Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2024.1.14

Research Article
Floristic Diversity and Ecological Structure of Protected Formations in the Sudano-Sahelian Zone of Cameroon: The Case of the Mayo-Kani Division

[1]Mai Nipa Yvette, [1]Tchobsala, [2,3]Kosma Philippe and [1]Bakoulou Ngamo Africa

[1]Department of Biological Sciences, Faculty of Science, University of Maroua, P.O. Box 814, Maroua, Cameroon
[2]National Advanced School of Engineering of Maroua, University of Maroua, P.O. Box 46, Maroua, Cameroon
[3]Department of Agriculture and Natural Disaster Management, Faculty of Science, University of Garoua, P.O. Box 317, Garoua, Cameroon

Abstract

Background and Objective: In the Sudano-Sahelian Zone, protected areas are transformed into supply centers for wood and energy. In North Cameroon, these formations are no exception to these anthropic activities. This study aims to characterize the floristic diversity and the structure of the woody stand in the Sudano-Sahelian Zone of Cameroon. **Materials and Methods:** In each protected area, 12 transects (1000×20 m) were installed and along each transect, all woody plants with dbh ≥10 cm at 1.30 m were inventoried, diameter and height were also measured. For statistical analysis the software Statgraphics Centurion version 16.1 was used and an LSD test to compare the means. **Results:** The floristic composition is 63 species belonging to 49 genera and 23 families. The specific diversity of formations in the Division of Mayo-Kani varies following the protected areas. The abundance of the Fabaceae and Combretaceae families underline the shrubby to arborescent character of the stands in the study area. Shannon's diversity index ranged from 2.24 bits in the tree savanna of the IRAD test site to 3.33 bits in the gallery forest of the Zibou community forest. The evaluation of the horizontal and vertical structure shows a predominance of the woody stratum. **Conclusion:** The study revealed a regressive evolution of the woody stand with a very high proportion of species of low height and circumference.

Key words: Diversity, woody stand, protected formations, Mayo-Kani Division, Cameroon

Citation: Yvette, M.N., Tchobsala, K. Philippe and B.N. Africa, 2024. Floristic diversity and ecological structure of protected formations in the Sudano-Sahelian Zone of Cameroon: The case of the Mayo-Kani Division. Asian J. Plant Sci., 23: 1-14.

Corresponding Author: Mai Nipa Yvette, Department of Biological Sciences, Faculty of Science, University of Maroua, P.O. Box 814, Maroua, Cameroon

Copyright: © 2024 Mai Nipa Yvette *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The tree occupies a primordial place in the life of man in society because of its multiple functions in the food, medicinal, cultural, agro-forestry and technological fields[1]. In Sub-Saharan Africa, the local populations depend on these ecosystems for food and/or income[2,3]. Cameroon has a high diversity of natural habitats related to the variability of its physical and climatic characteristics. This rich biodiversity is conserved for the most part in six habitat types[4]. The objective according to Article 22 of Law 94/01 is that protected areas should cover at least 30% of the national territory and preserve at least 90% of the country's biological diversity.

The acceleration of the rate of growth of the world's population has led to a relentless search for a new approach to the management of natural resources, particularly timber. In Cameroon, more specifically in the far north region, population growth changing exponentially each year. This population growth negatively impacts phytodiversity[5,6]. The growth of the rate of deforestation in tropical forests threatens biodiversity and disturbs into same the regulation of atmospheric carbon dioxygene. According to FAO in 2018, the forest cover of Sub-Saharan Africa passed from 30.6 to 27.1% between 1990 and 2015[7,8].

However, many woody species are now threatened with extinction in the Sudano-Sahelian Zone due to overexploitation of plant species, poor harvesting practices of the products and poor regeneration[6,9,10]. These protected areas are poorly managed and the lack of involvement of riparian populations in management is noticeable[11].

Since the top of the Convention of Rio in 1992, the principle of protection and conservation of biological diversity appears through various projects of durable development. To limit degradation, scarcity of resources, erosion of biodiversity and modification of ecosystems and protected formations, it is essential to have reliable and relevant environmental data to monitor long-term changes in natural environments, hence the main objective is to know the floristic and structural characterization of woody stands of protected formations in the Division of Mayo-Kani for sustainable management.

MATERIALS AND METHODS

Study area: The investigations were made from November 2021 to August, 2022 in the various formations protected targets of the Mayo-Kani Division. This study was conducted in the Mayo-Kani Division of the Far North Region of Cameroon, specifically in the Subdivision of Moutourwa and Kaele. This division is located in the North by the Subdivision of Maroua I and Dargala, in the West by the Subdivision of Ndoukoula, in the East by the Subdivision of Kar-Hay and Kalfou and in the South by the Republic of Chad. The climate is Sudan-Sahelian with two seasons, a long dry season lasting about eight months, from October to May and a rainy season of four months covering the months of June to September. Annual rainfall varies between 700 and 1000 mm with an average of 800 mm. The average annual temperature is 34°C, with March, April and May as the warmest months and December, January and February as the coldest months.

The relief is characterized by two geomorphological forms, namely vast plains where the terrain is relatively flat, with an average altitude of about 450 m. However, the landscape is dotted with a few granite-gneissic massifs with altitudes that are sometimes significant. The soils encountered are Vertisols (Karals), Planosols (Hardés) and hydromorphic soils (Yaceres) and ferruginous soils. The hydrographic network consists of intermittent streams.

The woody and herbaceous vegetation has elements of Sudano-Sahelian Savannahs, dry savannahs and Sahelian steppes. The flora is characteristic of the thorny steppes, consisting of tree savannas and shrub savannas with a very irregular herbaceous cover. It is dominated by thorny plants that generally develop on vertisols or degraded soils (hardé). The environment is traversed by flood zones whose species are the most represented in the woody stratum. *Acacia hockii*, *A. seyal*, *Anogeissus leiocarpus*, *Acacia senegal*, *Albizia chevalieri*, *Balanites aegyptiaca*, *Combretum aculeatum*, *Dichrostachys cinerea* and *Guiera senegalensis*. The grass cover is composed of *Cassia obtusifolia*, *Cassia mimosoides*, *Hypoëtes cancellata*, *Panicum subalbidum*, *Panicum maximum*, *Panicum repens*, *Loudetia togoensis*, *Schoenefeldia gracilis*, *Aristida* spp., *Pennisetum pedicellatum*, *Hyparrhenia involucrata* and *H. rufa*.

The populations of this division are composed mainly of the Guiziga, Moundang Toupouri and Foulbés. They practice three religions (Animism, Christianity and Islam) and engage in agropastoral activities.

