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(RESEARCH ARTICLE)

Floristic and phytogeographic analysis of the woody vegetation of the cliff of Ngaoundéré and its peripheries.

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Abstract
Field investigations have been carried out in the forest landscapes of the Ngaoundéré cliff and its outskirts, in the Vina Department of Cameroon. To learn more about the floristic richness and the chorologic position of the site of interest, an analysis of the flora, the autoecological and phytogeographic spectra of species has been undertaken. This analysis is based on floristic material from different surveys carried out in seven villages. On an area of 8.4 hectares prospected, through 84 phytosociological surveys, a floristic matrix of 87 species distributed in 46 genera and in 39 families was retained. Some of these species are of high ecological importance to the instar *Terminalia laxiflora* (16.58%), *Isoberlinia doka* (15.26%), *Terminalia glaucescens* (13.55%), *Vitellaria paradoxa* (10.17%), *Parkia biglobosa* (8.78%), *Sarcocephalus latifolius* (8.30%), *Pterocarpus lucens* (8.22%), *Daniellia oliveri* (7.92%).The families of the Fabaceae (64.83%), Combretaceae (43.18%), Euphorbiaceae (22.98%), Moraceae (16.35%), Rubiaceae (16.34%), Anacardiaceae (16.02%), Sapotaceae (10.17%), Myrtaceae (9.89%), Meliaceae (8.85%) and Annonaceae (7.51%) are the most diversified in cash. The ecological spectra highlight the high representativeness of microphanerophytes and ballochorous. On the phytogeographic level, the preponderance of multiregional species detected indicates the instability of forest landscapes in the study area. Moreover, the high rate of species with limited distribution in the African continent is an indication of disturbance and shows that the flora loses its specificity. All in all, this vegetation is in gradual degradation because of human activities.

Keywords: Flora; Autoecological spectra; Phytogeographic spectra; Cliff, Ngaoundéré

1. Introduction
With 22 523 732 hectares of forest, representing 48% of the country's surface, Cameroon is one of the major forest countries in the Congo Basin sub-region (FAO, 2013). However, these forests are degrading strongly and even tending to some places to disappear. The direct causes of this degradation are the expansion of unsustainable agricultural practices, the use of fuel wood as a source of energy, logging and the development of activities related to mining operations (Eba'a *et al.*, 2011). In addition to these direct causes, indirect causes of deforestation such as the increase in population pressure, economic pressure and the weakness of certain aspects of governance (FCPF, 2012). More than 80% of the local community are dependent on natural and forestry resources for their agricultural activities (Oumarou, 2000; Nyasiri, 2014) and for the collection of wood-energy (Tchobsala, 2011; Tchobsala *and al.*, 2016). Wood-energy remains one of the most used forms of energy. The use of firewood as a source of energy for households is widespread, not only in rural areas but also in urban areas. Nearly 53% of the population uses solid fuels and is found for almost all of them in rural areas (Ambrose-Oji, 2003). This pressure on forests and natural resources is growing as the annual growth rate in the country is 2.6% and even reaches 2.8% in some rural areas (Awona *et al.*, 2009). In the face of the degradation of forest resources, Cameroon's forestry policy has been strongly influenced by the major international environmental guidelines. Cameroon's Forest resource management system has moved from a system of organization of resource collection to a more streamlined scheme incorporating the main principles of

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sustainable management (FCPF, 2012). Indeed, a major obstacle to the sustainable management of tropical forests is the scarcity of knowledge about species, the structure of stands, the history of ecosystems and their relations with anthropogenic and climatic disturbances (Ndoye, 2005; Clark, 2007). The potential of these products, even indicatively, is not known. Due to the lack of inventory data, the sustainability of the exploitation of these resources cannot be projected in Cameroon (Tchatat *et al*., 1995). Forest resources, products and services have become increasingly sought-after, and existing information provides little knowledge of the level of use of these resources and the capacity of forests to meet growing needs in quantity and quality (Lescuyer, 2000). Knowledge about forests must therefore be diversified and deepened accordingly (FAO, 2001). The vegetation of the forest landscapes of the cliff of Ngaoundéré and its peripheries remains little known. However, it has a remarkable ecological, systematic, ethnobotany and tourist interest. A study carried out by Nyasiri *and al.* (2018) showed a decrease in the forest landscapes of the cliff of Ngaoundéré. This degradation results from the significant consumption of wood, the extension of agricultural stains, the camp and/or villages. In this respect, pastoral practices, herbal remedies and the practice of hunting, which undoubtedly influence flora, should be reported. The sampling is done without complying with the requirements of the development plan. The losses in forest area caused are more from the openings of the skidding lanes (development of the road infrastructure), the bases of life and even the migrations. The latter constitute additional pressure on forest resources: to meet their needs, migrants develop agriculture in forest landscapes and practice poaching (Nyasiri, 2018). For a better floristic knowledge, guaranteeing good management of natural resources and to make our contribution to the realization of the flora, it is necessary to make a floristic interpretation of the botanical inventories carried out, on the basis of systematic spectra, dissemination of diaspores and phytogeographic. The overall objective of this study is to contribute significantly to a better understanding of the flora of the forest landscapes of the cliff of Ngaoundéré and its peripheries and, beyond that, to clarify the distribution of species.

2. Material and methods

2.1. Study area

The study area is in the borough of Mbé, Department of Vina. It is located 50 km from Ngaoundéré between 07°42.00' and 07°48.60' North latitude and then between 013°31.80' and 013°38.40' East longitude (GPS readings). The study was carried out in seven villages (Taa-tooyo, Gob-gabdo, Gop, Wack, Ndom, Karna and Tchabbal) bordering on the cliff (Figure1).

