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REVIEW ARTICLE/ORIGINAL RESEARCH ARTICLE

Tree Species Diversity in Makurdi Zoological Garden, Benue State, Nigeria

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ABSTRACT
This study's primary emphasis was an ecological assessment of 16 different families of trees that were picked at random in an extended field survey conducted in the Makurdi Zoological Garden in Benue State, and this was done to assess the evenness, richness, and diversity of the tree species. The relative abundance of trees was estimated using the Shannon Weigner evenness index, while the variety of tree species was estimated using the Shannon Weigner diversity index. To determine the species richness in the research area, the Menhinick index was also employed. Danieli oliveri has the highest frequency of 43.37%, while Acacia seyal, and parkia biglobosa have the lowest frequency of 0.14%. The family Ceasalpiniodeae has the highest relative abundance of 0.4637, while Fabaceae and Anacardiaceae have the least relative abundance of 0.0027. The result shows the Zoological Garden's diversity index to be 2.06, indicating a moderate level of species diversity supported by cluster analysis. This suggests that some of the tree species found in the Makurdi Zoological Garden have experienced disturbances. A moderate distribution and low species richness are also indicated by the evenness and Menhinick values of 0.72 and 1.06, respectively. This suggests that some species are more abundant than others, leading to the domination of particular species. The study recommends close monitoring of the study area to mitigate disturbances, logging, and grazing activities.

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INTRODUCTION
Understanding the composition and distribution of trees is crucial for conservation efforts as it aids in the understanding of forest stand status, regeneration, and variety (Amonum *et al.*, 2019). Because trees offer nearly all wildlife species resources and habitats, the richness and diversity of tree species are essential to the overall biodiversity of forests (Malik *et al.*, 2014; Sushma *et al.*, 2016). Diversity is a metric that makes it possible to relate individual trees' richness and abundance, indicating the degree of vegetation stability or heterogeneity (Ifo *et al.*, 2016). In any particular geographic area, factors such as temperature, sunlight, moisture, nutrients, topography, bedrock geology, canopy structure, soil properties, and land use history determine the diversity and status of tree species (Saka *et al.*, 2018; Soba *et al.*, 2023), and human activities like farming, urbanization, overgrazing, fires in the bush, illicit logging, cattle ranching, soil erosion, and so forth (Usman *et al.*, 2022; Soba *et al.*, 2023).

Due to its favorable environment, Nigeria has a diverse range of flora; the country is one of the richest biodiversity hotspots in Africa and home to around 7,895 species of plants (Nodza *et al.*, 2014), numerous animal species, as well as thousands of indigenous people from various cultural backgrounds (Aigbe *et al.*, 2014). However, the conversion of forest lands into agricultural fields, the gathering of non-timber forest products (NTFPs) and indiscriminate bush fires, the building of roads, technological advancements, industrialization and urbanization, the removal of mature trees and the gathering of fuel wood all contribute to the devastating rate at which plant species destruction occurs in Nigeria (Barau *et al.*, 2015). Also, plant species' continued existence is in jeopardy because of a variety of man-made and natural disturbances, such as fire outbreaks, flooding, erosion, and deforestation, all of which have been significantly increasing recently and pose a significant risk of local extinction for some of these species (Nodza *et al.*, 2014). Adedutan and Olusola (2015) reported that a large amount of the ecosystem of the forest reserves and undisturbed forests in the 1980s has been lost in the last 20 years.

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Changes in wildlife and flora because of extensive human activity species of natural ecosystems have become a global concern in the second half of the 20th century (Amonum *et al*., 2019). To manage disturbed and undisturbed stands and to understand the provision of non-timber ecosystem services, it is imperative to describe patterns of species composition (Neelo *et al*., 2015). Also, to meet people's insatiable demands, these factors—along with the need for urbanization and rapid population growth—have prompted the construction of several infrastructure projects which have destroyed more forest vegetation both inside and outside the study area, raising serious socioeconomic issues that are getting harder to manage (Barau *et al.,* 2015).

Although there have been several types of research carried out in the Makurdi Zoological Garden, however, no work has been carried out on the tree species diversity in Makurdi Zoological Garden to evaluate the tree species diversity and the disturbance experienced by the tree species in Makurdi Zoological garden. Thus, periodic evaluations of tree species diversity and disturbance in Makurdi Zoological Garden will help track changes and assess the impact of anthropogenic activities and external factors like climate change on plant diversity. Therefore, an effort to determine the tree species variety status of the Makurdi Zoological Garden is required to supply baseline data for additional research, which will subsequently contribute to the extremely demanding environmental difficulties.