Data collection: The transect method was used for floristic surveys of the study area[12]. Each transect was 20,000 m^2 in size (1000×20 m) and the interval between transects was 100 m. Vegetation surveys for floristic structure and diversity were conducted by a team of five people. A survey pointer, three survey helpers who assist the pointer with the surveys and a survey guide who acts as a coordinator and monitors for survey boundaries. The team scans each 10×1000 m parallel

layon one after the other dendrometric parameters. Trunk circumference was measured at 1.30 m above ground level for trees and 20 cm above ground level for shrubs. The height of the trees was measured using a 4 m pole. During this exercise, trees and shrubs were identified using appropriate literature and identification keys.

Data processing and analysis: Data collected in the field were subjected to statistical processing. The APG III (Angiosperms Phylogeny Group) (2009) classification system was used to group families. Diameters were grouped into classes with a range of 10 cm. This grouping was used to analyze the horizontal structure of the stand.

Biological types were determined by referring to the previous work, which has been adapted to tropical regions[13,14]. For the woody stratum, these are essentially phanerophytes which have been subdivided into nanophanerophytes (NnPh), shrubs from 0.5 to 2 m in height; microphanerophytes (McPh), shrubs from 2 to 8 m in height; mesophanerophytes (MsPh), medium trees from 8 to 30 m in height.

The phytogeographic elements of Lebrun and White were used to determine the phytogeographic distribution of vegetation in the protected areas of Mayo-Kani Division[14]. These are the following chorological types.

- **Cosmopolitan (Cos):** Species distributed throughout the world
- **Pantropical (Pan):** Species are known in tropical Africa, America and Asia
- **Paleotropics (Pal):** Species present in Africa and tropical Asia, in Madagascar and Australia, Afromalgae
- **Pluriregional African (PRA):** Species whose distribution area covers several African floristic regions or two floristic regions that are not in contact. The link species. These are species with a spread out distribution area, supporting more or less particular ecological conditions distinguish for this purpose
- Afrotropical species (At)
- Sudano-Zambezian species (Sz)

The diversity index of Shannon and Weaver expresses the relative importance of the soil occupation by species in a given environment[6]. The index is minimum when all individuals belong to the same species. It is maximum when each individual represents a distinct species. It is expressed in bits per individual. It is given by the following relationship:

$$H' = -\sum\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right)$$

Where:

n_i = Number of species i

N = Number of all species

The evenness index is the ratio between the observed diversity and the maximum possible diversity of the number of species (N). It tends towards 0 when there is dominance and towards 1 when a maximum number of species participate in the cover. Its value is obtained using the following formula:

$$E = H'/\log_2 N$$

The importance value index (IVI) was determined by summing relative density, relative frequency and relative dominance[15]. It was used to characterize plant stands and to identify dominant species:

$$IVI = \text{Relative density+relative frequency+relative dominance}$$

The density (N) is the number of individuals per unit area. Density translates the soil occupation by the woody species and express in individuals/ha. It is obtained by the ratio of the total number of individuals in the sample (n) by the sampled surface (S):

$$N = n/S$$

Where:

n = Total number of individuals surveyed in each site

S = Total sampled area of the site in ha:

$$\text{Relative density} = \frac{n_i}{N}\times 100$$

Where:

n_i = Number of individuals of one species

N = Total number of individuals of all species

$$\text{Relative frequency} = \frac{\text{Frequency of one species}}{\text{Sum of all frequencies}}\times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of one species}}{\text{Total basal area of all species}}\times 100$$

$$\text{Relative diversity} = \frac{\text{Number of species in a family}}{\text{Total species counted}}\times 100$$

Basal area (BA) or basal cover is the sum of the basal areas of all individuals with a basal circumference (B) greater than or equal to 0.3 m. This basal area can be estimated by considering that the sections of the stems are circular. It is expressed per unit area (m^2 ha^{-1}) and is calculated as described by Ndiaye *et al.*[16]:

$$St = \sum \frac{C^2}{4\pi}$$

Where:

St = Basal area expressed in m^2 ha^{-1}

C = Circumference at 0.3 m from the ground of measured individuals

The family importance value index (FIV) represented the sum of relative density, relative frequency and relative dominance of a family[17]. It was used to identify dominant families in a setting:

FIV = Relative density of families+relative diversity+relative dominance

Statistical analysis: For the different plant formations identified, diversity indices and dendrometric parameters such as density, basal area, Diameter at Breast Height (DBH) and height were subjected to Analyses of Variance (ANOVA) to compare plant formations to each other and sites. The LSD test to separate means. These statistical tests were made with the software Statgraphics Centurion version 16.1 with a threshold of significativity of 5%.

RESULTS

Floristic composition: The species richness varies between plant formations for each of the three zones and between zones for each of the three plant formations (Table 1). Depending on the zone, floristic richness is higher in the shrubby savannahs (33 species) and trees (25 species) of the Laf Forest Reserve and lower in the IRAD test site (24 species). In the gallery forest, it is higher in the Zibou Community Forest (38 species) and lower in the IRAD test site (29 species). Between formations, species richness is higher in the gallery forest and lower in the savanna woodland for all zones. In total, 63 species divided into 49 genera and 25 families were recorded in the study area.

Biological and phytogeographical characteristics of the groups of plant formations: The grouping of woody species recorded in the study area varies according to the formations (Fig. 1). It appears from Fig. 1 that microphanerophytes are predominant for all formations with 54% in the shrub savanna, 52.72% in the gallery forest and 47.92% for the tree savanna. On the other hand, they are less represented in the group of megaphanerophytes for all formations.

Table 1: Floristic richness according to formates and protected areas

	Species			Genus			Family		
	SS	SW	GF	SS	SW	GF	SS	SW	GF
Zibou Community Forest	33	25	38	27	21	29	16	12	18
Laf Forest Reserve	36	29	34	26	23	25	15	11	15
IRAD trial	26	24	29	14	13	20	8	9	13

