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Floristic Composition and Diversity of Plants Across Three Vegetation Zones of Gashaka Gumti National Park, Northeastern Nigeria

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ABSTRACT

Gashaka Gumti National Park (GGNP) is Nigeria's biggest national park, with an elevation range of 300 m to its highest peak at 2400 m. Although GGNP has a wide range of plant species, particularly woody ones, there is limited information regarding its floristic composition along the vegetation zones. This study examined the floristic composition and species diversity of GGNP by systematically sampling plant species using quadrats of 25 m × 25 m and a point-centered quadrat (PCQ). A total of 228 plant species belonging to 114 genera and 49 families were recorded across the three major vegetation zones. Fabaceae was the most species-rich family (34 species), representing 14.9% of the species, followed by Malvaceae (18 species), representing 7.9%. Other important species include Moraceae and Rubiaceae, 15 species each, representing 6.6% of the species, respectively, while Combretaceae (10 species) represents 4.4% of the species recorded. The Lowland Tropical Rain Forest (LTRF) recorded 137 species in 42 families, and Montane Highland (MH) recorded 146 species in 43 families. In comparison, the Savannah Woodland (SW) recorded 68 species in 28 families. Twenty-five species, which account for 11% of the total, are threatened. Among them, 10 species are Vulnerable, six are Endangered,

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five are Critically Endangered, and four are Near Threatened, according to the International Union for Conservation of Nature (IUCN) Red List status. Across all plots, average Shannon-Weiner's species diversity indices of 2.40, 2.40, and 2.25 were recorded for MH, LTRF, and SW, respectively. According to Sorensen's similarity coefficient, LTRF and SW (33.42%) habitats recorded the highest species similarity, while MH, as against SW habitats, recorded the lowest (18.92%). The importance value indicated that the SW had the most important species based on the importance value (0.581) compared to other vegetation zones. The overall evenness values for LTRF, SW, and MH are 0.77, 0.78, and 0.77, respectively. This study offers significant insights into the flora variety and conservation situation of Gashaka Gumti National Park. It emphasizes the need for more research and conservation initiatives to save its distinct habitats and endangered species.

Keywords: Anthropogenic threats, biological conservation, Fabaceae family, flora diversity, Lowland Tropical Rainforest, montane vegetation, Savanna Woodland

INTRODUCTION

Nigeria boasts a wide variety of vegetation, encompassing nearly all African types (Nodza et al., 2021). This vegetational variety spans geopolitical zones, making it one of the most biodiverse countries in Africa (Ayodele & Yang, 2012). Despite this impressive biodiversity, Nigeria faces several environmental challenges that contribute to the decline of the country's vegetation resources. The most prominent environmental issues include deforestation, desertification, erosion, expansion of agricultural land, overgrazing, unsustainable utilization of biological resources, invasion of exotic species, and overexploitation for various purposes such as firewood, charcoal, construction material, farm implements, and timber (Bello et al., 2019; Borokini et al., 2023; Imarhiagbe et al., 2020; Okon et al., 2021). Ecosystem degradation occurs alarmingly, affecting designated conservation areas (Gumnior & Sommer, 2012). By 2006, almost 90% of Nigeria's rainforests had been cleared, with habitat destruction extending beyond forests, threatening various habitats through urbanization and unsustainable human practices. The widespread disregard for environmental protection and the high poverty rate exacerbates this ecological loss (Ayodele & Yang, 2012).

Nigerian authorities have established several parks, including Gashaka Gumti National Park (GGNP), the largest of Nigeria's eight gazetted national parks, covering 6731 km^2 of landmass to combat biodiversity loss (Sommer & Ross, 2011). Situated in the eastern highlands of Nigeria (Umar et al., 2019), the GGNP has great ecological and cultural importance (Febnteh et al., 2023), featuring diverse vegetation zones, ranging from lowland forests and savanna vegetation to mountains that harbor unique montane vegetation typical of Nigeria (Nodza et al., 2022a). However, the flora of GGNP remains poorly documented, with only a few botanical exploration records reported. For instance, Ezukanma et al. (2017) specifically cataloged the bryophyte species within the eastern highlands, encompassing

areas such as the Gashaka Gumti National Park (GGNP), documenting 27 species. Similarly, Chapman and Chapman (2001) identified no fewer than 24 plant species facing threats within the montane forests of Taraba State. In another study, Nodza et al. (2022a) concentrated solely on orchids, revealing a richness of 80 orchid species across 38 genera within the confines of the GGNP.

Recently, the GGNP has faced severe anthropogenic activities, such as illegal logging, intensive cattle grazing, and artisanal mining (Nodza et al., 2022b). Illegal logging of Rosewood (*Pterocarpus erinaceus*) has been a significant threat due to high demand in China and other Asian countries (Chen et al., 2022; Dumenu, 2019; Kombat & Chen, 2022; Siriwat & Nijman, 2023), a trend observed across tropical Africa (Adjonou et al., 2020; Kossi et al., 2021), including Taraba State (Ahmed et al., 2016), where GGNP is located. Massive logging of various timber species, such as *Afzelia africana, Erythrophleum suaveolens*, and *Pseudospondias macrocarpa* has significantly impacted the park. These activities have led to insecurity within the park, making it nearly inaccessible due to kidnapping, armed robbery, and cattle rustling. Herdsmen have encroached on park habitats, looping branches of *A. africana* and other species to feed their cattle in savanna vegetation (Nodza et al., 2022b).

Hence, the need for this study, as floristic studies play a crucial role in providing essential data on species numbers, forest variety, and vegetation types, aiding in forest management and enhancing our understanding of forest ecology and ecosystem functions (Anamo et al., 2023; Hammanjoda et al., 2022; Haq et al., 2023; Negesse & Woldearegay, 2022; Sewale & Mammo, 2022; van Rooyen et al., 2019). The objectives of this study are to identify and classify floristic species in the various vegetation zones of the GGNP and to assess the richness, similarity, and diversity of species in the different vegetation zones of the park.

MATERIALS AND METHODS

Study Area

The Gashaka Gumti National Park (GGNP) is the biggest in Nigeria, spanning roughly 6,700 square kilometers. It is situated in the country's northeastern region and is of great importance to national and international conservation efforts. The park extends from the Taraba state (Plateau), running northwards along the boundary with Cameroon and Africa's Gulf of Guinea forests. It continues to Adamawa State, reaching as far as Toungo, known for its high biodiversity (Sommer & Ross, 2011). The region is situated between 06°55′ latitude and 08°13′ longitude North and between 11°13′ latitude and 12°11′ longitude East (Figure 1). Pictures showing parts of the vegetation zones sampled in the GGNP are presented in Figure 2.

GGNP, located in Nigeria's Northern state, shares many ecological similarities with southern regions (Sommer & Ross, 2011). The park features extensive mountainous areas, part of the Eastern highlands, with altitudes ranging from 300 m to over 2,400 m above sea level. Chabbal Wadde (the highest mountain in Nigeria) is situated southeast of the park, near the Nigeria-Cameroon boundary (Sommer & Ross, 2011).

Gashaka Gumti is typically found in the Guinea savanna zone, although it stands out from other central habitats because of its lengthy and distinct dry season. It is common to lack rainfall over three months, from December to February. The onset of the rainy season often occurs in March or early April and concludes in mid-November. The park has a variation in annual rainfall, with the northern region receiving around 1200 mm and the southern region receiving over 3000 mm. The mountains facilitate high rainfall by causing the humidity from the Atlantic to rise to higher altitudes, cool down, and condense into clouds that produce rain. It enables the development of lush forests (Dishan et al., 2010; Nodza et al., 2022b).

