

Comparative Analyses of Tree species in puje forest and Rafin-Kada Crocodile Swamp Forest, Wukari, Taraba State, Nigeria

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ABSTRACT

Sacred forests like Puje Sacred Forest and Rafin Kada Crocodile Swamp Forest in Wukari remains the future hope of genuine conservation hubs. The inventory of tree species composition, distribution, structural characteristics (diameter at breast height (DBH, basal area), and conservation status of the two forests was conducted in 2024/2025. Systematic sampling technique was employed using 50m × 50m and 25m × 100m plots at Puje Forest and Rafin Kada Forest respectively. Quantitative data of trees with DBH ≥10 cm identified and biodiversity indices (Shannon-Wiener, Simpson, Margalef's richness, and Pielou evenness) were computed. 1487 individual trees with 46 tree species (33 in Puje, 22 in Rafin Kada) across 19 families were identified. Fabaceae was the most dominant due to their easy dispersal and socio-economic purposes. Puje Forest exhibited higher species richness (Shannon index $H' = 2.61$; Margalef's $d = 4.72$) compared to Rafin Kada ($H' = 2.78$; $d = 3.28$). *Gmelina aborea* (IVI = 141.4) and *Azadirachta indica* (IVI = 18.73) dominated Puje, while *Ficus thorningii* (IVI = 33.18) and *Bridelia micrantha* (IVI = 22.7) were abundant in Rafin Kada indicating their fast growth and adaptability in the ecological habitat. DBH distribution with inverse J-shape indicates active regeneration, with 62.23% (Puje) and 79.60% (Rafin Kada) of trees in 10–30 cm class. Basal area was higher in Puje (1.87 m²/ha) than Rafin Kada (0.71 m²/ha). Jaccard similarity index (0.33) confirmed distinct species compositions. This study reflects the role of genuine conservation practices based on religious beliefs, of Wukari tree species attributed to the sacredness of the sites.

Keywords: Puje Forests, Rafin-kada Forest, Shannon-Weiner index, Simpson index, Wukari.

INTRODUCTION

Taraba State is one of the few States in Nigeria that possess a unique characteristic of woody species vegetation, and the diversity of this vegetation seems to decrease in most of the ecological zones. This has resulted in decreasing size and quality of natural forests at alarming rates (Meer and Tella, 2018).

Trees are integral part of land resources that need careful management and sustainable utilization for future generations (Salami *et al.*, 2021).

Sacred natural sites can include individual trees, forests, rivers, waterfalls, meadows, wildlife, caves, lakes, and hills (Liljeblad and Verschuuren, 2019). Sacred groove is one of the prominent methods of *in-situ* conservation of biodiversity particularly in Nigeria

and the World in general and patches of vegetation protected on the basis of religious faith are referred to as sacred grooves (Aina-Oduntan *et al.*, 2022). Over the last two decades, many of these sites are also being recognized as “Indigenous peoples and local Communities Conserved Areas” (abbreviated to ICCAs) preserved through what the 10th Conference of the parties to the Convention on Biological Diversity (CBD 2010) termed “Other Effective Area-Based Conservation Measures” (OECMs). Sacred groves that hold strong cultural and religious importance to local people are increasingly recognized as a traditional form of community-based conservation (Bulkan, 2017). The Puje Forest and Rafin Kada Crocodile Swamp Forest are relatively undisturbed forest areas which are sacred natural sites playing essential roles in preserving the cultural heritage of the Jukun people of Wukari Local Government Area. The focus of this research is to investigate the conservation statuses of the two Forests through inventory of the the composition of the standing tree species.