GF: Gallery forest, WS: Wooded savannah and SS: Shrub savannah

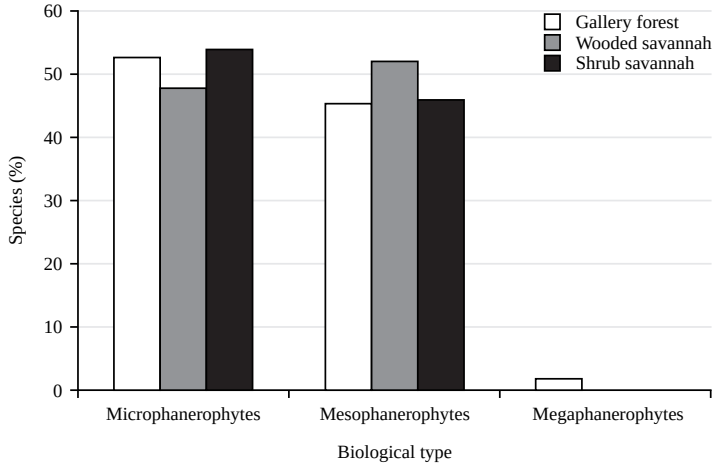

Fig. 1: Biological type according to plant formations

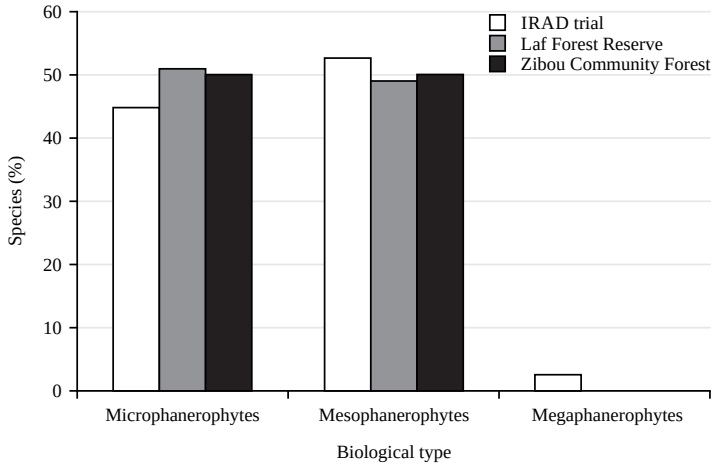

Fig. 2: Biological type by study area

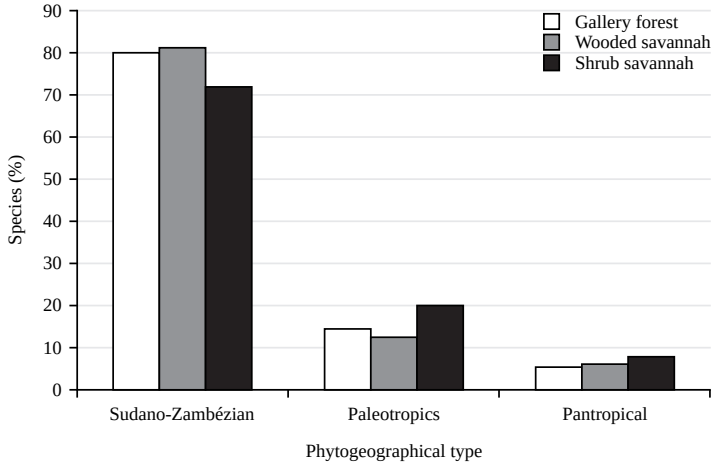

Fig. 3: Phytogeographic type by plant formations

The distribution of woody species according to biological type across the study areas (Fig. 2). Figure 2 shows that microphanerophytes (50.94% for the Laf Forest Reserve) and mesophanerophytes (52.63% for the IRAD trial). In the Zibou Community Forest, mesophanerophytes were more likely to be represented at 50% and microphanerophytes at 50%. In contrast, they are more poorly represented in the pantropical group in all zones.

The distribution of woody species according to their phytogeographical affinities and according to plant formations (Fig. 3). The analysis of this shows that Sudano-Zambézian species are the most represented in all formations, with 81.25% in the tree savanna, 80% in the gallery forest and 68% in the shrub savanna. On the other hand, they are less represented in the pantropical group for all formations.

The distribution of woody species according to their phytogeographical affinities and according to the study areas (Fig. 4). Analysis of this shows that Sudano-Zambézian species are the most represented for all zones, with 86.84% for the IRAD test site, 81.13% for the Laf Forest Reserve and 78% for the Zibou Community Forest. However, they are less represented in the pantropical group in all zones.

Diversity indices

Shannon index: The Shannon diversity index varies between plant formations for each of the three zones and between zones for each of the three plant formations (Table 2). Depending on the study area, the Shannon index is highest in the tree savanna (2.7 bits) and shrub savanna (3.1 bits) of the Laf Forest Reserve and in the gallery forest of the Zibou Community Forest (3.33 bits). It is more poorly represented in

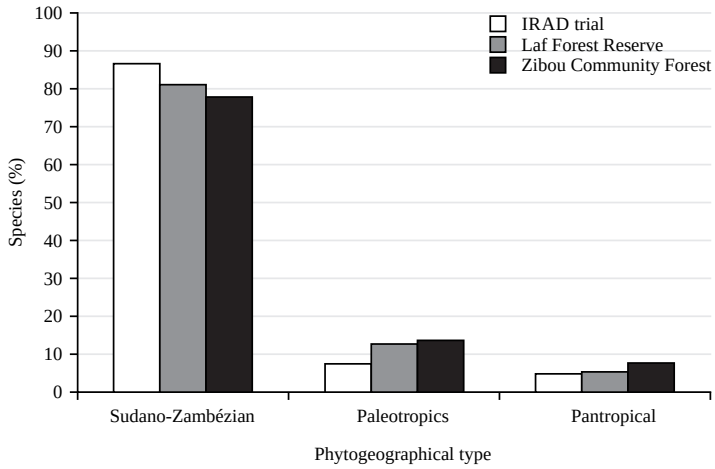

Fig. 4: Phytogeographic type by study area

Table 2: Shannon diversity indices (bits) according to formations and study sites

	Zibou Community Forest	Laf Forest Reserve	IRAD trial
Shrub savannah	2.85	3.10	2.26
Wooded savannah	2.52	2.70	2.24
Gallery forest	3.33	2.92	2.47

Table 3: Evenness index according to training and study sites

	Zibou Community Forest	Laf Forest Reserve	IRAD trial
Shrub savannah	0.53	0.65	0.40
Wooded savannah	0.50	0.41	0.35
Gallery forest	0.74	0.64	0.41

the formations of the IRAD test site. Between formations, species richness is higher in the gallery forest for the Zibou community forest (3.33 bits) and the IRAD test site (2.47 bits) and in the shrub savanna for the Laf Forest Reserve (3.1 bits). On the other hand, the tree savannah has a low floristic richness for all zones.

Evenness index: The equitability of varies between 0.35 and 0.74 among the plant formations in the study area (Table 3). Depending on the zone, it is higher, respectively in the shrub savanna of the Laf Forest Reserve (0.65), in the shrub savanna of the Zibou community forest (0.5) and in the forest gallery (0.74). On the other hand, it is less noticeable in the shrub savannah, tree savannah and gallery forest of the IRAD test site. Between formations, equitability is higher in the gallery forest for all protected areas. In the shrub and tree savanna of the Laf Forest Reserve and the IRAD test site, they are also higher. On the other hand, it is poorly represented in the wooded savannah for all zones.