MATERIALS AND METHODS

Study Area

The Makurdi Local Government Area in Benue State is home to the Makurdi Zoological Garden, which is the study area. Benue State's capital, Makurdi, is located on the south bank of the Benue River. The coordinates are 8032'10E and 7043'50N. In Figure 1, the study area is displayed.

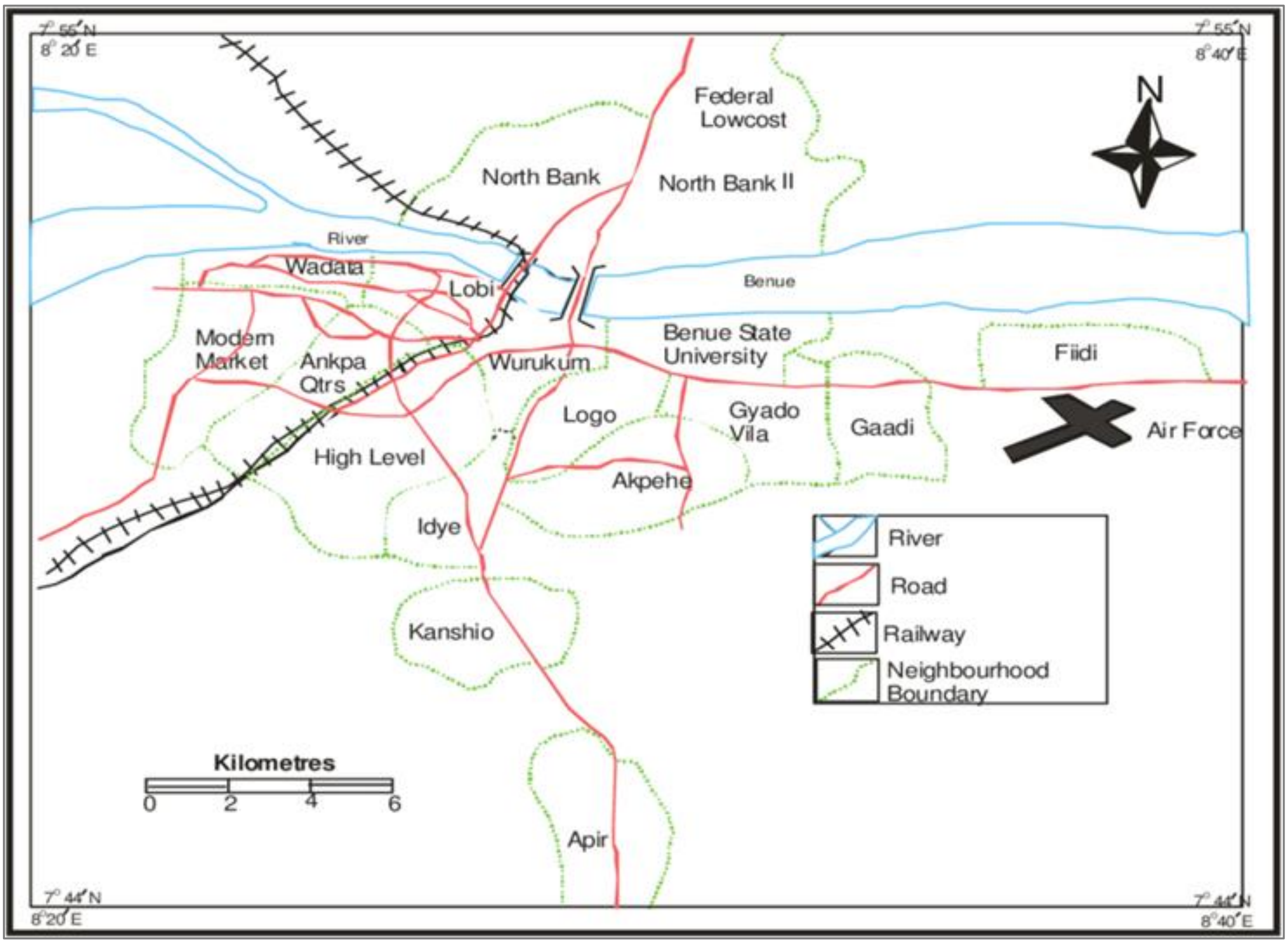

Figure 1: Map of Makurdi showing the study area

Data collection

The fieldwork included a sample plot inventory of tree species and a pilot survey as robust phytosociological data gathered with suitable field sampling methodologies are necessary for assessing biodiversity at the ecosystem level.