MATERIALS AND METHODS

Description of the Study Area: Geographically, Wukari is located between longitude $9^{\circ} 08'$ and $10^{\circ} 23'$ East ($392487.77E$, $81642288.39N$) of the Greenwich Meridian and Latitude $7^{\circ} 35'$ and $8^{\circ} 15'$ North ($500000.00E$, $90539916.70N$) of the Equator, with an elevation of 200m above sea level Southern Taraba zone, Nigeria (Yakub *et al.*, 2022). Wukari shares common boundaries with Gassol Local Government to the North and Ukum Local Government Area of Benue state to the South. In the west, it shares boundary with Ibi Local Government Area of Taraba state. While its Eastern boundaries are shared by Donga Local Government Areas of Taraba state and a little portion with Abako town of Katsina-Ala Local Government Area of Benue State. The area is characterized by savannah vegetation zone interspersed with riparian forests along water course and rocky outgrowths constituting the major land form of the area. Rainy and dry seasons are the two major climatic seasons in Wukari (Otitoju *et al.*, 2018).

Description of the Sampling Sites: The research work was conducted in Puje Sacred Forest and Rafin Kada Crocodile Swamp Forest in Wukari Local Government Area of Taraba State. Puje Forest is located between latitude $N7^{\circ}52'22.87531^{11}$ and $N7^{\circ}52'3.36508^{11}$ of the Equator and between longitude $E9^{\circ}48'18.2853^{11}$ and $E9^{\circ}47'18.89604^{11}$ of the Greenwich meridian. Rafin-Kada Crocodile swamp forest is located between latitude $N7^{\circ}40'44.40108^{11}$ and $N7^{\circ}43'4.81062^{11}$ and longitude $E9^{\circ}51'26.80207^{11}$ and $E9^{\circ}54'42.88673^{11}$ of the Greenwich meridian. These locations were recorded using Global Positioning System (GPS) device.

The satellite image map of the outlines of the sampling plots of the Puje Forest and the Rafin-Kada Crocodile Swamp are shown in Fig 1 and Fig 2.

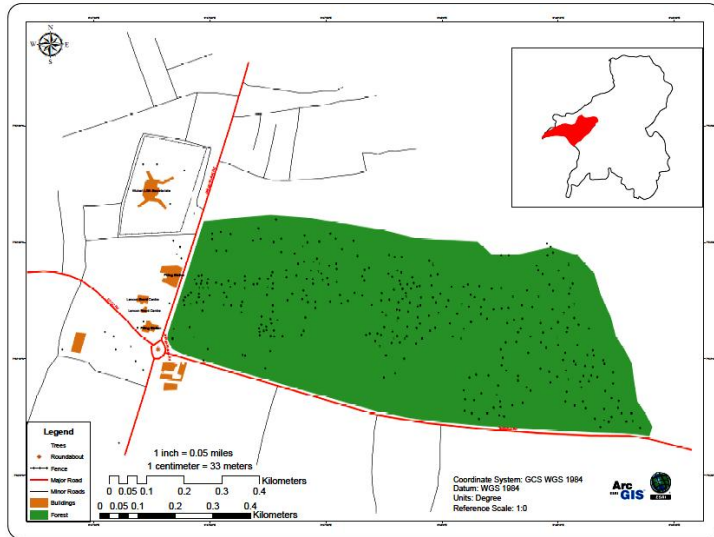


Fig 1: Map of Puje Forest (Source: Arc GIS using Coordinates)

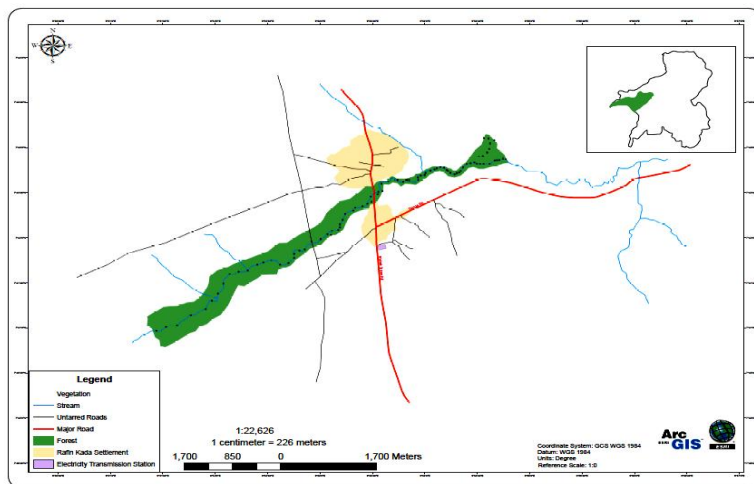


Fig 2: Map of Rafin-Kada Crocodile Swamp Forest (Source: Arc GIS using Coordinates)