Ecological importance

Ecological importance of species: The most ecologically important species according to plant formations are *Combretum glutinosum* (44.64) and *Anogeissus leiocarpus* (36.71) in the tree savannah, *Balanites aegyptiaca* (49.48) and *Azadirachta indica* (21.93) in the shrub savannah and *Balanites aegyptiaca* (72.12) and *Combretum glutinosum* (26.5) in the gallery forest (Table 4).

The ecological importance of the species differed from one area to another. The most ecologically important species are *Balanites aegyptiaca* (68.7) and *Anogeissus leiocarpus* (33.51) in the IRAD test site; *Anogeissus leiocarpus* (28.69) and *Balanites aegyptiaca* (26.19) in the Laf Forest Reserve and *Combretum glutinosum* (35.55) and *Balanites aegyptiaca* (37.34) in the Zibou Community Forest (Table 5).

Ecological importance of families: The families of importance value vary according to the plant formations (Table 6). The most strongly represented families in terms of importance value in the current study area are Fabaceae and Combretaceae. According to the formations, it is noticed that in the tree savannah the most dominant families are Fabaceae (52.18) and Combretaceae (46.71) and in the shrub savannah, the family of Zygophyllaceae (72.12) and Combretaceae (81.78) are the most represented. In the gallery forest, the families Combretaceae (90.93) and Fabaceae (31.25) are the most dominant, respectively.

Table 4: Indices of ecological importance of species according to formations

Species	Wooded savannah	Shrub savannah	Gallery forest	IVI total
Acacia ataxacantha	6.63	5.79	5.18	5.87
Acacia gerrardii	5.19	9.12	7.47	7.26
Acacia hockii	6.14	16.56	21.71	14.80
Acacia nilotica	/	1.57	0.98	0.85
Acacia polyacantha	1.07	2.14	4.71	2.64
Acacia senegal	2.73	1.37	3.49	2.53
Acacia seyal	6.80	6.45	9.38	7.54
Acacia sieberiana	3.07	2.12	3.94	3.04
Adenium obesum	1.63	/	/	0.54
Anacardium occidentale	/	1.57	/	0.52
Andira inermis	1.55	/	/	0.52
Annona senegalensis	3.11	7.37	5.59	5.36
Anogeissus leiocarpus	36.71	13.20	27.54	25.82
Azadirachta indica	1.49	21.93	5.06	9.49
Balanites aegyptiaca	8.85	49.48	72.12	43.48
Boswellia dalzielii	15.62	4.39	5.87	8.63
Bridelia scleroneura	3.27	1.12	0.96	1.78
Cadaba farinosa	1.07	1.12	2.02	1.40
Calotropis procera	/	/	1.36	0.45
Capparis sepiaria	1.29	/	2.42	1.23
Celtis integrifolia	2.04	/	/	0.68
Combretum aculeatum	4.51	2.91	6.65	4.69
Combretum adenogonium	6.86	1.63	3.11	3.87
Combretum collinum	7.26	3.89	14.00	8.38
Combretum glutinosum	44.64	3.91	26.50	25.01
Combretum molle	1.07	1.38	1.50	1.31
Commiphora africana	3.66	1.57	/	1.74
Commiphora pedunculata	/	/	1.22	0.41
Dalbergia melanoxylon	5.17	8.18	4.80	6.05
Dichrostachys cinerea	0.95	6.39	9.51	5.62
Diospyros mespiliformis	6.08	2.56	0.88	3.17
Entada africana	3.01	3.62	1.81	2.81
Eucalyptus camaldulensis	/	/	0.73	0.24
Feretia apodanthera	8.31	11.56	8.23	9.36
Ficus ingens	2.76	1.58	1.32	1.88
Flueggea virosa	0.46	3.20	0.63	1.43
Gardenia erubescens	0.53	1.49	2.31	1.44
Grewia villosa	1.46	/	/	0.49
Guiera senegalensis	2.35	/	1.22	1.19
Haematostaphis barteri	1.89	/	1.40	1.10
Hexalobus monopetalus	7.74	10.86	4.31	7.63
Khaya senegalensis	0.59	/	/	0.20
Lannea fruticosa	/	18.45	3.10	7.18
Lannea microcarpa	3.13	19.68	4.19	9.00
Maerua angolensis	0.84	1.32	0.83	1.00
Maytenus senegalensis	1.37	/	0.72	0.70
Piliostigma reticulatum	5.63	8.32	1.89	5.28
Piliostigma thonningii	2.21	2.97	/	1.73
Pseudocedrela kotschyi	0.75	1.88	/	0.88
Pterocarpus erinaceus	5.14	1.13	/	2.09
Sclerocarya birrea	22.06	9.46	4.48	12.00
Senna singueana	3.50	4.88	0.87	3.08
Steganotaenia araliacea	1.08	/	/	0.36
Sterculia setigera	4.09	1.07	1.75	2.30
Stereospermum kunthianum	1.21	1.07	/	0.76
Strychnos spinosa	/	1.38	1.16	0.84
Tamarindus indica	2.15	0.61	2.53	1.77
Terminalia avicennioides	3.60	8.40	1.31	4.44
Terminalia macroptera	12.65	/	/	4.22
Vitellaria paradoxa	2.56	1.38	0.65	1.53
Vitex doniana	/	/	0.66	0.22
Ximenia americana	2.17	1.32	0.65	1.38
Ziziphus mauritiana	8.32	6.61	5.31	6.75
Total	300	300	300	300