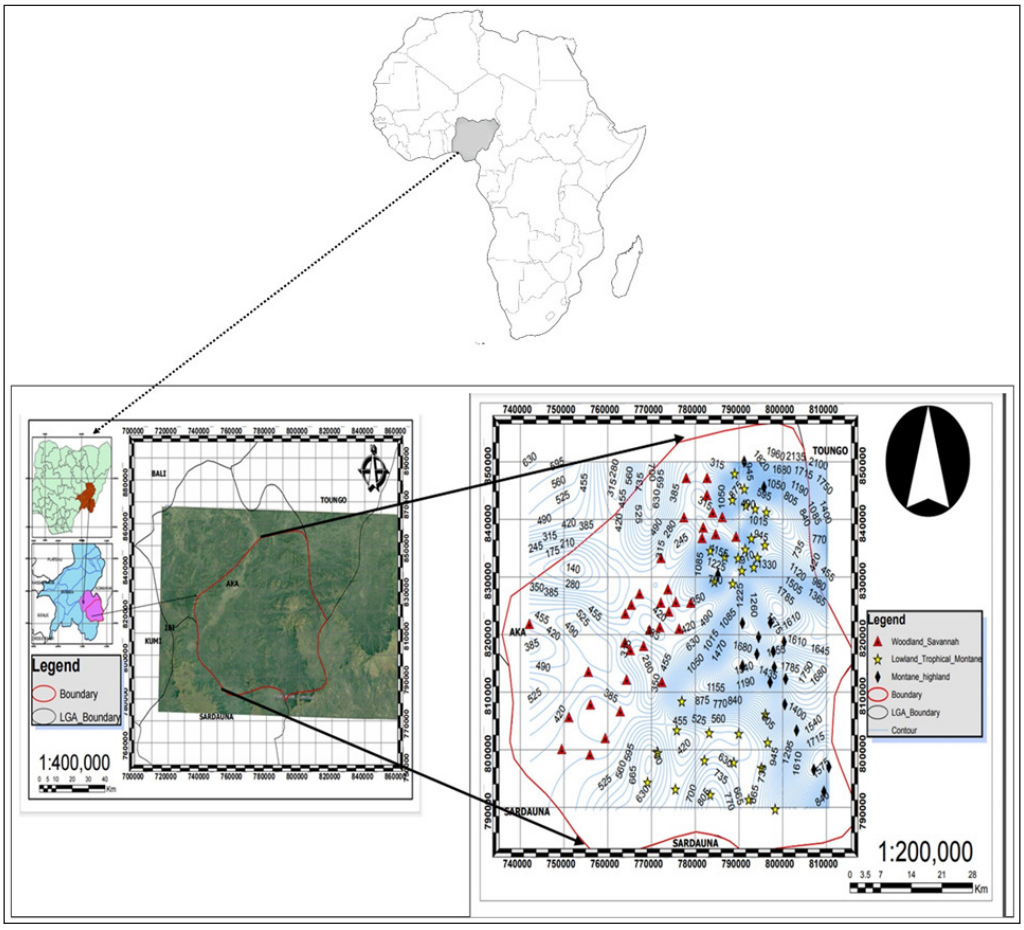

Figure 1. Sampling sites in the three vegetation zones of the Gashaka Gumti National Park

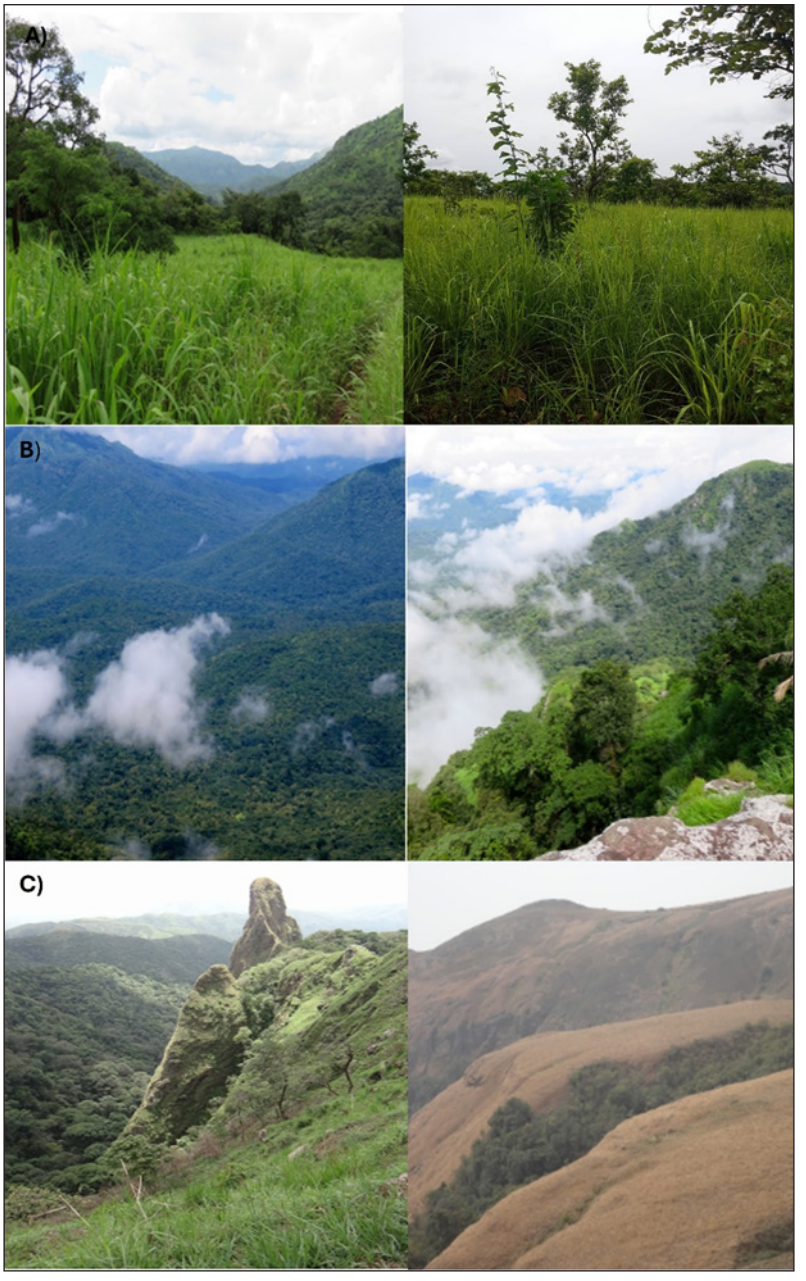

Figure 2. Picture showing parts of the sampled vegetation such as A) Savanna woodland, B) Lowland tropical rainforest, and C) Montane highland

The flora has been extensively modified by the cumulative and lasting impacts of fire, farming, and grazing activities (Dishan et al., 2010). Currently, the Park has a total of seven distinct habitat categories. These habitats include lowland gallery forests (specialized

forests along rivers and streams in tropical regions, characterized by unique vegetation and ecological characteristics), montane grassland, riverine or riparian forest, Southern guinea savanna, Northern guinea savanna, montane forest, and derived savanna. The Northern (Gumti) region mostly consists of forests, distinguished by trees with relatively short trunks, wide leaves, and tall grasses (Nodza et al., 2022b). The savanna is home to many often-seen tree species, such as *A. africana, Acacia* sp., *Danielia oliverii, Khaya senegalensis, Vitelleria paradoxa,* and *Isoberlinia doka*. The forest in the southern (Gashaka) region is mainly covered by moist Southern Guinea savanna. The dominant tree species in this area include *A. africana, Albizia gummifera*, *Symphonia globulifera*, *Aubrevillea kerstingii*, and *Triplochiton schleroxylon*. The montane vegetation in Gangirwal is characterized by elevated montane grassland, while a typical montane forest dominates the valleys. The dominant plant species in this forest are *Loudetia simplex*, *Rhytachne* sp., and*. Elionurus argenteus* (Nodza et al., 2022b).