The Puje Sacred Forest spans approximately 5178897.78 Square metres (51.79 ha) and is characterized by a flat terrain typical of tropical savanna forest, rich in diverse tree species. It is situated along Wukari-Tsokundi road with several footpaths from the road into the forest. The forest starts from the Tsokundi Roundabout in Wukari urban settlement to about 1700m along Tsokundi Road and about 363m along Wukari-Jalingo Road which implies that the forest is sited opposite the Wukari Local Government Secretariat. Agricultural activities are largely absent in the forest but there exists some small-scale encroachment by local farmers which has created separations between the various forest shrines particularly the Benji-ku areas. Cattles browse on the lower trees of the forest as well as the herbs on the forest floor.

The Rafin-Kada Crocodile Swamp Forest has unique wetland ecosystem in the tropical savanna belt with cultural significance. This forest is situated along Wukari-Takum road in Rafin-kada and has six ponds which are inhabited by crocodiles which thrive in the wetland habitat. The forest is cut into by the Wukari-Takum Road with a bridge across the stream. The inhabitant of Rafin-Kada are mostly farmers and agro-products traders. The forest has experienced significant destruction, primarily due to agricultural activities, particularly rice farming which has reduced tree cover to minimal species found only along the streams that meander through the forest landscape, ultimately emptying into river Donga. This makes the swamp forest to have a linear structure that follows the contours of the stream creating a distinctive ecological profile.

Sampling Technique and Sampling Plot: Systematic Sampling Technique was employed for the sampling of Experimental plots. In Puje Forest, Systematic line transects as described by Osemeobo (1992) was used in the laying of the plots at the central location of the forests. Two transects of 1000m in length parallel to each other at 100m apart were laid. Then, sample plots of 50m x 50m were established in alternate positions along the two transects as shown in Fig 3. In Rafin-Kada Crocodile Swamp Forest, the line transects were laid at the boundaries of forest whose trees has been reduced to grow in a meandering nature of the stream that flows from the swamp and sampling plots of 25m x 100m each were established in between the lines transects at regular intervals of 25m as shown in fig 3.

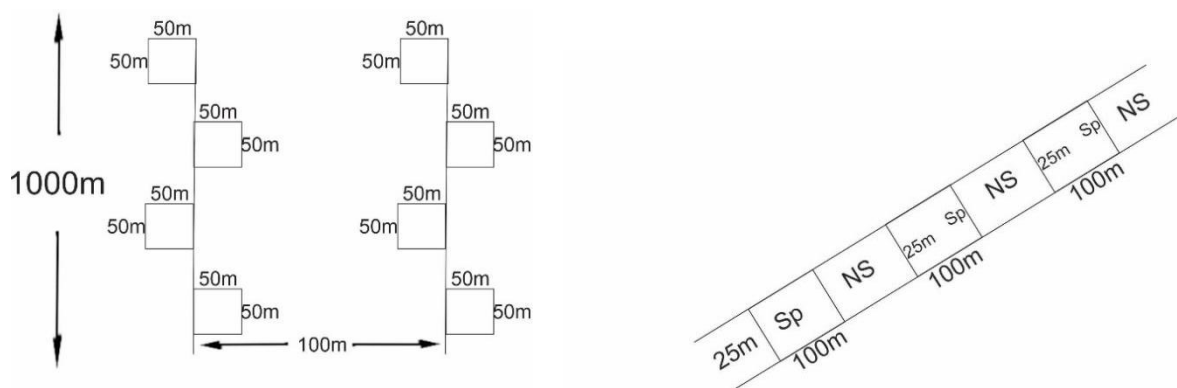


Fig 3: Line Transects layouts of Puje Forest and Rafin-Kada Crocodile Forest

Data Collection: All Trees with diameter at breast height equal or greater than 10cm on each sample plot were tagged, measured and identified to species level. Frequency of occurrence, the number and scientific name of all tree species encountered were recorded. Parts (Barks, leaves and fruits) of trees which cannot be identified on site were snapped for proper identification using Plantnet Apps (Coskunserce, 2024) and tree identification guide books, which include Tropical Community Tree Crops (Opeke, 2005), Trees of Nigeria (Keay, 2023), Useful Plants of West Tropical African (Burkill, 2000). Use of local names was also employed in identification of tree species.

