserve, *Gmelina arborea*, *Tectona grandis*, *Guajava psidium* (Guava), and *Anacardium occidentale* (Cashew) are multipurpose in nature, providing income incentives and nutritional and organic value. The increase in agroforestry crops among farmers encroaching reserves such as Cashew nuts is connected to the Nigerian Export Promotion Council (NEPC) factsheet. The NEPC disclosed that Nigeria is the world's fourth leading exporter of premium quality raw cashew nuts, with an average 48 kernel yield out-turn due to its high nutritional and commercial value.

5. Conclusion

The research clearly showed the reserve is rich in biodiversity and needs to be protected through sustainable community forest management, where farmers jointly protect and manage the economic and non-economic trees with forest managers for improved food security and conservation. The appraisal of tree stand structure on farmlands is crucial for sustainable agroforestry management decisions, particularly in the forest zones of Nigeria. Hence, a need for further assessment of agroforestry tree species (with a focus on native species from Fabaceae) to determine diversity and abundance in a changing climate of the transitional agroecological zones.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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