Sampling Procedure

We conducted a reconnaissance survey of all the different vegetation zones in GGNP starting from March 2023 (dry season). It was finalized in April 2023 (wet season) based on topographic and vegetation maps of the reserve (Sommer & Ross, 2012). The sample collection occurred at the onset of the rainy season, namely from mid-April to September 2023, by an average of nine individuals throughout the sampling period. The recorded data included geographical locations obtained via a Global Positioning System (GPS) device, namely the GARMIN GPS 12®. The latitudes and elevations were measured following the methodology described by Kumar and Moore (2002). We collected data on habitat type, topography, altitude, human activities, physical features of woody species, and land use patterns. The PCQ sampling approach, as described by Blydenstein (1967), was used to sample forest ecosystems characterized by challenging terrains, such as steep escarpments. We systematically sampled plant species using 25 m × 25 m quadrats and a PCQ. During the research period, 150 sample plots were surveyed, 50 in each vegetation zone. The quadrat dimension utilized in this study is a regularly used size for tropical forest sampling (van Rooyen et al., 2019). The number of plant species on each plot was tallied during the fieldwork, and their common names were documented.

Species Identification and Classification

Specimen identification was conducted in the field by a plant taxonomist. For those specimens that could not be identified in the field, voucher specimens were collected and brought to the Lagos University Herbarium (LUH) for identification by the same expert using taxonomic keys, descriptions, and illustrations, as described by Hutchinson and Dalziel (1927). The final scientific names and authorities were determined using the ‘Plants

of the World Online' (POWO: https://powo.science.kew.org/). Plant classification followed species lists in the Angiosperm Phylogeny Group (APG) (APG, 2016). The IUCN red list was used to assess the conservation status of the species (IUCN: https://www.iucn.org/).

Diversity Indices

Shannon-Weiner diversity index, Sorensen's similarity coefficient, important value index, and evenness index were computed. The Shannon-Weiner diversity index was applied based on the following Equation 1:

$$H' = - \sum Pi \ In \ Pi \quad [1]$$

where H' = Shannon-Wiener Diversity Index
Pi = ni/N = number of individuals within species (ni) /total number of individuals (N).
In = natural logarithm

The evenness index (J') was also calculated as Equation 2:

$$J' = \frac{H'}{\ln(S)} \quad [2]$$

where H' = Shannon-Wiener Diversity Index
H' max = LnS' where S refers to the number of species.

Sorensen's Similarity Coefficient was determined using the Equation 3:

$$S = \frac{2a}{2a + b + c} \quad [3]$$

where,
a is the number of species shared between the two habitats (or sampling sites).
b is the number of species unique to the first habitat (or sampling site).
c is the number of species unique to the second habitat (or sampling site).

The Importance Value Index of species (IVI) was determined using the Equation 4:

$$IVI = \frac{RF + RD + RDo}{3} \quad [4]$$

where,
RF = Relative Frequency
RD = Relative Density
RDo = Relative Dominance

RESULTS

Floristic Composition and Conservation Status

A total of 228 plant species belonging to 114 genera and 49 families were identified from the 150 plots in the study area (Table 1). Fabaceae was the most species-rich family, with 34 species, followed by Malvaceae, with 18 species. Moraceae and Rubiaceae each had 15 species, while Combretaceae had 10 species. (Figure 3). The LTRF recorded 137 species in 42 families, with Fabaceae having the highest frequency (22 species). Malvaceae followed with 12 species, Moraceae (nine species), Apocynaceae (eight species), and Anacardiaceae (seven species) (Figure 4).

The MH recorded 146 species in 43 families, with Fabaceae having the highest frequency of 15 species. Moraceae followed with 11 species, Rubiaceae and Malvaceae recorded nine species each, while Phyllanthaceae, Lamiaceae, and Apocynaceae recorded six species, respectively (Figure 5). The SW recorded 68 species in 28 families, with Fabaceae having the highest number of species (15). Combretaceae followed with six species, Moraceae and Malvaceae, five species each, while Rubiaceae and Phyllanthaceae recorded four species each (Figure 6). Conservation assessment revealed that 25 species (11% of the total) are threatened, with 10 Vulnerable, Six Endangered, Six Critically Endangered, and Four Near Threatened, according to the IUCN Red List status. Trees (T) dominate the landscape, making up 78.5% of the vegetation (Figure 9). It is important to note that many of these trees serve as hosts for epiphytes, including delicate orchids. In addition to trees, other life forms are also present. Shrubs (S) comprise 9.2% of the overall composition, while herbs (H) account for 7.0% of the plant community. Climbers (CL), lianas (L), and small herbs (SH) contribute the remaining percentages such as 2.2%, 2.2%, and 0.4%, respectively (Figure 7).

Table 1
List of floristic species distribution across the three vegetation zones of the Gashaka Gumti National Park

S/N	Family	Species Name	LTRF	MH	SW	CS
1	Acanthaceae	*Justicia striata* (Klotzsch) Bullock	-	×	-	1
2	Anacardiaceae	*Anacardium occidentale* L.	×	-	-	2
3		*Lannea acida* A.Rich.	×	×	×	1
4		*Lannea barteri* (Oliv.) Engl.	×	×	×	2
5		*Lannea nigritana* (Scott Elliot) Keay	×	×	-	1
6		*Lannea schimperi* (Hochst. ex A. Rich.) Engl.	-	×	-	1
7		*Mangifera indica* L.	×	×	×	3
8		*Pseudospondias microcarpa* (A.Rich.) Engl.	×	-	-	1
9		*Pseudospondias cf microcarpa* Engl.	×	-	-	2
10	Annonaceae	*Annona senegalensis* Pers.	×	×	×	2

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
11		*Isolona deightonii* Keay	×	×	-	4
12		*Xylopia aethiopica* (Dunal) A.Rich.	×	-	-	2
13	Apocynaceae	*Alstonia boonei* De Wild.	×	-	×	2
14		*Calotropis procera* (Aiton) W.T.Aiton	×	×	×	2
15		*Landolphia owariensis* P.Beauv.	×	×	-	1
16		*Landolphia togolana* (Hallier f.) Pichon	×	-	-	1
17		*Rauvolfia vomitoria* Wennberg	×	×	-	2
18		*Tabernaemontana* sp.	×	×	-	2
19		*Voacanga africana* Stapf	×	×	-	2
20		*Voacanga thouarsii* Roem. & Schult.	×	×	-	2
21	Aquifoliaceae	*Ilex mitis* (L.) Radlk.	×	-	×	4
22	Araceae	*Anchomanes difformis* (Blume) Engl.	-	-	×	2
23	Araliaceace	*Polyscias fulva* (Hiern) Harms	×	-	×	2
24		*Cussonia arborea* Hochst. ex A.Rich.	×	×	-	2
25		*Cussonia barteri* Seem.	×	-	-	NA
26		*Schefflera abyssinica* (Hochst. ex A.Richa.) Harms	-	×	-	4
27		*Schefflera mannii* (Hook.f.) Harms	-	×	-	4
28		*Strombosia scheffleri* Engl.	-	×	-	2
29	Arecaceae	*Borassus aethiopum* Mart.	×	-	×	2
30		*Elaeis guineensis* Jacq.	×	-	-	2
31		*Phoenix reclinata* Jacq.	×	×	-	2
32		*Raphia hookeri* G.Mann & H.Wendl.	×	×	-	1
33		*Raphia mambillensis* Otedoh	×	×	-	2
34	Asparagaceae	*Drimia coromandeliana* (Roxb.) Lekhak & P.B.Yadav	×	×	-	1
35		*Drimia indica* (Roxb.) Jessop	-	×	-	1
36	Asteraceae	*Aspilia africana* (Pers.) C. D. Adams	-	×	×	1
37		*Bidens pilosa* L	-	×	-	1
38		*Chromolaena alternifolia* Gardner	×	-	-	1
39		*Chromolaena* DC	×	-	-	1
40		*Chromolaena odorata* (L.) R.M.King & H.Rob.	×	×	-	1
41		*Guizotia abyssinica* (L.f.) Cass.	-	×	-	1
42		*Vernonia glabra* (Steetz) Vatke.	×	×	-	1
43	Bignonaceae	*Newbouldia laevis* (P. Beauv.) Seem. ex Bureau	×	×	-	2
44		*Daniella oliveri* Hutch. & Dalziel	×	-	×	NA
45		*Kigelia africana* (Lam.) Benth.	-	×	-	2
46		*Spathodea campanulata* P.Beauv.	-	×	-	2
47		*Stereospermum acuminatissimum* K.Schum.	×	-	-	2
48	Burseraceae	*Boswellia dalzielii* Hutch.	×	-	×	1