Tree Growth Measurement: The diameter at breast height (dbh) of all trees equal or greater than 10cm was measured using girth tape.

Basal Area: Basal area of each tree was calculated using the formula adopted from Zakaria *et. al.*, (2016).

$$\text{The basal area BA} = \frac{\pi D^2}{4}$$

Where: BA= Basal area (m²), D = Diameter at breast height (m) and π =pie (3.143).

Data Analysis: Quantitative parameters like frequency, relative frequency, density, relative density, relative dominance and important value index (IVI) were used to analyzed the data. The Species Diversity indices were estimated using SPSS software version Shannon-Weiner Index was used to measure diversity, both richness (number of species) and evenness (relative abundance of each species) within the community, while Margalef Species Richness Index measured Species richness. Simpson Diversity Index and Sorensen Similarity Coefficients assessed the dominant and common species in the community and compared the species composition within sites respectively. Pielou's Species Evenness Index was used to measure Jaccard Coefficient similarity (JCs) indices, as implemented in SPSS software, was used to compute the similarity between the study sites based on the presence/absence of species and number of species common to the Forests.

RESULTS AND DISCUSSION

A total of 884 individual trees belonging to 33 species and 15 families were recorded in Puje Forest while 603 individual trees belonging to 22 species and 12 families were identified in Rafin-Kada Crocodile Swamp Forest as presented in Tables 1 and 2 respectively. The most dominant family at both sites was Fabaceae with 8 species and 4 species in Puje Forest and Rafin-Kada Crocodile Swamp Forest respectively. The most abundant tree species at Puje Sacred Forest were *Gmelina arborea* (39.71%, IVI=141.4) and *Azadirachta indica* (10.07%, IVI= 18.73) (Table 1), while *Ficus thorningii* (20.23%, IVI= 33.18), *Bridelia micrantha* and *Antidessima venosum* having 9.95%, IVI =22.7 and 9.45%, IVI=20.97 respectively were the most abundant tree species at Rafin-Kada Crocodile Forest (Table 2). The high dominance of *Gmelina arborea* and *Azadirachta indica* is likely due to their fast growth and adaptability and the inconsistency with other studies might be attributed to the differences in the ecological zone. Also the dominance of *Gmelina arborea* followed by *Azadirachta indica* and *Prosopis africana* in Puje Sacred Forest as well as *Ficus thorningii* followed by *Bridelia micrantha* and *Antidessima venosum* in Rafin-Kada forest aligns with Abdullahi and Bada (2024) report of *Gmelina arborea* recording highest dominance in Edun Forest Reserves and Salami *et al.*, (2021) who reported that *Azadirachta indica* has the highest IVI in Bauchi, Katsina and Kogi States. The high dominant of *Vitex doniana* is similar to the report of Mato *et al.* (2024) in Nigerian Defence Academy Botanical Garden.

The diameter at breast height (DBH) and basal area of the trees identified at both the Puje Sacred Forest and Rafin Kada Crocodile Swamp Forest are shown in Fig 4. The DBH and basal area are the selected structural characteristics.

At both Puje Sacred Forest and Rafin-Kada Crocodile Swamp Forest, *Daniellia oliveri* had the highest mean diameter at breast height (DBH) and Basal Area of 0.54m and 0.23 m² and 0.25m and 0.06m² respectively. The DBH percentage distribution of trees was highest in the 10 -30cm class at both forests (Puje Sacred Forest = 62.23% and Rafin Kada Forest = 79.60% of trees) (Fig 4). This indicates that both forests are dominated by younger or medium-aged trees reflecting a good regeneration status and healthy forest ecosystem (Onyekwelu *et al.*, 2022). The structural characteristics of the two forests suggest that both are in a state of regeneration, with a higher proportion of younger trees. However, Puje Forest has a higher basal area, indicating greater biomass and carbon storage potential. This aligns with the finding where forests with higher basal areas were noted for their ecological productivity and carbon sequestration potential (Salami *et al.*, 2021).