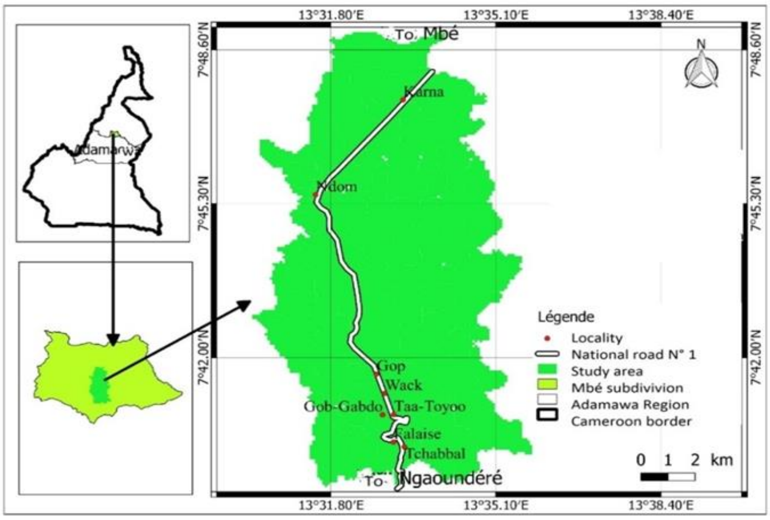


Figure 1 Location map of the study area

2.2. Inventory device

The surveys were carried out along the transects in the inventory plots installed from the inside to the outside of the cliff on floristic homogeneous areas.The sampling unit is the plot. The plots are contiguous and centered on the transect. The method of rectangular quadrats was used. The plots have an area of 1000 m^2 of dimensions 50 m x 20 m. The distribution of study stations within study sites is based on a rational approach (Grouzis and Methy, 1983). The reasoned method is to locate the plots on well-characteristic areas. Thus, areas without woody vegetation and non-accessible survey points are not considered. The experimental device is a split-plot consisting of seven villages, four plots and three repetitions (Figure 2). In each site, 12 inventory units were installed, a total of 84 overall. The survey was focused on identification and exhaustive counting of woody plants in each plot.

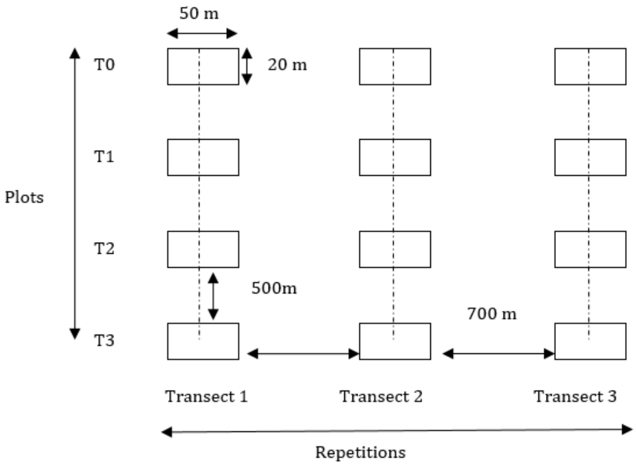


Figure 2 Experimental device installed at the level of each site.

T0: plot located inside the cliff; T1: plot located at 500 m from T0; T2: plot located at 500 m from T1; T3: plot located at 500 m from T2.

2.3. Assessment of floristic parameters

2.3.1. Taxonomic richness

The taxonomic richness of the flora is expressed in number of taxa. It also provides information on the number of genera and species per family, and species by genus.

2.3.2. Specific wealth

The specific wealth only provides information on the number of species in the sample. The specific richness is thus dependent on the scale of study so that the results of a study carried out on a given scale cannot be extrapolated or transposed to another scale.

2.3.3. Diversity Indices

Two indices were used to measure biological diversity: The Shannon-Wiener diversity index and the Piélou evenness index. These so-called heterogeneity indices have been developed to correct the lack of specific richness.

Shannon-Wiener diversity index

The Shannon-Wiener H' diversity index derives from information theory and measures the entropy of a sample, the "saturation" of the community (Kenth and Cooker, 1992). The index is given by the formula: $\mathbf{H' = -\sum_{i=1}^{ni} \left(\frac{Ni}{Nt} \ln \frac{Ni}{Nt}\right)}$

Ni = the number of species in the sample and Nt =the total number.

H ' varies from 0, when the stand consists of a single species, at Log2 Nt, when all species present have an equivalent abundance. In other words, the prevalence of dominant species in the community induces a low value of H ', while equitable distribution results in a high value of H '.

Index of evenness

The index of evenness **J'** of Piélou is inferred from the diversity index of Shannon-Wiener H'. This index measures the evenness in relation to an equal theoretical distribution for all species: $\mathbf{J' = H'/H'max = H'/lnS}$ with S being the total number of species.

J' vary from 0 to 1. The notion of evenness that expresses the regularity or equitable distribution of individuals within the Community species and is based on a combination of specific richness and species abundance.

2.4. Community structure

The relative importance of each family and species was determined by the calculation of an important index: the Importance Value Index (IVI) of Curtis and MacIntosh (1950), which corresponds to the sum of the relative density, relative dominance and relative frequency of the family or species: **IVI = Dr + Gr + Fr** with:

- Dr is the relative density (number of individuals of the species considered reported to the total number of individuals x 100);

- Gr is the relative dominance (basal area of the species considered relative to the total basal area of the Stand x 100);
- Fr is the relative frequency (frequency of the species considered reported at the sum of frequencies of all species x 100).

The IVI varies from 0 to 300. The IVI was calculated for individuals whose dbh were measured. It is used to characterize vegetation by referring to the most important family or species. The variation of IVI between the different sites makes it possible to highlight any changes in structure and floristic composition due to exploitation.

2.5. Biology, phytogeography and ecology

Referring to the work of White (1986) on the chorologyand phytogeography and those of Danserau and Lems (1957) relating to the diaspores cited by Senterre (2005) and Kouob (2009), chorologics types, types of phytogeographic distribution, types of diaspores, and methods of dissemination below have been taken up, corresponding to the flora of the study area.

2.6. Biological types

The classification of biological types adapted to tropical regions was adopted for this work (Senterre, 2005; Kouob, 2009). It provides several correspondences and hierarchical stratification (Table 1).