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
49		*Canarium schweinfurthii* Engl.	×	×	-	2
50		*Canarium vulgare* Leenh.	-	×	-	2
51		*Santiria trimera* (Oliv.) Aubrév.	×	×	-	2
52	Cannabaceae	*Celtis gomphophylla* Baker	×	-	-	1
53		*Trema guineense* (Schumach. & Thonn.)	-	×	-	2
54		*Trema orientale* (L.) Blume	×	×	-	2
55	Caricaceae	*Carica papaya* L	×	×	×	1
56	Celastraceae	*Maytenus elliptica* (Lam.) Krug & Urb.	-	×	-	2
57	Chrysobalanaceae	*Parinari excelsa* Sabine	×	-	-	1
58	Clusiaceae	*Garcinia ovalifolia* Oliv.	-	×	-	1
59		*Garcinia smeathmanii* (Planch. & Triana) Oliv.	-	×	-	1
60		*Symphonia acuminata* Baker	×	-	-	2
61		*Symphonia globulifera* L.f.	-	×	-	2
62		*Symphonia grandifolia* Spreng	×	×	-	2
63	Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	×	-	×	2
64		*Combretum micranthum* G.Don	×	×	-	1
65		*Combretum molle* R.Br. ex G.Don	×	×	×	2
66		*Combretum nigricans* Lepr. ex Guill. & Perr.	-	-	×	2
67		*Terminalia catappa* L.	-	×	-	2
68		*Terminalia glaucescens* Planch. ex Benth.	-	-	×	2
69		*Terminalia laxiflora* Engl.	-	×	-	2
70		*Terminalia superba* Engl. & Diels	×	-	-	1
71		*Strephonema mannii* Benth. & Hook.f.	-	×	×	2
72		*Terminalia schimperiana* Hochst	-	-	×	2
73	Cyatheaceae	*Cyathea manniana* (Diels) Tardieu	-	×	-	1
74	Dilleniaceae	*Tetracera alnifolia* Willd.	×	-	-	1
75	Euphorbiaceae	*Macaranga barteri* Müll.Arg.	×	×	×	2
76		*Macaranga occidentalis* Mull.Arg.	-	×	-	1
77		*Croton macrostachyus* Hochst. ex Delile	×	×	-	2
78		*Manihot esculenta* Crantz	×	×	-	3
79		*Jatropha curcas* var. *rufa* McVaugh	-	×	-	2
80	Fabaceae	*Acacia albida* Delile	×	-	-	1
81		*Acacia guianensis* (Aubl.) Willd.	×	-	×	NA
82		*Acacia nilotica* (L.) Willd. ex Delile	×	×	-	2
83		*Vachellia sieberiana* (DC.) Kyal. & Boatwr.	×	-	×	2
84		*Afrormosia laxiflora* (Benth. ex Baker) Harms	×	-	×	NA
85		*Afzelia africana* Sm. ex Pers.	-	-	×	2
86		*Albizia gummifera* (J.F.Gmel.) C.A.Sm.	-	×	-	2
87		*Albizia zygia* (DC.) J.F.Macbr.	×	×	-	2
88		*Anthonotha macrophylla* P.Beauv.	×	-	-	2

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
89		*Anthonotha noldeae* (Rossbach) Exell & Hillc.	×	×	-	1
90		*Brachystegia eurycoma* Harms	×	-	-	2
91		*Acacia seyal* f. *fistula* (Schweinf.) Cufod.	-	-	×	2
92		*Burkea africana* Hook.	×	-	×	2
93		*Chamaecrista mimosoides* (L.) Greene	-	×	-	2
94		*Dalbergia lactea* Vatke	×	×	-	2
95		*Detarium macrocarpum* Harms	×	×	-	1
96		*Entada abyssinica* Steud. ex A.Rich.	×	×	-	2
97		*Entada africana* Guill. & Perr.	-	-	×	2
98		*Erythrina abyssinica* Lam.	-	×	-	2
99		*Erythrina senegalensis* DC.	×	-	-	2
100		*Isoberlinia doka* Craib & Stapf	-	-	×	2
101		*Isoberlinia tomentosa* (Harms) Craib & Stapf	-	-	×	1
102		*Millettia conraui* Harms	-	×	-	6
103		*Newtonia buchananii* (Baker) G.C.C.Gilbert & Boutique	×	×	-	2
104		*Entandofragma* sp.	-	-	×	NA
105		*Papilionoideae* DC.	-	×	-	2
106		*Parkia bicolor* A.Chev.	×	×	-	2
107		*Parkia biglobosa* (Jacq.) R.Br. ex G.Don	×	-	×	2
108		*Piliostigma thonningii* (Schumach.) Milne-Redh.	×	-	×	2
109		*Prosopis africana* (Guill. & Perr.) Taub.	×	-	×	1
110		*Pterocarpus erinaceus* Poir.	-	×	-	6
111		*Tamarindus indica* L.	×	-	×	2
112		*Vachellia seyal* (Delile) P.J.H.Hurter	×	-	×	NA
113		*Erythrophleum suaveolens* (Guill. & Perr.) Brenan	×	×	-	2
114	Gentianaceae	*Anthocleista vogelii* Planch.	×	×	×	2
115	Hypericaceae	*Harungana madagascariensis* Lam. ex Poir.	×	×	-	1
116		*Psorospermum aurantiacum* Engl.	×	×	-	2
117		*Psorospermum febrifugum* Spach	-	×	-	1
118		*Psorospermum senegalense* Spach	-	×	-	1
119	Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	×	-	×	NA
120		*Platostoma africanum* P.Beauv.	-	×	-	1
121		*Vitex doniana* Sweet	×	×	×	2
122		*Vitex macrophylla* H.J.Lam	-	×	-	3
123		*Vitex rotundifolia* L.f.	×	×	-	1
124		*Tectona grandis* L.f.	-	×	×	1
125		*Platostoma rotundifolium* (Briq.)	-	×	-	NA