Table 1: Floristic Composition and Distribution of Tree Species in Puje Forest

S/ N	Species	No I (n)	%D	MDB H (m)	BA	F	R.F	D	R.D	R.Do	IVI
1	<i>Albizia lebeck</i>	6	0.68	0.22	0.04	0.25	2.03	1.2	0.68	0.01	2.72
2	<i>Anacardium occidentale</i>	14	1.59	0.25	0.05	0.35	2.84	2.8	1.59	0.05	4.47
3	<i>Andira inermis</i>	7	0.8	0.23	0.05	0.25	2.03	1.4	0.8	0.02	2.83
4	<i>Annona senegalensis</i>	6	0.68	0.13	0.02	0.25	2.03	1.2	0.68	0.01	2.71
5	<i>Annona squamosa</i>	8	0.91	0.17	0.03	0.25	2.03	1.6	0.91	0.01	2.94
6	<i>Asmina triloba</i>	4	0.46	0.22	0.04	0.1	0.81	0.8	0.46	0.01	1.27
7	<i>Azadirachta indica</i>	89	10.07	0.23	0.05	0.85	6.89	17.8	10.07	1.78	18.73
8	<i>Bombax ceiba</i>	9	1.02	0.26	0.06	0.35	2.84	1.8	1.02	0.03	3.88
9	<i>Cassia fistula</i>	13	1.48	0.23	0.05	0.5	4.05	2.6	1.48	0.04	5.56
10	<i>Ceiba pentandra</i>	4	0.46	0.22	0.04	0.2	1.62	0.8	0.46	0.01	2.08
11	<i>Combretum collinum</i>	4	0.46	0.24	0.05	0.1	0.81	0.8	0.46	0.01	1.27
12	<i>Ekebergia capensis</i>	1	0.12	0.24	0.05	0.05	0.41	0.2	0.12	0.01	0.52
13	<i>Erythrina crista-galli</i>	5	0.57	0.16	0.03	0.15	1.22	1	0.57	0.01	1.79
14	<i>Ficus racemosa</i>	5	0.57	0.23	0.05	0.2	1.62	1	0.57	0.01	2.2
15	<i>Ficus sycamorus</i>	22	2.49	0.27	0.06	0.55	4.46	4.4	2.49	0.15	7.09
16	<i>Gmelina arborea</i>	351	39.71	0.42	0.14	1	8.1	70.2	39.71	93.55	141.4
17	<i>Daniellia oliveri</i>	20	2.27	0.54	0.23	0.2	1.62	4	2.27	0.49	4.37
18	<i>Mangifera indica</i>	24	2.72	0.45	0.16	0.45	3.65	4.8	2.72	0.49	6.85
19	<i>Nauclea latifolia</i>	11	1.25	0.22	0.04	0.25	2.03	2.2	1.25	0.03	3.3
20	<i>Parkia biglobosa</i>	17	1.93	0.3	0.08	0.5	4.05	3.4	1.93	0.11	6.09
21	<i>Prosopis Africana</i>	59	6.68	0.34	0.1	0.9	7.29	11.8	6.68	1.73	15.69
22	<i>Quercus suber</i>	1	0.12	0.15	0.02	0.05	0.41	0.2	0.12	0.01	0.52
23	<i>Spathodea campanulata</i>	3	0.34	0.33	0.09	0.05	0.41	0.6	0.34	0.01	0.75
24	<i>Sterculia setigera</i>	10	1.14	0.3	0.08	0.4	3.24	2	1.14	0.04	4.41
25	<i>Strychros spinosa</i>	11	1.25	0.17	0.03	0.4	3.24	2.2	1.25	0.02	4.5