Table 1 Biological Types of tropical plants adapted to this study

Classification	Code	Correspondence	Height	Stratum
Mesophanerophyte	MsPh	Tree medium-dominant	10-30 m	Canopy
Microphanerophyte	McPh	Small tree-dominated	2-10 m	Undergrowth
Nanophanerophyte	NnPh	Shrub, subshrub	0-2 m	Shrub

2.7. Phytogeographic distribution

The first chorologic subdivisions of the Africa of White (1986) were used to determine the phytogeographic distribution of the flora of the Ngaoundéré cliff. This is:

- Species with wide geographic distribution (SWD):
  - Cosmopolitan (Cos): species distributed around the world;
  - Pantropical (Pan): known species in Africa, America and tropical Asia;
  - Paleo-Tropical (Pal): species present in Africa and tropical Asia, Madagascar and Australia,
- Species with limited distribution to the African continent (SLAC):
  - African Multiregional (AMR): species whose distribution area covers several African floristic regions or two floristic regions those are not in contact.
  - Afro-Tropical (At): species prevalent in tropical areas of Africa;
- Species of Liaison (SL): these are species with distribution range, supporting more or less specific ecological conditions. For this purpose, only the species Sudano-zambezian (Sz): species distributed in Sudano-Guinean zones and Zambia.

2.8. Types of diaspores

The types of dissemination of diaspores were determined by the classification of Danserau and Lems (1957). These different types are:

- the anemochorous (Anemo): diaspores scattered by the wind;
- the sclerochorous (Sclero): relatively light, non-fleshy diaspores scattered either by wind or by water or by animals;
- the sarcochorous (Sarco): diaspores totally or partially fleshy scattered either by wind or by water or by animals;
- the zoochorous (Zoo): diaspores disseminated by animals;
- the ballochorous (Ballo): diaspores expelled by the plants themselves;
- thebarrochorous (Barro): diaspores not fleshy, heavy scattered by the water stream.

2.9. Statistical analysis of the data

After going through and bringing together the data, a matrix known as the taking down of species was based on the presence/absence of species on line and steering column for statements. Some variance analyses were used to check the gaps between the number processing and the area. In the presence of significant variance analysis, the medium-sized comparisons were conducted with the help of the Fisher test.

3. Results and discussion

3.1. Taxonomic richness

The floristic inventory of the woody stratum identified a total of 5228 individuals belonging to 87 species, 66 genera and 39 families. The analysis in table 2 shows that the number of taxa decreases when one passes from T0 to T3. The highest numbers of species, genera, and families were observed in the T0 plots and the lowest in the T3 plots. The intermediate values are recorded in the T1 and T2 plots. The number of species varied from 76 in plots T0 to 63 in plots T3 with 73 species in plots T1 and 67 species in plots T2. The estimated number of families recorded 36, 33, 31, 29 families respectively in plots T0, T1, T2 and T3. The large decline in floristic composition is the result of the intensity of exploitation of the T2 and T3 plots due to their proximity to the villages.
Depending on the sites, the variations are also observed. Floristic richness is very high at the Karna level with 1136 individuals, 68 species, 50 genera and 37 families (Table 3). The lowest floristic richness is noted in the village Gob-gabdo, which is full of 622 individuals, 45 species, 39 genera and 29 families.

Table 2 Taxonomic richness according to plots

	T0	**T1**	**T2**	**T3**
NI	1734	1503	1095	896
NE	76	73	67	63
NG	57	56	53	48
NF	36	33	31	29

Table 3 Taxonomic richness according to sites

	Taa-toyo	**Gob-gabdo**	**Gop**	**Wack**	**Ndom**	**Karna**	**Tchabbal**
NI	663	622	638	764	715	1136	690
NE	47	45	51	60	64	68	64
NG	40	39	42	43	48	50	44
NF	26	29	34	35	36	37	35

NI: Number of individuals, NE: Number of species, NG: Number of genera, NF: Number of families

3.2. Ecological importance of wood

The values of Curtis importance value index of the woody trees inventoried in the forest landscapes of the cliff are given in table 4. Generally, a complete dominance of *Terminalia laxiflora* is noted. This species has a value index of Curtis of 16.58%. It is followed by the species *Isoberlinia doka* (15.26%), *Terminalia glaucescens* (13.55%), *Vitellaria paradoxa* (10.17%), *Parkia biglobosa* (8.78%), *Sarcocephalus latifolius* (8.30%), *Pterocarpus lucens* (8.22%), *Daniellia oliveri* (7.92%).

Table 4 Significance value Index of Ngaoundéré cliff species (%)

Species	Dr	Gr	Fr	IVI	Species	Dr	Gr	Fr	IVI
Acacia ehrenbergiana	1.00	0.19	1.13	2.32	*Khaya senegalensis*	1.11	0.40	1.92	3.43
Acacia polyacantha	1.22	0.90	1.86	3.98	*Lannea acida*	1.55	0.75	2.51	4.81
Acacia tortilis	0.89	0.42	0.87	2.18	*Lannea barteri*	1.00	0.46	1.62	3.08
Afzeliaafricana	2.00	1.26	3.66	6.92	*Lannea schimperi*	1.33	1.53	1.00	3.86
Albizia zygia	0.22	0.06	0.09	0.37	*Lophira lanceolata*	0.89	0.57	0.28	1.74
Allophyllus africanus	0.67	0.42	0.24	1.32	*Mangifera indica*	0.55	0.90	0.99	2.44
Annona senegalensis	2.77	3.67	0.78	7.23	*Maytenus senegalensis*	1.22	0.61	1.13	2.96
Anogeissus leiocarpus	1.22	0.59	2.38	4.19	*Mitragyna inermis*	0.44	0.08	1.06	1.58
Antidesma venosum	1.55	0.80	1.20	3.55	*Monotes kerstingii*	1.00	0.46	1.19	2.64