Ten (10) randomly placed, thirty-meter-by-thirty-meter plots were set up to sample trees. The number of trees discovered was noted in each plot. Shannon's diversity index was used to gather field data, and experts from Joseph Sarwuan Tarka University's Department of Forestry in Makurdi assisted in the identification of the species. For this research, a tree was considered any freestanding plant with a diameter at breast height (DBH) of at least 1cm.

Data Analysis

The Shannon Weiner's diversity index, H= -∑[(pi) ln (pi)] and Shannon's Equitability index, E_H = H/ln(s) were used to calculate the diversity index and equitability index respectively while Menhinick index, M = S/√N was used to calculate species richness index.

$$H' = \sum_{i=1}^{s} [(pi) \ln (pi)] \quad \text{i}$$

Where,

pi is the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ni/N.

n_i is the number of individuals in each species; the abundance of each species

S is the number of species.

N is the total number of all individuals

$$E_H = H/\ln(s) \quad \text{ii}$$

Where,

H is the Shannon diversity index

S is the total number of unique species

$$M = S/\sqrt{N} \quad \text{iii}$$

Where,

S is the total number of species in the community sample area

N is the total number of individual species.

Principal components analysis using frequency, pi, ln(pi), and (pi)ln(pi) and cluster analysis were also performed to determine the relatedness of the tree species studied. Principal components analysis and cluster analysis were performed using Minitab software version 21.

RESULTS

Tree Species and Their Frequency of Occurrence

The findings indicated that there are 27 species of trees in 15 different groups within the structure of the Makurdi Zoological Garden. Data on the forest structure revealed that, of the 731 tree species sampled, *Daniella oliveri* (n = 336, 46.37%) was the most dominant species. In descending order of dominance, this was followed by *Azadirachta indica* (n = 95, 12.99%), *Elaeis guinensis* (n = 39, 5.34%), and *Vitex doniana* (n = 34, 4.65%) but the least common species were *Acacia seyal* (n=1, 0.14%) and *Parkia biglobosa* (n=1, 0.14%), both of which were found in the area with equal coverage (Table 1). The high species richness of trees (27 taxa) found in this study indicates that the study area has a moderate level of diversity.

Table 1: Check Lists Of Tree Species in Makurdi Zoological Garden

Species	Family	Species number	% frequency
Anacardium occidentale	*Anacardiaceae*	2	0.27
Ficus sur	Moraceae	17	2.33
Daniella oliveri	Ceasalpinioidae	339	46.37
Gmelina arborea	Verbanaceae	21	2.87
Azadirachta indica	Meliaceae	95	12.99
Ficus exasperate	Moraceae	20	2.74
Acacia seyal	Fabaceae	1	0.14
Pterocarpus erinaceus	Fabaeae	26	3.56
Vitellaria paradoxa	*Sapotaceae*	10	1.37
Prosopis Africana	Mimosoideae	7	0.96
Vitex doniana	Verbanaceae	34	4.65
Lannea schimperi	Anacardiaceae	2	0.27
Elaeis guinensis	Arecaceae	39	5.34
Bridelia ferruginea	Euphorbiaceae	3	0.41
Pseudocedrela kotschyi	Meliaceae	6	0.82
Lannea acida	*Anacardiaceae*	23	3.15
Acacia nilotica	Mimosoideae	15	2.05
Mitragyna inermis	Rubiaceae	3	0.41
Terminalia avicennioides	Combretaceae	7	0.96
Magnifera indica	Anacardiaceae	29	3.97
Hannoa undulate	Simaroubaceae	6	0.82
Sterculia setigera	Sterculiaceae	2	0.27
Albizia zygia	Mimosoideae	6	0.82
Delonix regia	Fabaceae	2	0.27
Schefflera actinophylla	Araliaceae	12	1.64
Parkia biglobosa	Mimosoideae	1	0.14
Lophira lanceolata	Onchnaceae	3	0.41
Total		731	100

Tree Species Diversity

Table 2 displays the values of the natural logarithm of pi, the relative abundance of each species, and the different species counts. The species evenness and richness of the trees were determined to be E_H = 0.6203 and M = 0.9986, respectively, while the species diversity (Shannon diversity H') was found to be 2.0443. These values imply a moderate level of diversity in Makurdi Zoological Garden.