26	<i>Tectona grandis</i>	18	2.04	0.11	0.01	0.25	2.03	3.6	2.04	0.02	4.08
27	<i>Toona ciliata</i>	1	0.12	0.36	0.11	0.05	0.41	0.2	0.12	0.01	0.52
28	<i>Trema orientale</i>	11	1.25	0.21	0.04	0.15	1.22	2.2	1.25	0.03	2.49
29	<i>Trichilia emetic</i>	42	4.76	0.24	0.05	0.95	7.7	8.4	4.76	0.42	12.86
30	<i>Vachelia seyal</i>	45	5.1	0.22	0.04	0.75	6.08	9	5.1	0.43	11.59
31	<i>Vitellaria paradoxa</i>	17	1.93	0.24	0.05	0.65	5.27	3.4	1.93	0.42	7.6
32	<i>Vitex doniana</i>	44	4.98	0.16	0.03	0.85	6.89	8.8	4.98	0.22	12.08
33	<i>Ziziphus mauritiana</i>	2	0.23	0.28	0.07	0.1	0.81	0.4	0.23	0.01	1.04
Total		88	100	8.2	1.87	12.4	100	176.	100	100	300
		4						8			

Where NoI= Number of Individuals, %D=Percentage of Distribution, MDBH= Mean Diameter at Breast Height, B.A=Basal Area, F=Frequency, R.F=Relative Frequency, D=Density, R.D=Relative Density, Do = Dominance and IVI=Important Value Index

Table 2: Floristic Composition and Distribution of Tree Species in Rafin Kada Crocodile Swamp Forest

S/N	Species	NoI	%D	MDHB	B.A	F	R.F	D	R.D	R.Do	IVI
1	<i>Annona Squamosa</i>	13	2.16	0.15	0.02	0.5	3.58	2.6	2.16	2.47	8.2
2	<i>Antidessima venosum</i>	57	9.45	0.21	0.04	0.95	6.79	11.4	9.46	4.72	20.97
3	<i>Azadirachta indica</i>	10	1.66	0.17	0.03	0.4	2.86	2	1.66	3.31	7.83
4	<i>Bridelia micrantha</i>	60	9.95	0.22	0.04	1	7.15	12	9.96	5.61	22.7
5	<i>Elaeis guineensis</i>	11	1.82	0.16	0.02	0.4	2.86	2.2	1.83	2.8	7.49
6	<i>Ficus altissima</i>	41	6.8	0.2	0.04	0.75	5.36	8.2	6.8	4.52	16.68
7	<i>Ficus sycamorus</i>	19	3.15	0.22	0.04	0.75	5.36	3.8	3.16	5.49	14.01
8	<i>Ficus thorningii</i>	122	20.23	0.23	0.05	1	7.15	24.4	20.2	5.8	33.18
9	<i>Hymenaea courbail</i>	27	4.48	0.22	0.04	0.75	5.36	5.4	4.48	5.23	15.07
10	<i>Daniellia oliveri</i>	14	2.32	0.25	0.06	0.5	3.58	2.8	2.33	7.15	13.05
11	<i>Mangifera indica</i>	9	1.49	0.21	0.04	0.35	2.5	1.8	1.5	4.99	8.98
12	<i>Parkia biglobossa</i>	11	1.82	0.26	0.06	0.4	2.86	2.2	1.83	7.3	11.99
13	<i>Pouteria campechiana</i>	35	5.8	0.18	0.03	0.9	6.43	7	5.81	3.65	15.89
14	<i>Prunus serotina</i>	19	3.15	0.23	0.05	0.4	2.86	3.8	3.16	5.7	11.72
15	<i>Psidium guajava</i>	4	0.66	0.15	0.02	0.2	1.43	0.8	0.67	2.6	4.7
16	<i>Raphia sudanica</i>	12	1.99	0.15	0.02	0.5	3.58	2.4	2	2.65	8.23
17	<i>Samanea saman</i>	25	4.15	0.2	0.04	0.75	5.36	5	4.15	4.51	14.02
18	<i>Syzygium cumin</i>	25	4.15	0.19	0.04	0.85	6.08	5	4.15	4.32	14.54
19	<i>Vitellaria paradoxa</i>	16	2.65	0.19	0.03	0.5	3.58	3.2	2.66	4.15	10.38
20	<i>Vitex doniana</i>	13	2.16	0.16	0.02	0.55	3.93	2.6	2.16	2.76	8.84
21	<i>Vitex polygona</i>	27	4.48	0.21	0.04	0.7	5	5.4	4.48	5.11	14.59
22	<i>Ziziphus mauritiana</i>	33	5.48	0.22	0.04	0.9	6.43	6.6	5.48	5.16	17.07
Total		603	100	4.38	0.71	14	100	121	100	100	300