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
126	Lauraceae	*Beilschmiedia mannii* (Meisn.) Benth. & Hook.f. ex B.D.Jacks.	-	×	-	2
127		*Persea americana* Mill.	-	×	×	1
128	Malvaceae	*Adansonia digitata* L.	-	-	×	NA
129		*Bombax costatum* Pellegr. & Vuillet	×	-	×	2
130		*Ceiba pentandra* (L.) Gaertn.	×	-	×	2
131		*Cola nitida* (Vent.) Schott & Endl.	×	×	-	2
132		*Cola acuminata* (P.Beauv.) Schott & Endl.	×	-	-	2
133		*Cola gigantea* A.Chev.	×	-	-	2
134		*Cola hispida* Brenan & Keay	×	-	-	NA
135		*Cola millenii* K.Schum.	×	×	-	2
136		*Cola verticillata* (Thonn.) Stapf ex A.Chev.	×	×	-	1
137		*Dombeya buettneri* K.Schum.	-	×	-	1
138		*Dombeya ledermannii* Engl.	×	×	-	7
139		*Grewia mollis* Juss.	×		×	2
140		*Pavonia urens* Cav.	-	×	-	1
141		*Pterospermum acerifolium* (L.) Willd.	×	-	-	2
142		*Sida acuminata* DC.	-	×	-	1
143		*Sterculia oblonga* Mast.	-	×	-	4
144		*Sterculia setigera* Delile	-	-	×	2
145		*Sterculia tragacantha* Lindl.	×	×	-	2
146	Melastomataceae	*Melastomastrum afzelii* (Hook.f.) A.Fern. & R.Fern.	-	×	-	NA
147	Meliaceae	*Azadirachta indica* A.Juss.	-	-	×	2
148		*Carapa grandiflora* Sprague	-	×	-	2
149		*Carapa procera* DC.	×	×	-	2
150		*Entandrophragma angolense* (Welw.) C.DC.	×	×	-	5
151		*Guarea cedrata* (A.Chev.) Pellegr.	-	×	-	5
152		*Khaya grandifoliola* C.DC.	×	-	-	4
153		*Khaya senegalensis* (Desr.) A.Juss	×	-	×	4
154		*Lovoa trichilioides* Harms	×	-	-	2
155		*Pseudocedrela kotschyi* (Schweinf.) Harms	-	-	×	2
156	Moraceae	*Ficus asperifolia* Miq.	-	×	-	2
157		*Ficus capensis* Thunb	×	×	×	2
158		*Ficus congesta* Roxb	-	-	×	2
159		*Ficus exasperata* Vahl	×	×	-	2
160		*Ficus lutea* Vahl	×	×	×	2
161		*Ficus sur* Forssk.	-	×	-	2
162		*Ficus sycomorus* L.	×	×	×	2
163		*Ficus thonningii* Blume	-	×	-	2

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
164		*Ficus todayensis* Elmer	×	-	-	2
165		*Milicia excelsa* (Welw.) C.C.Berg	×	×	-	1
166		*Ficus auticulata* Lour.	×	-	×	NA
167		*Ficus* sp.	-	×	-	NA
168		*Trilepisium gymnandrum* (Baker) J.Gerlach	×	-	-	7
169		*Trilepisium madagascariense* DC.	-	×	-	2
170		*Uapaca albida* De Wild.	×	×	-	2
171	Moringaceae	*Moringa oleifera* Lam.	×	×	×	2
172	Urticaceae	*Musanga cecropioides* R.Br. ex Tedlie	×	×	-	2
173	Myrtaceae	*Psidium guajava* L.	×	×	×	2
174		*Syzygium guineense* (Willd.) DC.	×	×	-	2
175		*Syzygium macrocarpum* (Blume) Bahadur & R.C.Gaur	×	×	-	6
176		*Eugenia gilgii* Engl. & Brehmer.	×	×	-	6
177	Ochnaceae	*Lophira alata* Banks ex C.F.Gaertn.	×	-	×	4
178		*Lophira lanceolata* Tiegh. ex Keay	×	-	-	2
179	Oleaceae	*Strombosia grandifolia* Hook.f. ex Benth.	×	×	-	2
180	Pandanaceae	*Pandanus candelabrum* P.Beauv	×	×	×	2
181		*Pandanus panayensis* Merr.	×	-	-	6
182	Phyllanthaceae	*Antidesma laciniatum* Müll.Arg.	-	×	-	2
183		*Antidesma venosum* E.Mey. ex Tul.	-	×	-	2
184		*Bridelia ferruginea* Benth.	×	-	×	2
185		*Bridelia micrantha* (Hocks) Bail	-	×	-	2
186		*Bridelia speciosa* Müll.Arg.	×	×	×	1
187		*Hymenocardia acida* Tul.	×	×	×	2
188		*Phyllanthus niruri* L.	-	×	-	2
189		*Uapaca togoensis* Pax	×	-	×	2
190	Primulaceae	*Maesa lanceolata* Forssk.	-	×	-	2
191	Proteaceae	*Protea madiensis* Oliv.	-	×	-	2
192	Ranunculaceae	*Clematis grandiflora* DC	-	×	-	2
193		*Clematis hirsutissima* Pursh	-	×	-	1
194	Rosaceae	*Prunus africana* (Hook.f.) Kalkman	×	-	-	4
195		*Rubus fellatae* A.Chev.	-	×	-	2
196	Rubiaceae	*Rytigynia senegalensis* Blume	-	×	-	2
197		*Canthium* sp.	-	×	-	NA
198		*Coffea ambongensis* J.-F.Leroy ex A.P.Davis & Rakotonas.	×	-	-	6
199		*Crossopteryx febrifuga* (Afzel. ex G.Don) Benth.	-	-	×	2
200		*Gardenia aqualla* Stapf & Hutch.	-	-	×	7

Table 1 (*continue*)

S/N	Family	Species Name	LTRF	MH	SW	CS
201		*Nauclea latifolia* Sm.	-	-	×	2
202		*Oxyanthus racemosus* (Schumach. & Thonn.) Keay	×	-	-	2
203		*Oxyanthus speciosus* DC.	×	×	×	2
204		*Psychotria lanata* Müll.Arg.	-	×	-	NA
205		*Psychotria pedunculata* Sw.	-	×	-	5
206		*Psychotria succulenta* (Hiern) E.M.A.Petit	-	×	-	2
207		*Rothmannia annae* (E.P.Wright) Keay	-	×	-	7
208		*Rothmannia buchananii* (Oliv.) Fagerl.	-	×	-	2
209		*Rothmannia octomera* (Hook.) Fagerl.	×	-	-	2
210		*Rothmannia urcelliformis* (Hiern) Bullock ex Robyns	-	×	-	2
211	Rutaceae	*Clausena anisata* (Willd.) Hook.f. ex Benth.	×	×	-	2
212		*Zanthoxylum leprieurii* Guill. & Perr.	×	-	-	2
213	Sapindaceae	*Allophylus africanus* P.Beauv.	×	×	×	2
214		*Deinbollia pinnata* (Poir.) Schumach. & Thonn.	-	×	-	2
215		*Paullinia paullinioides* Radlk	-	×	-	2
216		*Paullinia pinnata* L.	-	×	-	1
217	Sapotaceae	*Aningeria altissima* (A.Chev.) Aubrév. & Pellegr.apo	×	×	-	2
218		*Faurea rochetiana* (A.Rich.) Chiov. ex Pic. Serm.	-	×	-	2
219		*Pouteria altissima* (A.Chev.) Baehni	×	-	-	1
220		*Pouteria macrophylla* (Lam.) Eyma.	-	×	-	2
221		*Strephenomina mannii* Benth. & Hook.f.	×	-	-	NA
222		*Vitellaria paradoxa* C.F.Gaertn.	×	-	×	4
223	Smilacaceae	*Smilax anceps* L.	×	-	-	2
224	Stilbaceae	*Nuxia congesta* R.Br. ex Fresen.	×	×	-	2
225	Thymelaeaceae	*Aquilaria crassna* Pierre ex Lecomte	×	-	-	7
226	Vitaceae	*Leea guineensis* G.Don	×	×	-	1
227		*Cissus purpurea* Roxb. ex Steud.	-	×	-	1
228	Zingiberaceae	*Aframomum angustifolium* (Sonn.)	-	×	-	2