Table 2: Trees Species Diversity in Makurdi Zoological Garden

Species	Family	Frequency	pi	ln(pi)	(pi)ln(pi)
Anacardium occidentale	Anacardiaceae	2	0.0027	-5.9012	-0.0159
Ficus sur	Moraceae	17	0.0233	-3.7612	-0.0874
Daniella oliveri	Ceasalpinioidae	339	0.4637	-0.7684	-0.3563
Gmelina aborea	Verbanaceae	21	0.0287	-3.5499	-0.1019
Azadirachta indica	Meliaceae	95	0.1299	-2.0405	-0.2651
Ficus exasperate	Moraceae	20	0.0274	-3.5987	-0.0986
Acacia seyal	Fabaceae	1	0.0014	-6.5944	-0.0092
Pterocarpus erinaceus	Fabaeae	26	0.0356	-3.3363	-0.1188
Vattelleria paradoxa	Sapotaceae	10	0.0137	-4.2918	-0.0588
Prosopis Africana	Mimosoideae	7	0.0096	-4.6485	-0.0446
Vitex doniana	Verbanaceae	34	0.0465	-3.0681	-0.1427
Lannea schimperi	Anacardiaceae	2	0.0027	-5.9012	-0.0159
Elaeis guinensis	Arecaceae	39	0.0534	-2.931	-0.1565
Bridelia ferruginea	Euphorbiaceae	3	0.0041	-5.4958	-0.0225
Pseudocedrela kotschyi	Meliaceae	6	0.0082	-4.8027	-0.0394
Lannea acida	Anacardiaceae	23	0.0315	-3.4589	-0.0109
Acacia nilotica	Mimosoideae	15	0.0205	-3.8864	-0.0797
Mitragyna inermis	Rubiaceae	3	0.0041	-5.4958	-0.0225
Terminalia avicennioides	Combretaceae	7	0.0096	-4.6485	-0.0446
Magnifera indica	Anacardiaceae	29	0.0397	-3.2271	-0.1281
Hannoa undulate	Simaroubaceae	6	0.0082	-4.8027	-0.0394
Sterculia setigera	Sterculiaceae	2	0.0027	-5.9012	-0.0159
Albizia zygia	Mimosoideae	6	0.0082	-4.8027	-0.0394
Delonix regia	Fabaceae	2	0.0027	-5.9012	-0.0159
Schefflera actinophylla	Araliaceae	12	0.0164	-4.1095	-0.0674
Parkia biglobosa	Mimosoideae	1	0.0037	-6.5944	-0.0244
Lophira lanceolata	Onchnaceae	3	0.0041	-5.4958	-0.0225

H' =2.0443, N = 731, E_H =0.6203, M' = 0.9986

Principal Components Analysis

In the third principal component, 100% variability was recorded among the tree species studied (Table 3). Frequencies of occurrence of the species and their diversity (richness and evenness) contributed to the variability and were associated with the different principal components. The first principal component contributed 87.7% of the total variability, positively linked to species occurrence frequency and species richness.

Table 3: Principal Components Analysis

Variable	PC 1	PC 2	PC 3
Frequency	0.510	0.455	-0.184
pi	0.509	0.457	-0.178
ln(pi)	0.466	-0.723	-0.510
(pi)ln(pi)	-0.514	0.248	-0.821
Eigenvalue	3.5061	0.4206	0.0733
Proportion	0.877	0.105	0.018
Cumulative (%)	0.877	0.982	1.000

Cluster Analysis

Cluster analysis shows 8 distinct clusters, with *Daniella oliveri* alone in cluster 8, *Gmelina arborea* alone in cluster 7, *Pterocarpus erinaceus* alone in cluster 6, *Parkia biglobosa* alone in cluster 5, among others. Cluster 1 has the highest number of plant species (10) belonging to the families Anacardiaceae, Rubiaceae, Sterculiaceae, Mimosoideae, Meliaceae, Combretaceae and Fabaceae; cluster 2 has 4 tree species belonging to the families Moraceae, Verbanaceae and Mimosoideae; cluster 3 has 5 tree species belonging to the families Sapotaceae, Araliaceae, Euphorbiaceae, Sterculiaceae and Onchnaceae and cluster 4 has 3 tree species belonging to the families Arecaceae and Anacardiaceae.