Bombax costatum	1.00	0.42	1.77	3.19	*Neocarya macrophylla*	0.55	0.11	0.75	1.42
Borassus aethiopum	1.66	1.70	1.95	5.31	*Parkia biglobosa*	2.66	1.89	4.23	8.78
Breonadia salicina	0.44	0.10	1.55	2.09	*Phyllanthus muellerianus*	1.66	0.78	0.52	2.97
Bridelia ferruginea	2.22	1.11	1.43	4.76	*Piliostigma thonningii*	2.44	4.09	1.08	7.61
Bridelia retusa	0.11	0.02	0.01	0.14	*Protea madiensis*	0.89	0.92	0.47	2.28
Bridelia scleroneura	2.44	2.60	1.29	6.33	*Pseudocedrela kotschyi*	1.55	1.19	1.50	4.24
Burkea africana	1.55	1.07	3.66	6.28	*Psidium guajava*	0.55	0.46	0.77	1.79
Ceiba pentandra	0.22	0.06	0.45	0.73	*Pterocarpus erinaceus*	1.00	1.40	1.87	4.26
Citrus decumana	0.44	0.38	0.67	1.50	*Pterocarpus lucens*	2.33	3.37	2.52	8.22
Combretum glutinosum	1.33	0.90	2.15	4.38	*Sarcocephalus latifolius*	2.77	4.23	1.30	8.30
Commiphora kerstingii	0.44	0.36	0.14	0.94	*Sclerocarya birrea*	0.33	0.46	1.04	1.83
Crossopteryx febrifuga	0.78	0.38	0.36	1.52	*Securidaca longepedonculata*	0.44	0.10	0.33	0.87
Croton macrostachyus	0.11	0.06	0.22	0.39	*Psorospermum febrifigum*	1.66	1.34	0.83	3.83
Croton pseudopulchellus	1.22	0.69	0.08	1.98	*Psorospermum senegalense*	0.55	0.21	0.27	1.04
Croton zambesicus	0.22	0.06	0.25	0.53	*Steganotaenia araliaceae*	1.77	1.32	0.69	3.79
Cussonia arborea	1.00	1.36	0.61	2.97	*Sterculia setigera*	0.44	0.27	0.42	1.13
Dalbergia boehmii	1.44	0.63	0.99	3.07	*Stereospermum kunthianum*	0.78	0.44	0.72	1.94
Daniellia oliveri	2.66	2.75	2.51	7.92	*Strychnos innocua*	0.44	0.15	0.18	0.77
Detarium microcarpum	1.22	0.23	0.12	1.57	*Strychnos spinosa*	1.66	0.88	1.17	3.71
Diospyros mespiliformis	0.11	0.06	0.02	0.19	*Syzyguim guineense var guineense*	1.00	0.82	1.67	3.49
Entada abyssinia	0.11	0.08	0.18	0.37	*Syzyguim guineense var macrocarpum*	1.33	0.92	2.36	4.61
Entada africana	2.33	2.58	2.14	7.05	*Terminalia glaucescens*	2.77	8.34	2.44	13.55
Erythrina sigmoidea	0.11	0.08	0.06	0.25	*Terminalia laxiflora*	2.44	11.15	2.99	16.58
Erythrophleum africanum	0.22	0.04	0.53	0.79	*Terminalia macroptera*	1.55	0.90	0.50	2.95
Ficus platyphylla	1.55	0.61	2.53	4.70	*Terminalia molle*	0.55	0.17	0.79	1.52
Ficus sur	1.55	0.57	1.05	3.18	*Trichilia emetica*	0.44	0.13	0.60	1.18
Ficus sycomorhus	1.66	0.78	2.49	4.94	*Uapaga togoensis*	0.44	1.07	0.82	2.33
Ficus trichopoda	0.44	0.10	0.37	0.91	*Vernonia amygdalina*	1.00	0.31	0.22	1.53
Ficus vogelii	0.78	0.38	1.47	2.63	*Vitellaria paradoxa*	2.66	3.88	3.63	10.17
Gardenia aqualla	1.44	0.65	0.75	2.85	*Vitex donania*	2.33	1.30	2.00	5.63
Grewia flavescens	2.00	2.18	0.42	4.60	*Vitex madiensis*	0.22	0.06	0.36	0.64
Gyrocarpus americanus	0.11	0.02	0.03	0.16	*Ximenia americana*	1.22	0.44	0.97	2.63
Harungana madagascariensis	0.55	0.29	0.17	1.01	*Xylopia parviflora*	0.11	0.11	0.06	0.29
Hymenocardia acida	0.55	0.13	0.09	0.78	*Ziziphus mauritiania*	0.22	0.04	0.02	0.28
Isoberlinia doka	2.55	9.24	3.48	15.26	Total	100	100	100	300

Dr: Relative density, Gr: relative dominance, Fr: Relative frequency, IVI: Significance value Index of Curtis

3.3. Ecological importance of families

The importance of a family depends on the cumulative importance of its species and individuals. For example, on all study sites, there is a dominance of Fabaceae with 21 species in 13 genera (Table 5). This family has an significance value index of 64.83%. It is followed by the Combretaceae (43.18%), Euphorbiaceae (22.98%), Moraceae (16.35%), Rubiaceae (16.34%), Anacardiaceae (16.02%), (15.79%), Sapotaceae (10.17%), Myrtaceae (9.89%), Meliaceae (8.85%), Annonaceae (7.51%). The least represented families i.e. Hernandiaceae (0.16%), Ebenaceae (0.19%), Rhamnaceae (0.28%), Hymenocardiaceae (0.78%), Polygalaceae (0.87%), Burseraceae (0.94%), Hypericaceae (1.01%), Sterculiaceae (1.13%), Sapindaceae (1.32%), Chrysobalanaceae (1.42%), Rutaceae (1.50%), Asteraceae (1.53%) are only represented by one species each.

Table 5 Number of species, types and significance value index of families

Plant Families	NS	NG	Dr	Gr	Fr	IVI	Plant Families	NS	NG	Dr	Gr	Fr	IVI
Anacardiaceae	5	3	4.77	4.09	7.16	16.02	Hypericaceae	1	1	0.55	0.29	0.17	1.01
Annonaceae	2	2	2.88	3.79	0.84	7.51	Loganiaceae	2	1	2.11	1.03	1.34	4.48
Apiaceae	1	1	1.77	1.32	0.69	3.79	Malvaceae	2	2	1.22	0.48	2.22	3.92
Araliaceae	1	1	1.00	1.36	0.61	2.97	Meliaceae	4	4	3.10	1.72	4.02	8.85
Arecaceae	1	1	1.66	1.70	1.95	5.31	Moraceae	5	1	5.99	2.45	7.92	16.35
Asteraceae	1	1	1.00	0.31	0.22	1.53	Myrtaceae	3	2	2.88	2.20	4.81	9.89
Bignoniaceae	1	1	0.78	0.44	0.72	1.94	Ochnaceae	1	1	0.89	0.57	0.28	1.74
Burseraceae	1	1	0.44	0.36	0.14	0.94	Olacaceae	1	1	1.22	0.44	0.97	2.63
Celastraceae	1	1	1.22	0.61	1.13	2.96	Polygalaceae	1	1	0.44	0.10	0.33	0.87
Chrysobalanaceae	1	1	0.55	0.11	0.75	1.42	Proteaceae	1	1	0.89	0.92	0.47	2.28
Combretaceae	6	3	9.87	22.05	11.26	43.18	Rhamnaceae	1	1	0.22	0.04	0.02	0.28
Dipterocarpaceae	1	1	1.00	0.46	1.19	2.64	Rubiaceae	5	5	5.88	5.43	5.03	16.34
Ebenaceae	1	1	0.11	0.06	0.02	0.19	Rutaceae	1	1	0.44	0.38	0.67	1.50
Euphorbiaceae	9	5	9.98	7.19	5.81	22.98	Sapindaceae	1	1	0.67	0.42	0.24	1.32
Fabaceae	21	13	22.84	20.87	21.12	64.83	Sapotaceae	1	1	2.66	3.88	3.63	10.17
Guttiferaceae	2	1	2.22	1.55	1.10	4.87	Sterculiaceae	1	1	0.44	0.27	0.42	1.13
Hernandiaceae	1	1	0.11	0.02	0.03	0.16	Tiliaceae	1	1	2.00	2.18	0.42	4.60
Hymenocardiaceae	1	1	0.55	0.13	0.09	0.78	Verbenaceae	2	1	2.55	1.36	2.36	6.26