Note. × = Presence of species, Dash (-) = Absence, CS = IUCN Conservation Status, LTRF = Lowland Tropical Rainforest, MH = Montane Highland, SW = Savanna Woodland, NE (Not Evaluated) =1, LC (Least Concern) = 2, DD (Data Deficient) = 3, VU (Vulnerable) = 4, NT (Near Threatened) = 5, EN (Endangered) = 6, CR (Critically Endangered) = 7

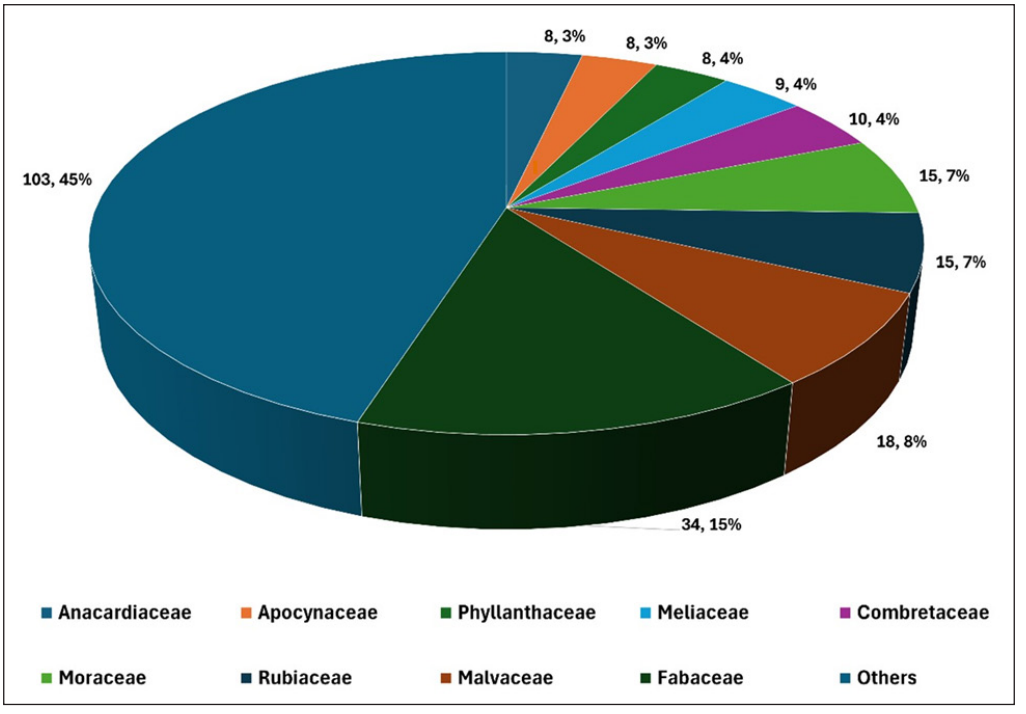

Figure 3. Frequency and percentage frequency of sampled plants by family from the three vegetation zones

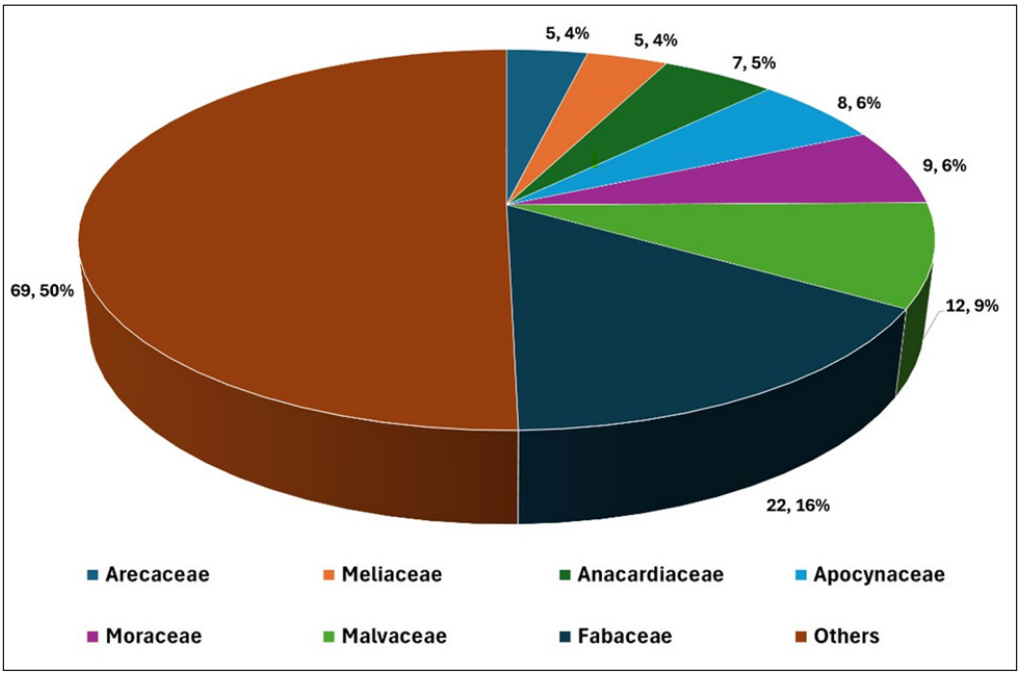

Figure 4. Frequency and percentage frequency of sampled plants by family from the Lowland Tropical Rainforest

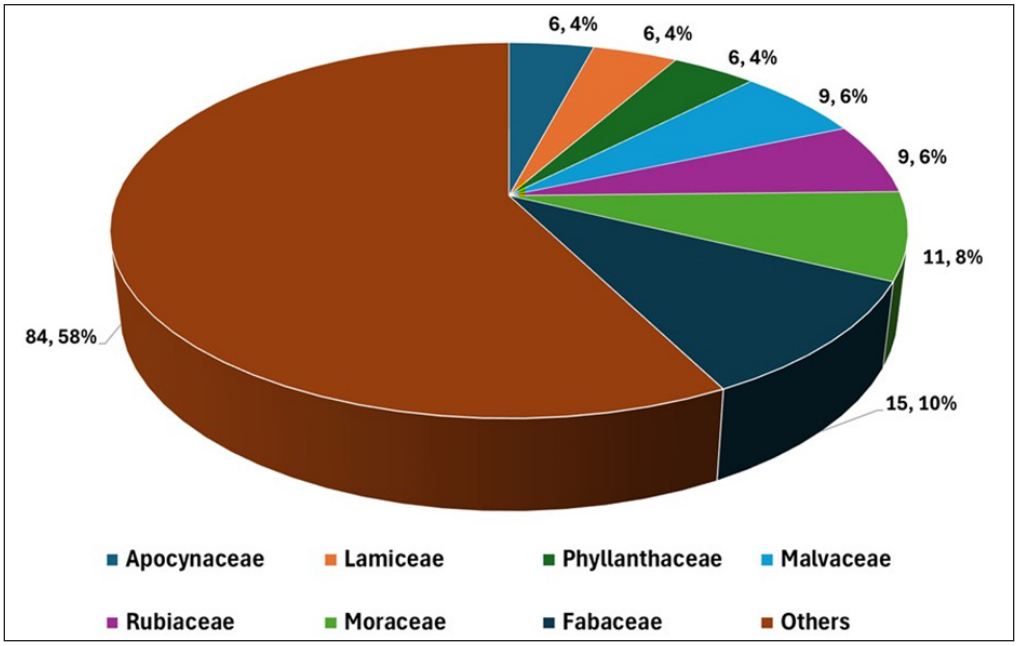

Figure 5. Frequency and percentage frequency of sampled plants by family from the Montane Highlands