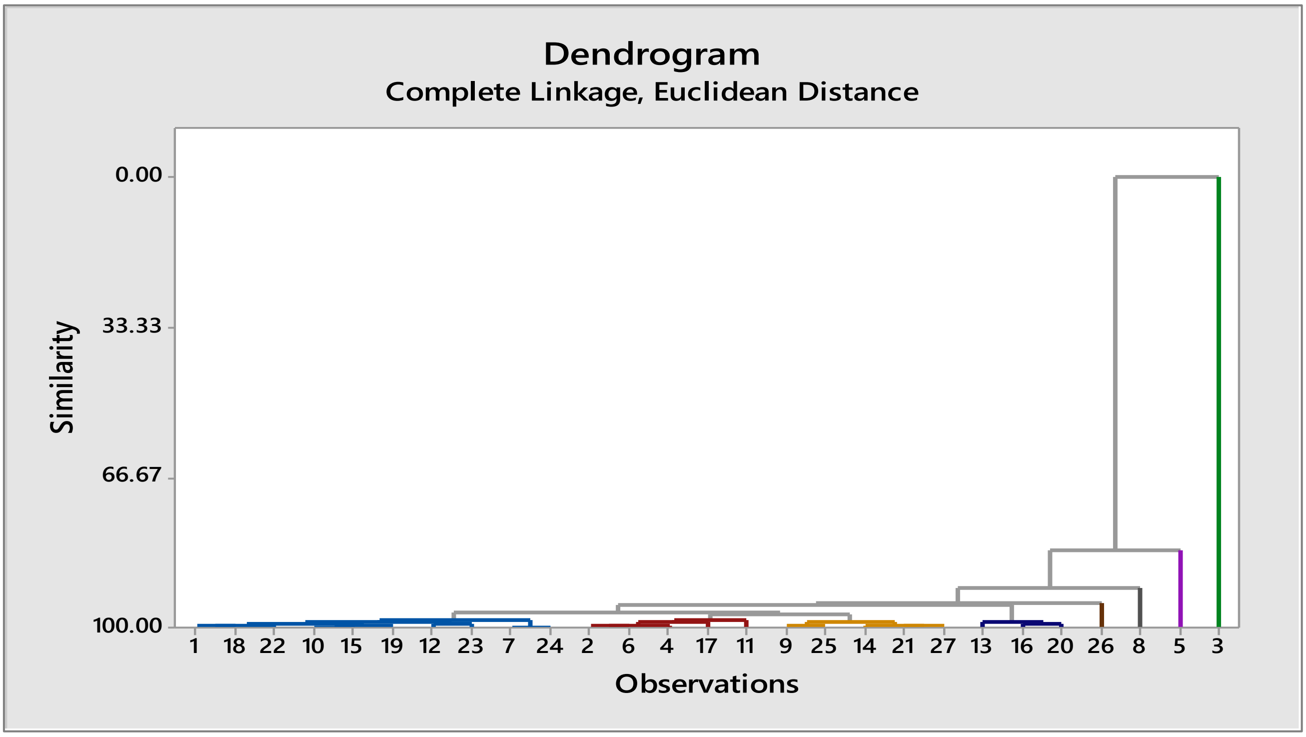

Figure 2: Cluster Analysis

Key: 1 **=** *Anacardium occidentale*, 2 = *Ficus sur*, 3 = *Daniella oliveri*, 4 = *Gmelina arborea*, 5 = *Azadirachta indica*, 6 = *Ficus exasperate*, 7 = *Acacia seyal*, 8 = *Pterocarpus erinaceus*, 9 = *Vitellaria paradoxa*, 10 = *Prosopis Africana*, 11 = *Vitex doniana*, 12 = *Lannea schimperi*, 13 = *Elaeis guineensis*, 14 = *Bridelia ferruginea*, 15 = *Pseudocedrela kotschyi*, 16 = *Lannea acida*, 17 = *Acacia nilotica*, 18 = *Mitragyna inermis*, 19 = *Terminalia avicennioides*, 20 = *Mangifera indica*, 21 = *Hannoa undulate*, 22 = *Sterculia setigera*, 23 = *Albizia zygia*, 24 = *Delonix regia*, 25 = *Schefflera actinophylla*, 26 = *Parkia biglobosa*, 27 = *Lophira lanceolata*.