Table 5: Ecological importance value indices of species according to zones

Species	IRAD trial	Laf Forest Reserve	Zibou Community Forest	IVI total
Acacia ataxacantha	5.71	6.09	5.81	5.87
Acacia gerardii	14.01	7.77	/	7.26
Acacia hockii	30.46	8.53	6.33	15.11
Acacia nilotica	/	0.98	1.57	0.85
Acacia polyacantha	2.50	2.46	2.96	2.64
Acacia senegal	5.00	2.59	/	2.53
Acacia seyal	12.84	6.30	3.49	7.54
Acacia sieberiana	4.34	1.44	1.73	2.50
Adenium obesum	/	/	1.63	0.54
Anacardium occidentale	/	/	1.57	0.52
Andira inermis	1.55	/	/	0.52
Annona senegalensis	/	7.90	11.14	6.34
Anogeissus leiocarpus	33.51	28.69	15.25	25.82
Azadirachta indica	/	22.91	2.25	8.39
Balanites aegyptiaca	68.70	26.19	35.55	43.48
Boswellia dalzielii	1.64	13.89	10.35	8.63
Bridelia scleroneura	/	1.71	2.51	1.41
Cadaba farinosa	3.38	0.83	/	1.40
Calotropis procera	/	/	1.36	0.45
Capparis sepiaria	2.31	2.51	/	1.61
Celtis integrifolia	/	0.45	1.59	0.68
Combretum aculeatum	5.36	3.01	5.70	4.69
Combretum adenogonium	6.95	2.81	1.83	3.87
Combretum collinum	4.99	6.08	14.09	8.38
Combretum glutinosum	20.48	17.43	37.34	25.08
Combretum molle	1.07	1.38	1.50	1.31
Commiphora africana	/	2.27	2.96	1.74
Commiphora pedunculata	/	1.22	/	0.41
Dalbergia melanoxylon	7.11	4.50	6.54	6.05
Dichrostachys cinerea	4.27	8.61	3.96	5.62
Diospyros mespiliformis	4.97	2.19	2.36	3.17
Entada africana	1.55	5.08	1.81	2.81
Eucalyptus camaldulensis	/	0.73	/	0.24
Feretia apodanthera	7.25	9.69	11.15	9.36
Ficus ingens	/	1.32	4.33	1.88
Flueggea virosa	1.88	2.41	/	1.43
Gardenia erubescens	/	3.24	1.08	1.44
Grewia villosa	/	/	1.46	0.49
Guiera senegalensis	/	2.61	0.96	1.19
Haematostaphis barteri	/	0.44	2.85	1.10
Hexalobus monopetalus	/	7.81	15.09	7.63
Khaya senegalensis	0.59	/	/	0.20
Lannea fruticosa	11.09	9.23	/	6.77
Lannea microcarpa	4.45	5.09	18.63	9.39
Maerua angolensis	/	2.99	/	1.00
Maytenus senegalensis	/	/	2.09	0.70
Piliostigma reticulatum	1.55	6.44	7.86	5.28
Piliostigma thonningii	/	4.34	0.84	1.73
Pseudocedrela kotschyi	/	2.63	/	0.88
Pterocarpus erinaceus	1.55	2.49	1.10	1.71
Sclerocarya birrea	10.86	17.70	7.89	12.15
Senna singueana	/	6.64	2.60	3.08
Steganotaenia araliacea	1.08	/	/	0.36
Sterculia setigera	1.26	2.59	3.66	2.51
Stereospermum kunthianum	0.59	1.09	0.60	0.76
Strychnos spinosa	/	1.38	1.16	0.84
Tamarindus indica	1.27	2.60	1.43	1.77
Terminalia avicennioides	2.25	2.45	8.61	4.44
Terminalia macroptera	/	/	12.65	4.22
Vitellaria paradoxa	1.62	0.48	3.51	1.87
Vitex doniana	/	/	0.66	0.22
Ximenia americana	0.60	2.89	0.65	1.38
Ziziphus mauritiana	9.40	4.89	5.96	6.75
Total	300	300	300	300

Table 6: Importance value indices of the families according to the formations

Families	Wooded savannah	Shrub savannah	Gallery forest	IVI total
Anacardiaceae	20.89	17.65	32.89	23.81
Annonaceae	27.35	14.84	20.71	20.97
Apiaceae	/	/	3.24	3.24
Apocynaceae	/	/	4.89	4.89
Asclepiadaceae	/	4.08	/	4.08
Bignoniaceae	1.61	/	1.81	1.71
Burseraceae	9.11	12.48	28.92	16.83
Cannabaceae	/	/	3.06	3.06
Capparaceae	10.69	9.16	9.58	9.81
Celastraceae		2.15	4.11	3.13
Combretaceae	46.71	81.78	90.73	73.07
Ebenaceae	3.84	2.64	6.08	4.18
Fabaceae	52.18	39.61	31.25	41.01
Lamiaceae	/	1.98	/	1.98
Loganiaceae	4.13	3.47	/	3.80
Malvaceae	13.24	10.85	18.82	14.30
Meliaceae	38.53	7.58	8.52	18.21
Myrtaceae	/	2.19	/	2.19
Phyllanthaceae	4.80	4.76	6.29	5.28
Rhamnaceae	6.61	5.31	8.32	6.75
Rubiaceae	4.46	3.46	1.59	3.17
Sapotaceae	2.39	1.96	3.84	2.73
Ximenaceae	3.96	1.95	6.51	4.14
Zygophyllaceae	49.48	72.12	8.85	43.48
Total	300	300	300	

Table 7: Importance value indices of families according to zones

Families	IRAD trial	Laf Forest Reserve	Zibou Community Forest	IVI total
Anacardiaceae	26.40	32.46	30.94	29.93
Annonaceae	/	15.71	26.22	13.98
Apiaceae	1.08	/	/	0.36
Apocynaceae	/	/	1.63	0.54
Asclepiadaceae	/	/	1.36	0.45
Bignoniaceae	0.59	1.09	0.60	0.76
Burseraceae	1.64	17.38	13.32	10.78
Cannabaceae	/	0.45	1.59	0.68
Capparaceae	5.69	6.33	/	4.01
Celastraceae	/	/	2.09	0.70
Combretaceae	74.61	61.15	97.93	77.90
Ebenaceae	4.97	2.19	2.36	3.17
Fabaceae	93.92	78.16	52.38	74.82
Lamiaceae	/	/	0.66	0.22
Loganiaceae	/	1.38	1.16	0.84
Malvaceae	8.51	12.29	16.27	12.36
Meliaceae	0.59	28.86	2.25	10.57
Myrtaceae	/	0.73	/	0.24
Phyllanthaceae	1.88	4.12	2.51	2.84
Rhamnaceae	9.40	4.89	5.96	6.75
Rubiaceae	/	3.24	1.08	1.44
Sapotaceae	1.62	0.48	3.51	1.87
Ximenaceae	0.60	2.89	0.65	1.38
Zygophyllaceae	68.49	26.19	35.55	43.41
Total	300	300	300	

Families of importance value vary by study area (Table 7). The families with the highest importance values in our study area are Fabaceae (78.16) and Combretaceae (61.15) in the Laf Forest Reserve, Fabaceae (93.92) and Combretaceae (74.61) in the IRAD test site and Combretaceae (97.93) and Fabaceae (52.38) in the Zibou Community Forest.