Where NoI= Number of Individuals, %D=Percentage of Distribution, MDHB= Mean Diameter at Breast Height, B.A=Basal Area, F=Frequency, R.F=Relative Frequency, D=Density, R.D=Relative Density, Do = Dominance and IVI=Important Value Index

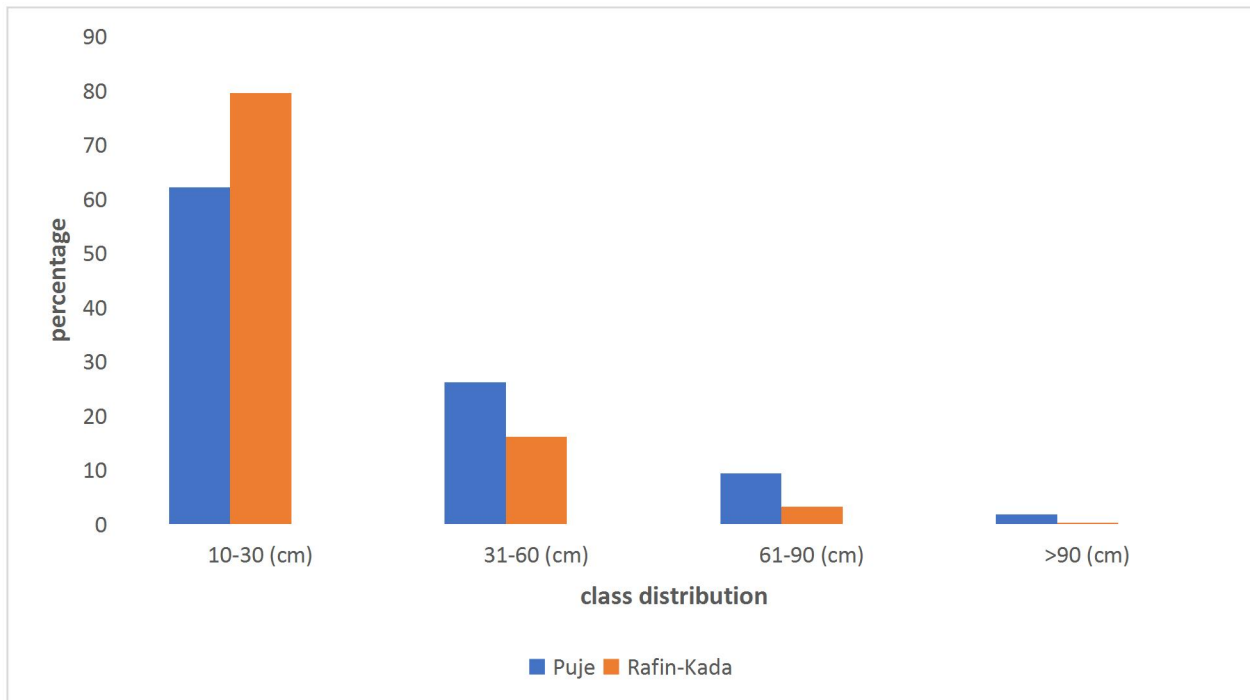


Fig 4: Percentage distribution of DBH Class Distribution of Puje Forest and Rafin-Kada Crocodile Swamp Forest

The Shannon-Weiner Index compares diversity in different habitats and assesses impacts of pollution or conservation. Margalef's index indicates species richness in the sampling sites. Pielous index signifies the uniformity or equity in the distribution of individuals among different species within an ecological community