NS: number of species; NG: number of genera; Dr: Relative density, Gr: relative dominance, Fr: Relative frequency, IVI: Significance value Index of Curtis

3.4. Biological diversity of plant groups

The values of specific richness and other indices of diversity and evenness are presented in Table 6. The values of the Shannon index vary according to the plots. They show that the grouping corresponding to the T0 plots is floristic more diversified than the other three. For this grouping, the value of the Shannon index is the highest (5.26 bits) compared to the others. The grouping corresponding to the T3 plots is the least diversified because it has a value of the lowest Shannon index (3.98 bits). The values of the Piélou index are greater than 0.5 for all groupings. This means that in all four plots, species share individuals in ecological niches in a relatively equitable manner. Similar results were obtained by Ousmane *et al*. (2017). The latter showed that the shrub savannas have a Shannon index of 4.42 bits and that the Piélou evenness gives a strong value of 0.90. The measured Shannon index is on average high for the entire stand, but also varies by site (table 7). It is higher at Tchabbal (4.85 bits), Ndom (4.93 bits) and Karna (5.03 bits) and lowers at Taa-tooyo (4.17 bits), Gob-gabdo (4.13 bits), Gop (4.21 bits) and Wack (4.25 bits). The Piélou index follows the same trend. This confirms the strong representation of the different species of the zone in Tchabbal, Ndom and Karna but also a greater stability of these sites compared to others. The diversity values obtained indicate a high specific diversity in these forest landscapes.

Table 6 Biological diversity of plant groups in plots

	T0	T1	T2	T3
S	76	73	67	63
H' (bits)	5.26	5.15	4.17	3.98
J'	0.67	0.6	0.63	0.57

Table 7 Biological diversity of different sites

	Taa-toyo	Gog-gabdo	Gop	Wack	Ndom	Karna	Tchabbal
S	47	45	51	60	64	68	64
H'(bits)	4.17	4.13	4.21	4.25	4.93	5.03	4.85
J'	0.63	0.64	0.62	0.68	0.72	0.77	0.7

S: specific richness; H ': Shannon's index; I: Index of Piélou.

3.5. Analysis of the matrix surveys/presence of species

The records/presence of species matrix has been subjected to multiple correspondence analysis (ACM). The information provided by the factorial axes ranges from 5.01% to 43.39% (Table 8). The axes F1 and F2 accumulate 90.52% of the information. It is on this plane formed by the first two axes that the bulk of the analysis was carried out (Figure 6). It shows a grouped distribution of observations around the intersection of the two axes, which is a sign of high similarity between the sites. Some species far removed from the others are noted. This is the case of observation 13 in the positive x-axis of F1, the observations 7, 48 and 50 at the original ax of F1, the observations 39 and 50 at the original axis of F1 and F2. In addition, the dendrogram from the Hierarchical Ascending Classification of the survey/presence matrix is used to discriminate against the dissimilarity threshold of 14.95%, three groups (Figure 7). The first group has for centre *Gyrocarpus americanus* (Table 9). It includes 16 species including *Daniellia oliveri* (7.92%) and *Vitellaria paradoxa* (10.17%) Having high value values indexes have equal frequencies of 85.71%. However, within this grouping, the central object is only present at Taa-tooyo, which shows a low diversity therefore the grouping is mostly made up of gregarious species. The second grouping is centered on *Ficus vogelii* and includes 33 species. The characteristic species are *Terminalia glaucescens* and *Annona senegalensis*. They have a value index of 13.54% and 7.22% respectively; a frequency of 89.28% each. The central object is present at Wack, Ndom, Karna, and Tchabbal. This shows that the diversity is average in this grouping. The third grouping is the central object *Afzelia africana*. A total of 38 species have been identified, including *Sarcocephalus latifolius*, *Parkia biglobosa* are characteristic species. *Sarcocephalus latifolius* has a value index of 8.29% and a frequency of distribution of 89.29%. As for *Parkia biglobosa*, it has a value index of 8.78% and a frequency of 85.71%. The central object is ubiquitous, which is present in all sites. These results indicate that the diversity within this grouping is high.