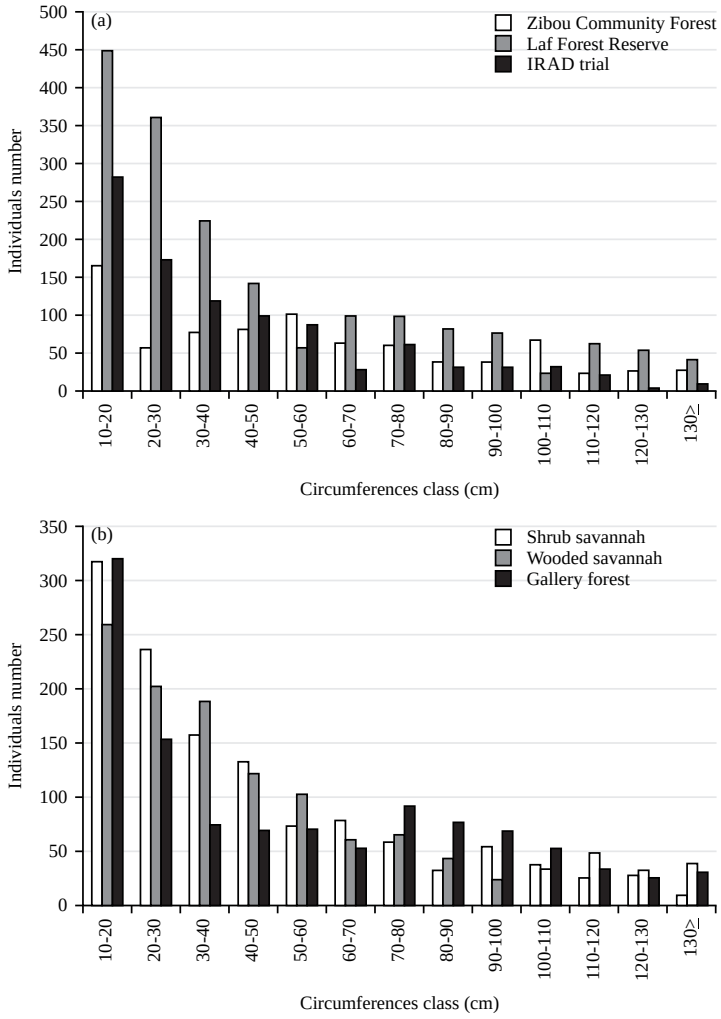

Fig. 5(a-b): Distribution of individuals in circumference classes according to (a) Study areas and (b) Formations

Dendrometric characterization

Density: Densities vary significantly ($p<0.01$) between plant formations for each of the three sites and sites for each of the three plant formations (Table 8). Depending on the study area, density is respectively higher in Laf Forest Reserve for the tree savanna (57.28 ind ha^{-1}) and shrub savanna (97.44 ind ha^{-1}) and in Zibou Community Forest for the gallery forest (67.04 ind ha^{-1}). Between formations, the density is higher in the gallery forest for the Zibou Community Forest (67.04 ind ha^{-1}) and the IRAD test site (40.96 ind ha^{-1}) and in the shrub savanna for the Laf Forest Reserve (97.44 ind ha^{-1}). On the other hand, the wooded savannah has a low density for all zones.

Basal area: Basal area varied significantly ($p<0.01$) between plant formations for each of the three sites and sites for each of the three plant formations (Table 9). Depending on the study area, the basal area is higher in Laf Forest Reserve for tree savanna (9.88 m^2 ha^{-1}) and shrub savanna (11.03 m^2 ha^{-1}) respectively and in Zibou Community Forest for gallery forest (13.05 m^2 ha^{-1}). Between formations, species richness is higher in the gallery forest for the Zibou Community Forest (13.05 m^2 ha^{-1}) and the IRAD test site (9.48 m^2 ha^{-1}) and in the shrub savanna for the Laf Forest Reserve (11.03 m^2 ha^{-1}). On the other hand, the tree savannah has a low density for all zones.

Horizontal structure: Figure 5 has the horizontal structure according to protected zones (Fig. 5a) and types of formation (Fig. 5b). This horizontal structure varies according to the formations and the zones of study. The majority of the individuals find itself in the first three classes of circumferences (10-20, 20-30 and 30-40). These classes represent the greatest number of the listed stems. For the other classes, the manpower of the individuals go in decreases as the class of circumference increases.

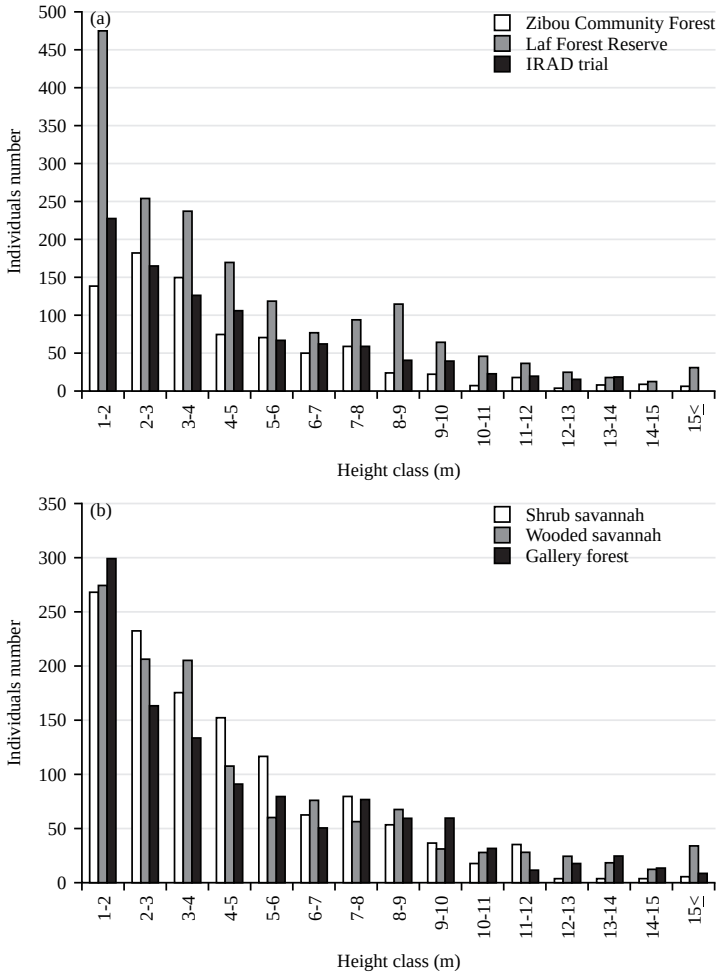

Fig. 6(a-b): Distribution of individuals in height class according to (a) Study areas and (b) Formations

Table 8: Densities according to formations and zones (ind ha^{-1})