All biodiversity indices (Shannon-Weiner, Simpson, Pielou's evenness) were higher at Rafin-kada Crocodile Swamp Forest than at Puje Sacred Forest except for the Margalef's Richness Index. However, Jaccard Similarity and Dissimilarity coefficients were presented as 0.33 and 0.67 respectively for Puje Sacred Forest and Rafin-Kada Crocodile Swamp Forest in Table 3. The high tree species identified at both sampling sites reflect less anthropogenic activities which contributed to favorable microclimate within the forests and availability of viable seeds of trees for sustainable regeneration (Ijomah *et al.*, 2022). This agrees with the findings of Mato *et al.* (2024) in Nigeria Defence Academy Botanical Garden (NDABG) and Soba *et al.* (2023) in Nasarawa State. Other similar range were reported by Bello *et al.* (2022) in Rabadi Forest Reserve, Afimy *et al.* (2024) in Gunung Inas Forest. Puje Forest exhibited higher species richness compared to Rafin Kada Forest which may be attributed the traditional conservation practices of the Sacred forest resulting to high bioversity. While the Rafin Kada Crocodile Forest has reduced into a linear forest growing along the swampy area due to farming activities.

Fabaceae are commonly in abundance in Savanna ecosystem and contribute significantly to the social and economic existence of the people as observed by Akwaji

and Edu (2017); Wakawa *et al.*, (2017) and Akwaji *et al.*, (2022). Also, most members of the Fabaceae Family are hardseeded with globarous seed coats which protects and enable availability of viable seeds in the soil and easily dispersed to sustain regeneration. Similarly, Mato *et al.*, (2024); Sodimu *et al.*,(2024); Chisom *et al.*, (2024); Ezenwenyi *et al.*,(2024); Jeyol and Yerima (2023); Salami *et al.*,(2022) and Okechalu *et al.*, (2021) all reported Fabaceae as dominate family in their studies.

The Important Value Index (IVI) measures a plant species' overall dominance and ecological significance in a community. It helps ecology understand the structure, biodiversity and dynamics of ecosystems guiding conservation efforts by identifying key species. *Gmelina arborea* was the most abundant tree observed in the study area reflecting its high economic uses (fodder, softwood timber for roofing and furniture etc) and fast growth or regeneration. Gmelina is mostly used for re-afforestation measures in Nigeria though it is an exotic species.

Table 3: Summary of Diversity Indices.

Indices	Puje Forest	Rafin-Kada Forest
Shannon-Weiner Index H^1	2.61	2.78
Simpson Diversity Index SDI	0.82	0.92
Margalef's Richness Index d	4.72	3.28
Pielou's Evenness Index E	0.75	0.90
Jaccard Similarity Coefficient		0.33
Jaccard Dissimilarity Coefficient		0.67

CONCLUSION

Forests are the lungs of the Earth due to their complex and intricate network of high diversity of trees. The high diversity of tree species in Puje and Rafin-Kada Crocodile Forests is an indication of the impact of the strict conservation practices and their structural characteristics arising from their natural regeneration ability. However, the Rafin-Kada Crocodile Swamp Forest, being a swampy forest has more restrictive growing conditions, leading to lower species richness and the farming activities that reduced the entire forest area to a linear forest growing along the stream. The dominant species of *Gmelina* and *Ficus* is an indication of their high economic uses and fast growth. The dominance of the Fabaceae Family is due to their hardseeded and globarous seed coats which protects and enable availability of viable seeds in the soil and easily dispersed to sustain regeneration. The DBH distributions in the forests indicated that they have good regeneration potentials. Further inventory of trees in the Puje Sacred Forest to provide a concrete baseline data should be encouraged and polycultures of the least dominant trees should be produced by horticulturists to enable their continuous sustainability. Also categorization of the trees into fast growing and slow growing ones should be identified for future re-afforestation measures of highly disturbed areas within Wukari.

CONFLICTS OF INTEREST

The Authors declare no conflicts of interest

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