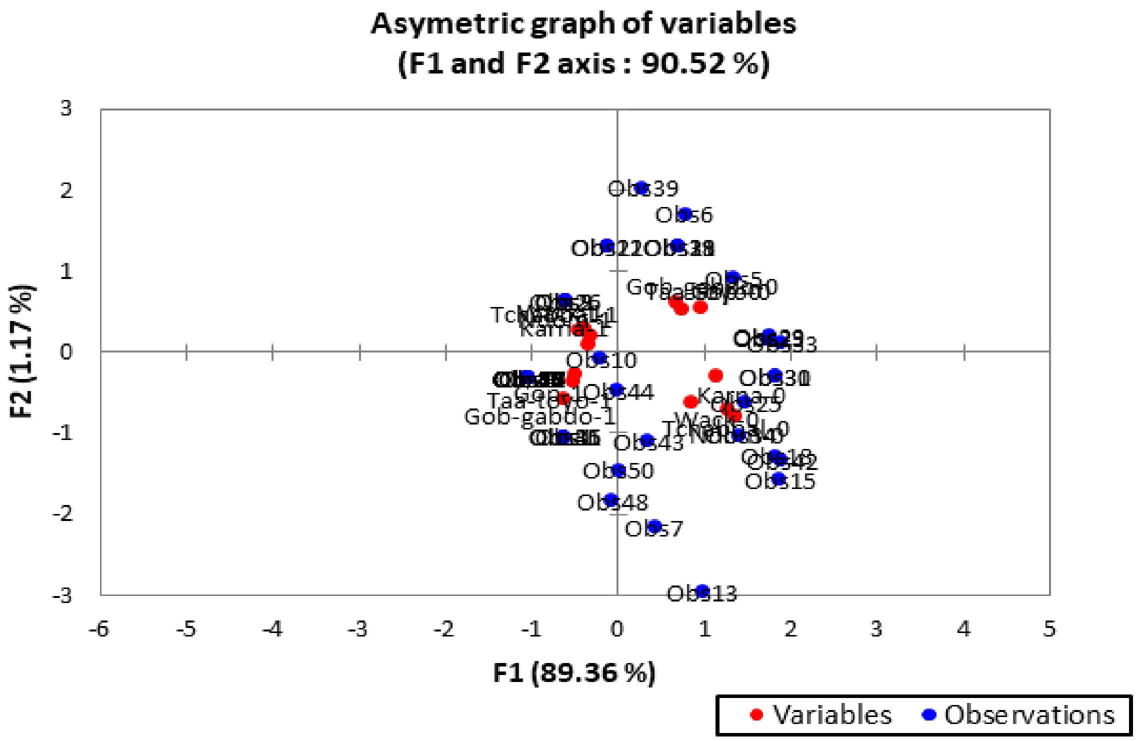


Figure 7 ACM of the Matrix Records/presence of species

Table 8 Eigenvalues and inertia of the factorial axes of the matrix readings/presence

FS	F1	F2	F3	F4	F5	F6	F7
Own value	0.434	0.176	0.120	0.099	0.067	0.053	0.050
Inertia (%)	43.394	17.612	12.038	9.901	6.736	5.309	5.009
% cumulative	43.394	61.006	73.044	82.945	89.682	94.991	100.000
Inertia ajusted	0.115	0.002					
Inertie ajusted (%)	89.357	1.167					
% cumulative	89.357	90.523					

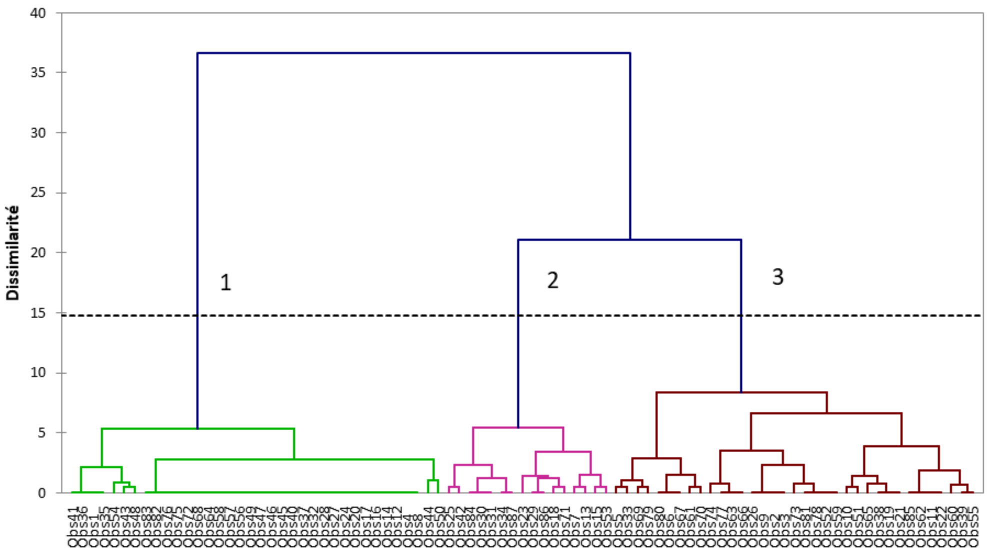


Figure 8 Dendrogram derived from CAH of the matrix survey/presence of species

Table 9 Central Objects

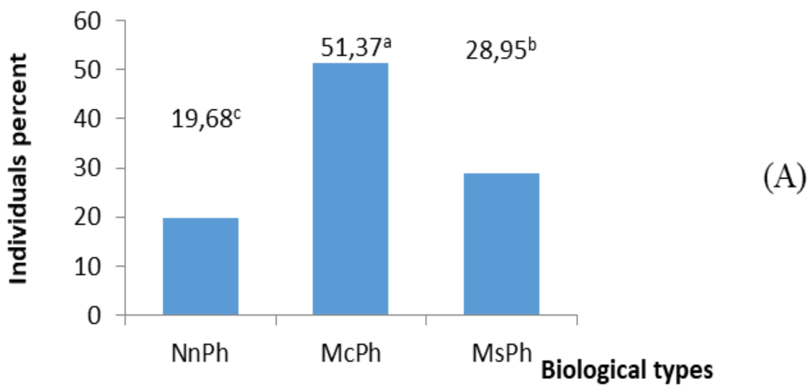
Classes	Taa-toyo	Gob-gabdo	Gop	Wack	Ndom	Karna	Tchabbal
1 (Obs41)	1.000	0.000	0.000	0.000	0.000	0.000	0.000
2 (Obs38)	0.000	0.000	0.000	1.000	1.000	1.000	1.000
3 (Obs4)	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Obs: Species, Obs41: *Gyrocarpus americanus*, Obs38: *Ficus vogelii*, Obs4: *Afzelia africana*.

3.6. Ecological characteristics of the stand

3.6.1. Biological types

Quantitative analysis of biological types highlights the dominance of microphanerophytes in the Ngaoundéré cliff (Figure 9A). They make up more than half of the flora with 51.37%. Then come the mesophanerophytes that represent 28.95% deflecting nanophanerophytes that make 19.68% of the flora. Figure 9B illustrates the spectrum of biological types at the different plots. The microphanerophytes are the majority in the T2 plots (57.82%), the plots T1 (58.46%) And in plots T0 except the T3 plots which are dominated by the nanophanerophytes. The mesophanerophytes come in second place in these same plots but at the T3 level they are poorly represented or 10.21%. At the plots T0 and T1, the mesophanerophytes are the majority compared to the nanophanerophytes, whereas at the level of the plots T2 and T3, the inverse is observed. Overall, the 5% threshold variance analyses revealed a significant difference between the different plots (p<5%).