	Wooded savannah	Shrub savannah	Gallery forest	LSD
IRAD trial	33.6±0.04$^{c\delta}$	36.96±0.05$^{c\beta}$	40.96±0.24$^{c\alpha}$	1268.81***
Laf Forest Reserve	57.28±0.23$^{a\beta}$	97.44±0.16$^{a\alpha}$	53.44±0.08$^{b\delta}$	32903.04***
Zibou Community Forest	42.4±0.33$^{b\delta}$	53.12±0.1$^{b\beta}$	67.04±0.03$^{a\alpha}$	1927.08***
LSD	164144.24***	15081.33***	7687.02***	

Different Arabic letters (a, b and c) in columns indicate that densities are significantly different between zones by Fisher's LSD (least significant difference) at the 5% threshold. Values in brackets represent standard deviations. Different Greek letters (α, β, δ and Ω) in rows indicate that densities are significantly different between plant formations by Fisher's LSD at the 5% threshold and Difference not significant (ns) difference significant at ***p<0.001

Table 9: Basal area according to zones and formations

	Wooded savannah	Shrub savannah	Gallery forest	LSD
IRAD trial	5.02±001$^{c\delta}$	7.74±002$^{c\beta}$	9.48±002$^{b\alpha}$	50320.74***
Laf Forest Reserve	9.88±006$^{a\delta}$	11.03±002$^{a\alpha}$	10.62±002$^{c\beta}$	3378.07***
Zibou Community Forest	6.91±002$^{b\delta}$	8.08±002$^{b\beta}$	13.05±003$^{a\alpha}$	6766.72***
LSD	9996.63***	13387.80***	10380.12***	

Different Arabic letters (a, b and c) in columns indicate that land areas are significantly different between zones by Fisher's LSD (least significant difference) at the 5% threshold. Values in brackets represent standard deviations. Different Greek letters (α, β, δ and Ω) in rows indicate that land areas are significantly different between plant formations by Fisher's LSD at the 5% threshold and Difference not significant (ns) difference significant at ***p<0.001

Vertical structure: Figure 6 shows the vertical structure according to protected zones (Fig. 6a) and types of formation (Fig. 6b). The distribution in height of the individuals in these sites follows the same tendency as the horizontal distribution. In different zones and formations, the greatest numbers of the individuals are gathered in the first classes height (1-2, 2-3 and 3-4). The individuals with height superior to 8 m were fewer.

DISCUSSION

The present study on the woody stands of the Mayo-Kani Division reveals that out of all the surveys that were carried out, 63 species were distributed in 49 genera and 25 families. These results were similar to those of Todou *et al.*[18], who found 75 species, distributed in 54 genera and belonging to 28 families in the Moutourwa forest massifs and those of Sani *et al.*[19] in the Mozogo-Gokoro National Park, who obtained 62 woody species. These results were compared to those of Jiagho *et al.*[20] in the periphery of Waza National Park where he counted 52 woody species distributed in 41 genera and 21 families were richer.

The analysis of biological types shows a strong representation of mesophanerophytes and microphanerophytes in all plant formations and study areas. This dominance of microphanerophytes and mesophanerophytes translates into a preponderance of shrubby to arborescent formations. It could be explained by the fact that most species are better adapted to the climatic and edaphic conditions of the study areas. This result corroborated with that of Abdourhamane *et al.*[21] and confirmed that the most widespread physiognomic type in the study area is shrub and tree formations. This result confirmed the assertion of Schmidt *et al.*[22] that biological types reflect not only structural parameters in vegetation but also varied environmental conditions.

The dominance of Sudanese-Zambézian species attests that the flora of the Sudanese zone still retains its phytogeographic specificity despite anthropization. This predominance of Sudano-Zambézian species over other phytogeographic types is a characteristic of Sudanian savannas[23].

The Shannon diversity index varied significantly between plant formations for each of the three zones and between zones for each of the three plant formations. Depending on the study area, the Shannon index is higher in the Laf Forest Reserve and lower at the IRAD test site for the tree and shrub savannahs. In contrast, in the gallery forest, it is highest in the Zibou Community Forest and lowest in the IRAD test site. The low Shannon diversity indices obtained reflect low species richness. They can be explained by anthropogenic activities. They can also be explained by the fact that the two study sites are located in the same climatic conditions and the same agro-ecological zones. The evenness index follows the same trend as the Shannon index. Our results are similar to those of Konsala *et al.*[24], who found the evenness index (E) varied from 0.31 to 0.47 in the Laf Forest Reserve, Cameroon. This low index of areas can be attributed to anthropogenic disturbances.

The ecological importance of the species differs according to the formations and study areas. The high values of ecological importance of species such as *Balanites aegyptiaca*, *Combretum glutinosum* and *Anogeissus leiocarpus* could be explained on the one hand by the fact that these are more adapted to the climatic conditions of this agro-ecological zone, but also by their frequency due to their importance for the local population that protects these species.

The families best represented in the index of importance value are Fabaceae, Combretaceae and Zygophyllaceae. These results were comparable to those found by several authors who have worked on woody vegetation in the Sudano-Sahelian Zone[6,19,24]. This confirmed that the Fabaceae and Combretaceae are characteristic of the Sudano-Sahelian Zone of Cameroon.

The high densities translate the fact that anthropic activities are accentuated still in these sites. On the other hand in the sites presenting low values of density, these anthropic activities are more intense through the production of wood for heating and demolition charcoal with short-nap cloth of the woody species during the clearings for agricultural pieces.

The importance of the actual values of surface terrière would be explained by the fact that the species that have a diameter very high are dense in these sites whereas surface terrière is a function of the diameter. These results were in agreement with previous studies[16,25]. On the other hand, the low values of surface terrière it would be due to the anthropic activities which are related to various uses of the ligneous family.

The woody stand structures of the protected formations of the Mayo-Kani Division established according to diameter and height classes show a predominance of the first classes for all sites and present the shape of an "inverted J", translating a decrease in the number of stems when one passes from the small diameter classes to the larger diameter classes. The predominance of individuals measured and considered young are stunted adults. This stunted state is the consequence of the combined effects of stresses and disturbances due to anthropic activities and climatic hazards[6,23].

Additional investigations on the other types of surfaces protected and their types of formations can bring an adaptive response for a better durable management of the surfaces protected from Cameroon North.

CONCLUSION

The study made it possible to evaluate the floristic composition and structural characteristics of the woody vegetation of the protected formations of the Mayo-Kani Division. The investigations allowed the identification of 63 woody species belonging to 49 genera and 23 families dominated by Fabaceae and Combretaceae. The diversity index shows that the gallery forest of the Zibou Community Forest (3.33 bits) and the shrub savanna of the Laf forest reserve (3.10 bits) are moderately diverse. Analysis of biological forms shows a significant proportion of microphanerophytes and mesophanerophytes characteristic of dry climatic conditions and phytogeographic types are dominated by Sudano-Zambézian species. The evolution of the vertical and horizontal structures shows a regression of the woody stand with a very high proportion of species of low circumference and height. Thus, the observation of this floristic composition and the dendrometric structures of the study area allows affirming that the woody vegetation is in degradation under the anthropic action and the phenomena of climatic change.