DISCUSSION

Data on the forest structure revealed that, of the 731 tree species sampled, *Daniella oliveri* (n = 336, 46.37%) was the most dominant species (Table 1). Similarly, Amonum *et al.* (2019), in their study, which was carried out in the College of Forestry and Fisheries, Joseph Sarwuan Tarka University in Makurdi, reported *Daniella oliveri* as the dominant species with a frequency of 29%, and Paul *et al.* (2019) asserted that *Daniela oliveri* was the most dominant species of plant found in Makurdi Zoological Garden. However, one must exercise caution in comparing results because of the study differences in forest types, methodology, and equations used in the different studies. In the study region, 731 tree stands were found, but there was a wide range in the number of occurrences; certain trees (*Daniella oliveri*) had as many as 336 individuals, while other trees (*Parkiabiglobosa* and *Acacia seyal*) had as few as one stand (Table 1). These notable differences may not be unrelated to human preferences regarding use since the species with smaller populations may be more valued for firewood, building materials for nearby homes, lumber, yam farming, or as forest minor products whose fruits, leaves, and flowers are significant to the local population. Also, this study shows that the family Ceasalpiniodeae have the highest relative abundance of 0.4637, while Fabaceae and Anacardiaceae have the least relative abundance of 0.0027 (Table 1). These findings contradict Amonum *et al.* (2019) who reported the family Combretaceae to have the highest dominance.

The high species richness of trees (27 taxa) found in this study (Table 2) indicates that the flora was once more diversified than it is now. The garden's flora has a modest degree of species diversity, as shown by the Shannon diversity index value of 2.0443 (Table 2), demonstrating a respectable diversity of species. This agrees with the findings of Soba *et al.* (2023) in the neighboring State of Nasarawa, who reported a Shannon diversity index value of 2.74. The Makurdi Zoological Garden's flora exhibits a poor distribution of individual species, as indicated by the evenness score of 0.6203 (Table 2). This suggests that certain species are more abundant than others, leading to an uneven distribution of species; also, the Menhinick value of 0.9986 (Table 2) suggests that the flora of the Makurdi Zoological Garden has low species richness, which implies that some species predominate in the flora. This low species richness is also supported by the findings of Soba *et al.* (2023), who reported low species richness and asserted that most of the species in their study were either rare or endangered. Arguably, the differences within the study area may be a pointer to the effects of anthropogenic activities leading to the loss of rich biodiversity and the need to bring such activities under control to prevent further loss of plant species. The species diversity indices and evenness index revealed the presence of high tree diversity and even representation of species in the studied forest compared to other forests (Oluwatosin and Jimoh, 2016). Similarly, Olaoti-Laaro *et al.* (2021), in their study reported that the evenness index and species diversity were moderate, which is in agreement with Salami *et al.* (2016) and Akinyemi *et al.* (2020). Notably, the Shannon diversity index value of 2.0443 (Table 2) recorded in this study is lower than the 3.52 and 3.83 reported by Osabiya *et al.* (2022) for Akure Forest Reserve and Okomu National Park, respectively.

Furthermore, cluster analysis revealed a moderate level of diversity with 8 distinct clusters and species like *Daniella oliveri*, *Gmelina arborea*, *Pterocarpus erinaceus*, and *Parkia biglobosa being* 'Stand-alone-species' (Figure 2). Similarly, the dendrogram in Akinyemi *et al.* (2020) study revealed intimate relationships between species determined by their density inside the natural forest reserve, with *Triplochiton scleroxylon* being a 'Stand-alone species'. This low level of diversity is due to the observation that crops were being grown in the Makurdi Zoological Garden, indicating that human disturbances such as tree felling occurred in the natural forest to make room for agricultural produce. Apart from this, Amonum *et al.* (2019) reported that in Makurdi, Farming and grazing were some of the major problems in have, resulting in diversity depletion.

CONCLUSION

Conducting long-term monitoring of tree species diversity in Makurdi Zoological Garden periodically will help track changes and assess the impacts of anthropogenic activities and external factors like climate change. The data points to moderate species diversity in the Makurdi Zoological Garden's flora. A relatively uneven and diversified distribution of species indicates a relatively low level of species richness and may also point to the dominance of a particular species. It is concluded that a moderate level of species diversity exists in the zoological garden. Some of the tree species have experienced disturbances, making some species more abundant than others. Comparative studies with other botanical gardens, natural forest areas, or urban green spaces in Nigeria are necessary to understand differences in tree species composition, diversity patterns, and conservation strategies.

Additionally, local communities, conservation organizations, and policymakers should be involved in tree planting initiatives and biodiversity conservation awareness programs on sustainable management practices to enhance tree species diversity and ecosystem resilience in the region, particularly in Makurdi Zoo. Furthermore, this research area needs to be properly restricted and monitored. By taking this action, the research area's economically significant tree species will remain safe from potential threats.

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