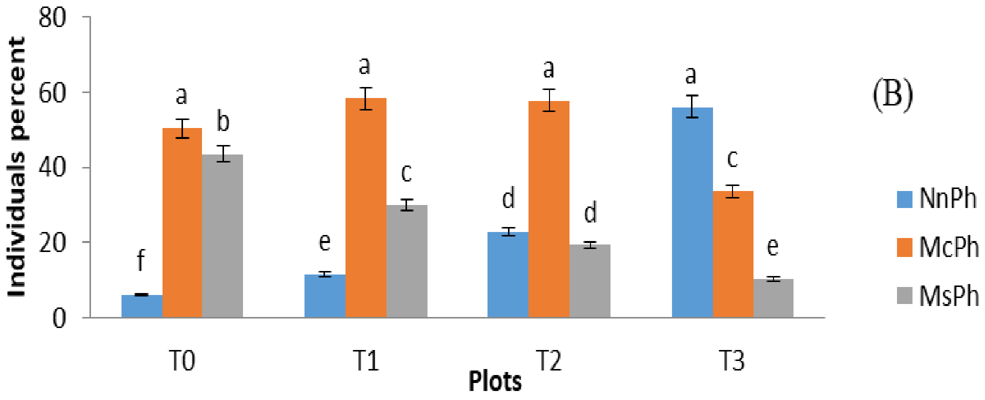


Figure 9 Spectrum of biological types in zone (A) and in different plots (B)

The bands surmounted by the same letter indicate that the corresponding values are not statistically different at the 5% threshold.

3.6.2. Phytogeographic Types

The phytogeographic distribution of species in the study area is governed by six modalities (Table 10). African multiregional species (AMR), whose existence can be in one or more floristic regions, sometimes disjunct from each other, represent 65.73% of the flora of the inventoried site. The Paleotropicales species (Pal) are then spread in tropical Africa, tropical Asia, Madagascar, Australia, and Afrotropicales (At) species distributed throughout tropical Africa. They account for 16.07% and 13.37% of the flora, respectively. Pantropical species (Pan) such as Cosmopolitan species (Cos) are represented by 106 species or 2.03% each. The Sudano-Zambezian (Sz) species are only represented by 30 species or 0.57%. The numerical significance of the phytogeographic types studied is as follows: large-scale species (SWD) with 20.12%, species with limited distribution to the African continent (SLAC) with 79.30% and species of Bond (SL) with 0.57%. Figure 10 illustrates the distribution of phytogeographic types in different plots. This figure shows that the multiregional species dominate in all plots, i.e. 71.99% in the T3 plots, 66.5% in the T2 plots, 61.35% in the T1 plots and 63.88% in the T0 plots. Pantropical species were absent in the T3 and T2 plots, whereas the Sudano-Zambian species were present only in the T1 plots. Statistical analysis reveals a significant difference between the different plots (p<5%).

Table 10 Distribution of phytogeographic types in the study area

	Phytogeographic types	Number of species	Percent (%)
	Cos	106	2.03
SWD	Pal	840	16.07
	Pan	106	2.03
	Total	1052	20.12
	AMR	3 447	65.93
SLAC	At	699	13.37
	Total	4 146	79.30
SL	SG	30	0.57
	Total	30	0.57

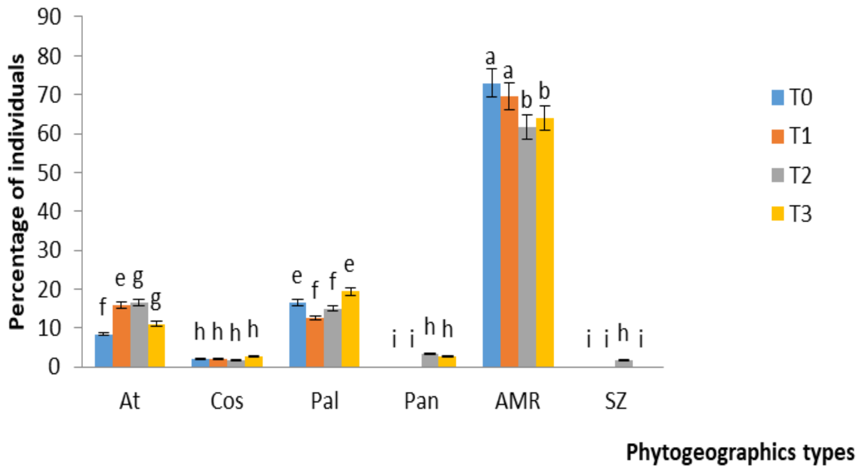


Figure 9 Spectrum of phytogeographic types in the study area

3.6.3. Distribution of diaspores types

For morphological types of diaspores, ballochorous species representing 26.73% of the total population are the most dominant type (Figure 10A). They are followed by anemochorous (21.77%) and zoochorous (17.70%). Barochorous and sarcochorous were almost equal and accounted for 12.71% and 12.05% of the flora, respectively. Sclerochorous are poorly represented with 9.03%. At the level of the different plots, the same observation was made (Figure 10B). Anemochorous, ballochorous and barochorouswere more represented in the T0 plots than in the other plots. The sarcochorous are majority at the T1 plots, whereas the zoochorous see their high proportion at the T2, T1, and T3 plots. The low proportion of zoochorous at the T0 plots explains that these plots being remote from the villages have not undergone too much human action.