SIGNIFICANCE STATEMENT

This study evaluated the floristic composition and structural characteristics of the woody vegetation of the protected formations of the Mayo-Kani Division. These results provide an insight into the management and they can also be used as a database for the redevelopment of these protected areas in the Sudano-Sahelian zone of Cameroon.

REFERENCES

1. Rasmussen, L.V., M.E. Fagan, A. Ickowitz, S.L.R. Wood and G. Kennedy *et al*., 2020. Forest pattern, not just amount, influences dietary quality in five African countries. Global Food Secur., Vol. 25. 10.1016/j.gfs.2019.100331.
2. Baudron, F., S.A. Tomscha, B. Powell, J.C.J. Groot, S.E. Gergel and T. Sunderland, 2019. Testing the various pathways linking forest cover to dietary diversity in tropical landscapes. Front. Sustainable Food Syst., Vol. 3. 10.3389/fsufs.2019.00097.
3. Hamawa, Y., J. Balna and K. Souare, 2018. Ecological structure and fruit production of *Haematostaphis barteri* Hook. F in the Sahelian Zone of Cameroon [In French]. J. Appl. Biosci., 130: 13232-13243.
4. Onana, J.M., J.L. Fobane, E.H. Biye, E.N. Tchatchouang and M.M.A. Mbolo, 2019. Natural habitats of Cameroon ecosystems. Int. J. Biol. Chem. Sci., 13: 3247-3265.
5. Mapongmetsem, P.M., B.A. Nkongmeneck, G. Rongoumi, D.N. Dongock and E.B. Dongmo, 2011. Impact of land use systems on the conservation of *Vitellaria paradoxa* Gaertn. F. (*Sapotaceae*) in the Sudano-Guinean Savannah Region. Int. J. Environ. Stud., 68: 851-872.
6. Africa, B.N., S. Konsala and I. Adamou, 2020. Characterization of the woody vegetation of savannah ecosystems of Mayo-Danay Division in the Sudano-Sahelian Zone of Cameroon. J. Plant Sci., 8: 41-56.
7. Ahononga, F.C., G.N. Gouwakinnou, S.S.H. Biaou and S. Biaou, 2020. Vulnerability of land in the Sudanian domain ecosystems in Benin from 1995 to 2015. Bois Forêts Tropiques, 346: 35-50.
8. Liu, J., D.A. Coomes, L. Gibson, G. Hu and J. Liu *et al*., 2019. Forest fragmentation in China and its effect on biodiversity. Biol. Rev., 94: 1636-1657.
9. Ervin, J., 2003. Protected area assessments in perspective. Bioscience, 53: 819-822.
10. Ervin, J., 2003. Rapid assessment of protected area management effectiveness in four countries. BioScience, 53: 833-841.
11. Brandt, M., J.P. Wigneron, J. Chave, T. Tagesson and J. Penuelas *et al*., 2018. Satellite passive microwaves reveal recent climate-induced carbon losses in African drylands. Nat. Ecol. Evol., 2: 827-835.
12. Hall, P. and K. Bawa, 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Econ. Bot., 47: 234-247.
13. Habou, M.K.A., B. Morou and A. Mahamane, 2022. Phytoecological characteristics of woody plant groups in natural *Balanites aegyptiaca* (L.) Del. formations. in Central-Eastern Niger. Eur. Sci. J., 18: 333-355.
14. Mbaiyetom, H., M.L.A. Tientcheu, M.T. Ngankam and J.B.W. Taffo, 2021. Floristic diversity and structure of woody vegetation in wooded parks in the Sudanian Zone of Chad. Int. J. Biol. Chem. Sci., 15: 68-80.
15. Cottam, G. and J.T. Curtis, 1956. The use of distance measures in phytosociological sampling. Ecology, 37: 451-460.
16. Ndiaye, O., A. Diallo, S.A. Wood and A. Guisse, 2014. Structural diversity of woody species in the Senegalese Semi-Arid Zone-Ferlo. Am. J. Plant Sci., 5: 416-426.
17. Mori, S.A., B.M. Boom, A.M. de Carvalino and T.S. dos Santos, 1983. Ecological importance of Myrtaceae in an Eastern Brazilian wet forest. Biotropica, 15: 68-70.
18. Todou, G., M. Froumsia, K. Souaré and J.F. Nnanga, 2016. Woody plants diversity and type of vegetation in non cultivated plain of Moutourwa, Far-North, Cameroon. J. Agric. Environ. Int. Dev., 110: 217-227.
19. Sani, R.C.S., M. Ntoupka, A. Ibrahima and V. Toua, 2013. Ecological study of the Mozogo-Gokoro National Park (Cameroon): Preliminary surveys of woody flora and soil for its conservation and development. Int. J. Biol. Chem. Sci., 7: 2434-2449.

20. Jiagho, E.R., L. Zapfack, L.P.R.K. Banoho, M. Tsayem-Demaze, J. Corbonnois and P. Tchawa, 2016. Diversity of woody flora on the periphery of Waza National Park (Cameroon) [In French]. Vertigo, Vol. 16. 10.4000/vertigo.17249.
21. Abdourhamane, H., B. Morou, H. Rabiou and A. Amhamane, 2013. Floristic characteristics, diversity and structure of woody vegetation in South-Central Niger: Case of the Dan kada Dodo-Dan Gado classified forest complex. Int. J. Biol. Chem. Sci., 7: 1048-1068.
22. Schmidt, M., H. Kreft, A. Thiombiano and G. Zizka, 2005. Herbarium collections and field data-based plant diversity maps for Burkina Faso. Divers. Distrib., 11: 509-516.
23. Pallo, F.J.P. and N. Sawadogo, 2010. Correlation test between climate, vegetation and soil characteristics in Burkina Faso. Int. J. Biol. Chem. Sci., 4: 1839-1850.
24. Konsala, S., F. Moksia, B.N. Claudette, M.T.H. Wilfrande, Tchobsala and I. Adamou, 2020. Effects of anthropogenic disturbances on biomass and potential carbon storage in LAF Forest Reserve (Cameroon). Int. J. Adv. Res., 8: 1-11.
25. Mbaikoubou, M., A. Guihini, A. Diallo, N. Faye, M.M. Saleh, T.D. Moussa and A. Guisse, 2021. Characteristics of woody populations along the route of the Great Green Wall in the provinces of Wadi-Fira East and Ennedi East of Chad. Int. J. Biol. Chem. Sci., 15: 1885-1901.