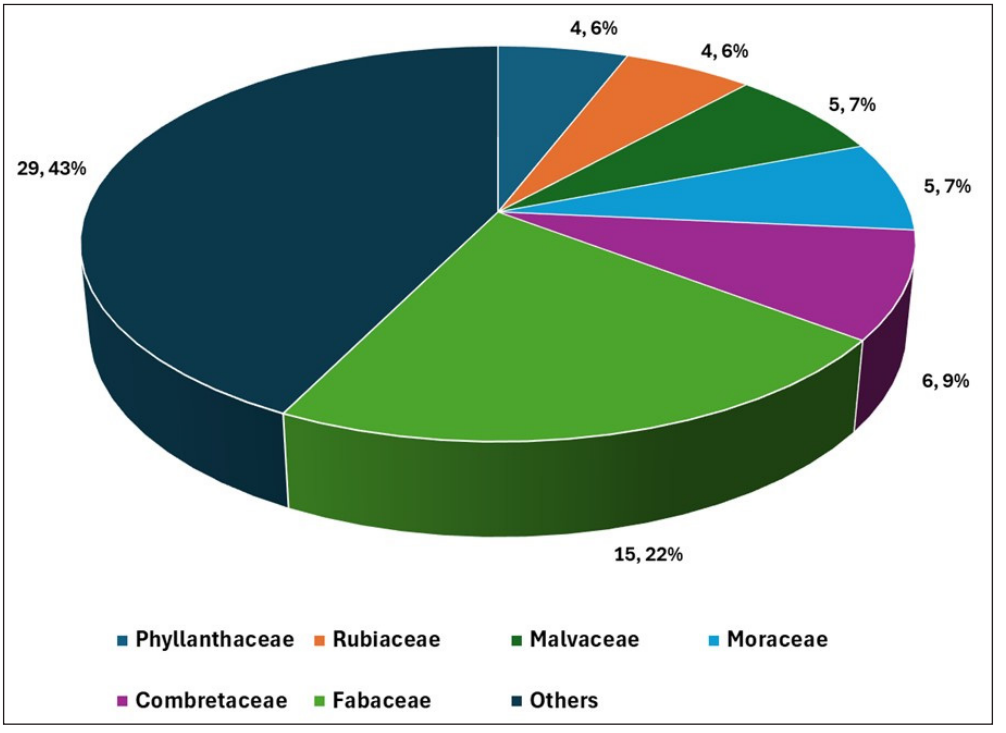

Figure 6. Frequency and percentage frequency of sampled plants by family from the Savannah Woodland

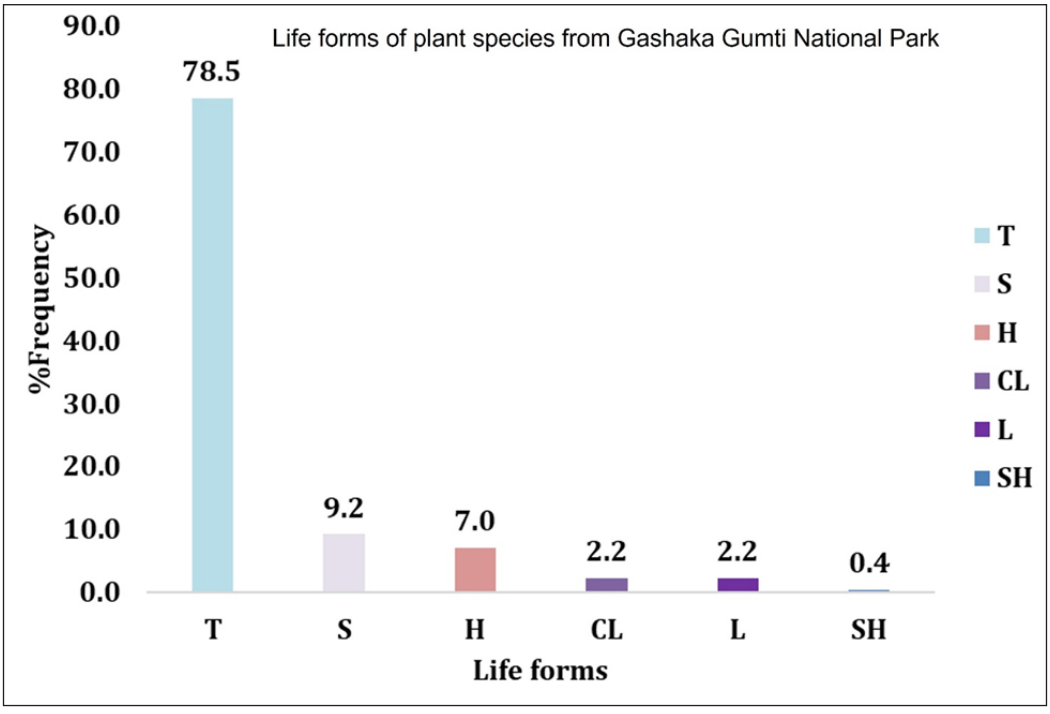

Figure 7. Summary of the life forms of the species in the study area
Note. T = Trees, S = Shrubs, H = Herbs, CL = Climbers, L = Lianas, SH = Small herbs

Diversity Indices

Across all plots, average Shannon-Weiner's species diversity indices of 2.40, 2.40, and 2.25 were recorded for MH, LTRF, and SW, respectively. It shows that LTRF has the highest species diversity, while MH has the lowest (Supplementary File 1).

Supplementary File 2 shows the plot-by-plot richness of species across the three habitats. According to Sorensen's similarity coefficient, LTRF and SW (33.42%) habitat recorded the highest species similarity, while MH, as against SW habitat, recorded the lowest (18.92%) (Figure 8). Based on the Importance Value (IVI), the most significant species within the habitat documented from the SW. with a value of 0.581, followed by lowland with a value of 0.548, while montane has the least important species across the three habitats with a value of 0.272. The Species evenness per plot across the three vegetation zones is shown in Supplementary File 3. The overall evenness values for LTRF, SW, and MH are 0.77, 0.78, and 0.77. Figure 9 shows the number of species shared across the three vegetation zones.

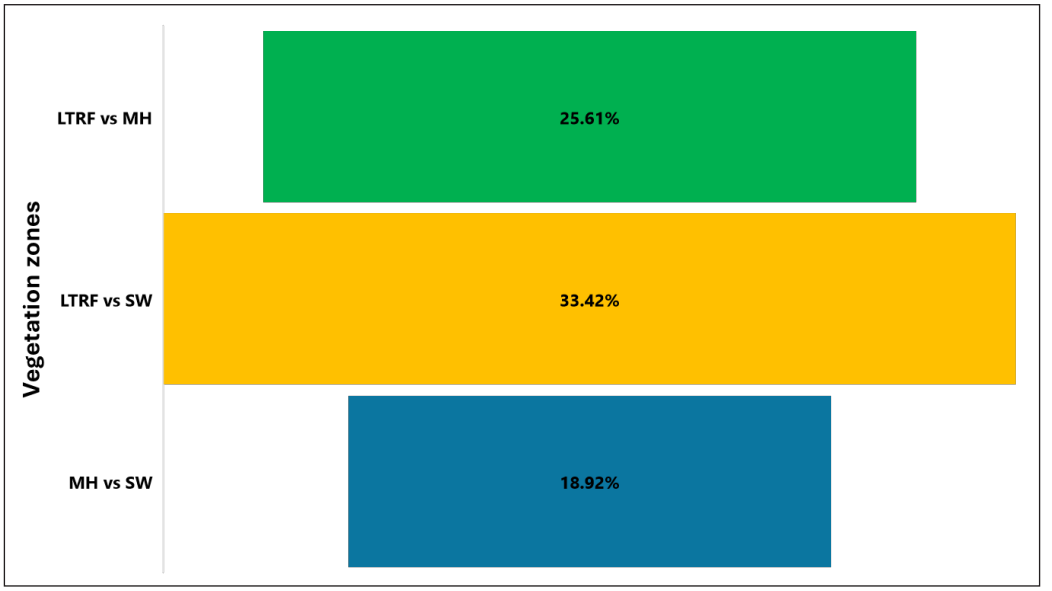

Figure 8. Sorensen's similarity coefficient of floristic species for the three different vegetation zones in the Gashaka Gumti National Park
Note. MH = Montane Highlands, SW = Savannah Woodland, LTRF = Lowland Tropical Rain Forest