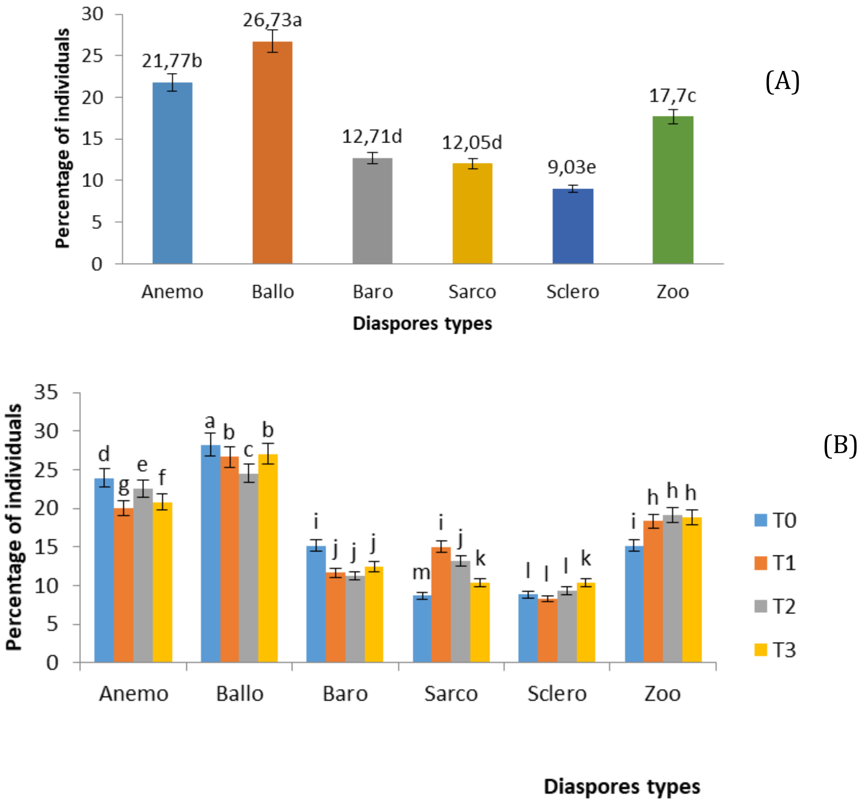


Figure 10 Distribution of diaspores types according to plot

The bands surmounted by the same letter indicate that the corresponding values are not statistically different at the 5% threshold.

4. Discussion

4.1. Floristic diversity

The woody flora of the cliff of Ngaoundéré and its peripheries abounds 87 species divided into 46 genera and 39 families. This floristic richness decreases from the inside of the cliff to its peripheries. The species that dominate this florule are *Terminalia laxiflora*, *Isoberlinia doka*, *Terminalia glaucescens and Vitellaria paradoxa*. A non-similar situation was obtained by Letouzey (1968) and Tchobsala (2011) in neighbouring sites. The work of these two authors showed that vegetation in peri-urban areas of Adamawa is dominated by *Daniellia oliveri*, *Lophira lanceolata*, and *Hymenocardia acida*. The strong dominance of *Terminalia laxiflora* in the study area would be due to its high regeneration power, Anemochorous release mode, and the middle-adapted pivoting root system. The numerical importance of some families could partly be explained by the method of disseminating the species belonging to these families. Indeed, Fabaceae, usually forage, with zoochorous seeds are disseminated by the herbivores that consume them (Ouédraogo, 2009) while the Combretaceae are characterized by their winged fruits easily dispersed by the wind. These families are composed of species that are resistant to lack of water and high temperatures (Savadogo *et al.*, 2016). Fabaceae, Rubiaceae, and Euphorbiaceae are also better represented in other continental forest ecosystems in Central Africa (Kouka, 2001; Lubini, 2001). Likewise, Guillaumet (1967) reported the preponderance of these three families in the mesophilic forests at Bas-Cavalo in Ivory Coast, an area of Upper Guinea. However, the flora of the cliff is characterized by a specific poverty in Hymenocardiaceae, yet well represented in the peri-urban savannahs of Ngaoundéré (Tchobsala and Mbolo, 2013). This is justified by the fact that floristic diversity varies according to the study area. Some species are specific to the environments in which they live.

4.2. Eco-friendly Features

The study area is characterized by predominance of microphanerophytes, ballochorous, and multiregional species. The dominance of microphanerophytes confirms the most common physiognomic type in the study area, namely shrub savannas. Similar results were found by Ousmane *et al.* (2007) for whom, microphanerophytes represent 67.39% followed by mesophanerophytes (23.91%) and nanophanerophytes (8.70%). In contrast, other work in the Sudanian zone revealed the prevalence of mesophanerophytes on other types. The work of Tchobsala (2011) in the peri-urban savannahs of Ngaoundéré showed that more than 60% of the vegetation is dominated by mesophanerophytes. Similarly, Aubréville (1962) found that the most widespread forms in Gabon are the mesophanerophytes. This would be explained by the development of human activities such as overgrazing, farming and agricultural harvesting. In fact, the man in his activities operates a selection which favours certain species influencing the physiognomy of the original vegetation. The high proportion of multiregional species denotes the instability of forest landscapes in the study area. Tchobsala *et al.* (2016) noted that the high rate of species with limited distribution in the African continent is an indication of disturbance and that the flora loses its specificity. Nyasiri (2014), having worked in the same phytogeographic zone, obtained similar results concluding that the area is disturbed by transhumant breeding and agricultural practices. In addition, ballochorous represent the most common type of diaspores in the area. These results are like those obtained by Tchobsala (2011) for whom the dominance of ballochorous (70.63%) is highlighted. However, it shows that the sarcochorous (0.86%) are the least represented diaspores in the peri-urban savannahs of Ngaoundéré. They differ from those of Kayumba *et al.* (2015) that showed that the spectrum of diaspores types is dominated by sarcochorous (63.37%) in the mature formation of Bombo-Lumene in the Democratic Republic of the Congo. This could be justified by the specific character of each biogeographic zone.

5. Conclusion

This study on the contribution to the knowledge of plant biodiversity in the cliff of Ngaoundéré and its peripheries detected a floristic richness of 87 species distributed in 46 genera and 39 families. This reinforces the interest of the conservation of the phytodiversity of the site. *Terminalia laxiflora* and *Isoberlinia doka* largely dominate this florule. The best-represented families are the Fabaceae, Combretaceae, Euphorbiaceae, Moraceae, Rubiaceae, Anacardiaceae, Sapotaceae, Myrtaceae, Meliaceae and Annonaceae. The ecological spectra highlight the numerical superiority of microphanerophytes and ballochorous. Similarly, the high representativeness of species with limited distribution to the African continent is an indication of disturbance.

Compliance with ethical standards

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