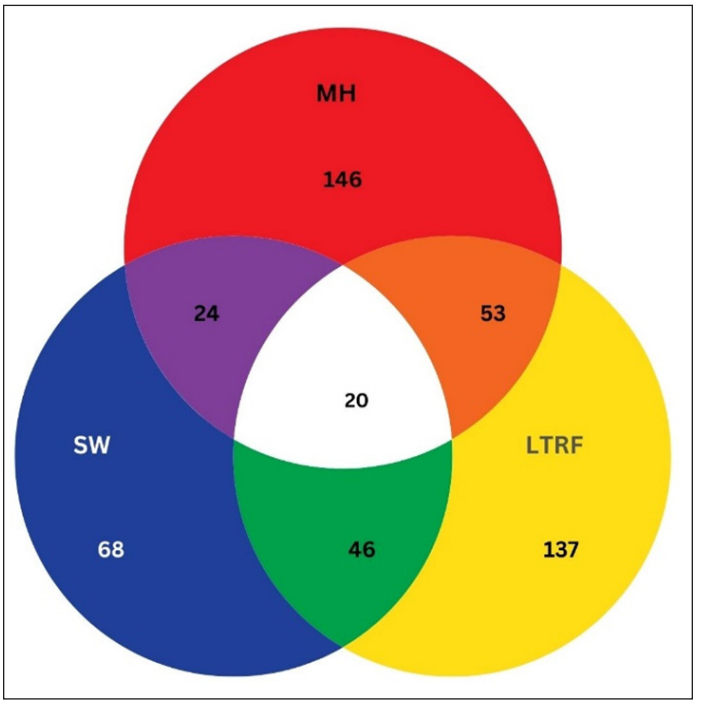

Figure 9. Venn diagram showing the species distribution from the three vegetation zones
Note. MH = Montane Highlands, SW = Savannah Woodlands, LTRF = Lowland Tropical Rain Forest

DISCUSSION

This study presents an updated checklist and explores the flora diversity across three distinct vegetation zones within Gashaka Gumti National Park (GGNP). The recorded total of 228 species surpasses the previous report of 77 species by Chapman & Chapman (2002), indicating a significant augmentation in species richness. The frequency of families and species reported in this study is also higher than that reported by Abiem et al. (2018), who reported 134 species from 44 families for a forest reserve in Jos, Nigeria, and the study of Mato et al. (2024) who reported 38 species in 19 families for the biological garden of the Nigerian Defence Academy. One possible explanation for this is the vastness of the GGNP, the largest national park in Nigeria, and Abiem et al. (2018) focused only on the woody species. Throughout the vegetation zones, the family Fabaceae was the most notable. This aligns with the findings of Abba et al. (2022) and Mato et al. (2024), who also reported that the Fabaceae family was the dominant plant family in their study areas.

Compared to previous reports, the high number of threatened species underscores the urgency for enhanced conservation efforts within the park. Our findings highlight only a slight disparity in plant species diversity and evenness across different regions, with the MH and LTRF vegetation strata exhibiting the highest species diversity. Therefore, the three zones can be said to possess similarly high species diversity and evenness. Despite the closeness of these two habitats in richness, evenness, and diversity, they recorded a lower similarity compared to the LTRF as against SW. Moreover, SW recorded the highest importance, indicating that it harbors the most important species. The Shannon-Weiner diversity index provided in this research is comparatively lower than the findings of Abiem et al. (2018). The possible reason for this variance might be attributed to the fact that our study area includes three distinct vegetation zones, in contrast to their previous research, which concentrated only on woodlands. Additionally, variations in the methods used to collect samples and the number of samples taken in each study could contribute to the differences in diversity index values.

Factors such as altitude, seedling regeneration, and seed quality may have contributed to the differences in species diversity. Naidu and Kumar (2016) emphasized the significance of biotic factors in maintaining tree diversity. Another possibility is that the montane habitat's varied terrain, natural forests, and limited human disturbances create favorable conditions for a diverse range of plant species. The savanna woodland displayed lower species diversity, which could be attributed to heightened anthropogenic activities such as land clearing for agriculture, logging, and bush burning, leading to habitat loss, biodiversity decline, and ecosystem degradation (Skarpe & Hester, 2008). Habitats with high-importance values support specialized species but do not significantly increase species diversity. These species sometimes serve as keystone species in ecosystems, maintaining habitat health and function (Narango et al., 2020).

Human settlements and associated activities further exacerbate habitat fragmentation and introduce invasive species, negatively impacting plant diversity. Bush-burning Fires can strip away vegetation and expose soil to erosion, leading to sedimentation of water bodies and reduced soil fertility (Birhanu et al., 2019). Conservation strategies must prioritize mitigating these anthropogenic impacts to safeguard the health of this ecosystem. Human settlements can fragment natural habitats and introduce invasive species that can compete with indigenous species in harnessing available resources (Tadele et al., 2014). More so, uncontrolled or excessive grazing can lead to the removal of too much vegetation through consumption and trampling saplings, seeds, and seedlings, causing soil erosion, reduction in soil fertility, and degrading pastures and ecosystems (Gebeyehu et al., 2019; Sartorello et al., 2020).

This study highlights the crucial significance of comprehending the intricate interaction between human activities and environmental elements in determining the patterns of plant diversity. This knowledge may guide conservation and management initiatives to protect these areas with high biodiversity. Similarly, the practice of selective cutting leads to a shortage of seed sources and the opening of the canopy, which exposes the surface to high temperatures, light, and evaporative transpiration. These factors limit plant regeneration and promote certain species' development. In addition, variables such as elevated temperatures, fluctuations in weather patterns, decreased vegetation coverage, and restricted water availability may have a role in the reported decrease in plant variety in these ecosystems (Kelly & Goulden, 2008). In their study, Hejda et al. (2009) found a significant reduction of almost 90% in the number of species in the buffer zones of some protected areas due to anthropogenic disturbances. Conservation efforts should prioritize the mitigation of these consequences to preserve the environment's biodiversity.

CONCLUSION

This research provides valuable insights into the flora diversity and conservation condition of Gashaka Gumti National Park (GGNP), emphasizing its importance as the biggest park in Nigeria. The cataloging of 228 plant species across three vegetation zones highlights the substantial botanical diversity found within GGNP. The results of our study indicate differences in the variation of species and diversity measures seen in various environments, highlighting the crucial role of habitat heterogeneity in influencing the organization of plant communities. Moreover, recognizing endangered species highlights the immediate need for aggressive conservation efforts to protect the park's biodiversity. The significant resemblance in species composition between the LTRF and SW habitats and the prevalence of certain plant families, such as Fabaceae, offers an essential understanding of the ecological processes in GGNP. Nevertheless, the dearth of research on the park's botanical diversity emphasizes the need for ongoing scientific investigation and conservation initiatives to address risks and save its unique ecosystems and endangered organisms.

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