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Research Article
Floristic Characteristics, Diversity and Structure of the Woody Vegetation of the Mayo-Oulo Forest Reserve, North Cameroon

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Abstract

Background and Objective: The conservation and rational management of forest reserves require preliminary studies of ecological and floristic characterization. It is for this reason that the present study on the woody vegetation of the forest reserve of Mayo-Oulo subjected to human activities was undertaken. The aim of this study was to evaluate its floristic composition, floristic diversity and woody stand structure. **Materials and Methods:** The experimental set-up is a split plot with the villages constituting the main treatments. Data were collected through floristic surveys in 36 plots of 100×100 m, counting individuals of size ≥1.8 m and measuring DBH at 1.30 m from the ground for trees made and were subject to analysis of variance and multifactor text. Floristic richness, diversity indices, structure and biological and phytogeographic types were determined. **Results:** This resulted in 2174 individuals divided into 29 species, 24 genera and 14 families with dominance of Fabaceae, Shannon's diversity index ranged from 1.21 to 2.33 bits and Pielou's equitability from 0.41 to 0.79. The density is 60.38 ind ha^{-1}, the basal area is 2.62 m^2 ha^{-1} and vertical and horizontal structures are "L" shaped. Microphanerophytes (62.06%) and phytogeographic types dominate biological types by multi-regional and pantropical species. **Conclusion:** The results confirmed the poverty and low diversity of the reserve, which is evidence of the state of degradation and disturbance of the woody stratum of the studied formation. This constitutes basic data for the development of conservation strategies and sustainable management of forest resources.

Key words: Floristic, characteristics, diversity, structure, woody vegetation, North-Cameroon

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

INTRODUCTION

The forest reserve is an extensive and varied natural environment with an important biodiversity potential. The plant species it contains are very important to human populations, especially in Sub-Saharan Africa for the many services[1-4]. Their importance in biodiversity conservation is currently widely recognized[5]. Indeed, they serve as refuges for many species and constitute an exceptional heritage for local populations because of the goods and services they provide. Moreover, woody vegetation plays an important role in maintaining the ecological balance in a Sahelian environment that is facing the extension of the desert[6]. This awareness of the need to preserve biodiversity has resulted in the establishment of regulatory provisions to protect forest lands and the multiplication of various research fields.

The issue of biodiversity conservation has been a reality in the daily lives of local people since the Earth Summit in 1992[7]. In Cameroon, significant progress has been made in the development of legal texts on the management and conservation of natural resources in general and wildlife resources and in the involvement of riparian communities in the sustainable management of forest and wildlife heritage[8]. Ranked second in the Congo Basin after the Democratic Republic of Congo and fifth in Africa[9]. It is home to a multitude of flora and fauna. This important forest and wildlife potential is sometimes at the center of divergent conflicts of interest on the part of the different actors involved. Given the usefulness of these natural ecosystems that constitute habitats for biodiversity, Cameroon has proceeded to create conservation areas. Thus, the first protected areas were created in 1932-1933 by the colonial administration. After independence in 1960 and awareness of the importance and challenges of biodiversity conservation, the Cameroonian government has regularly created new protected areas and changed the status of other protected areas to strengthen their conservation.

Despite their importance for populations and the maintenance of ecological balance, forest landscapes are facing anthropogenic pressures that modify their structures and functions leading to the erosion of biodiversity which constitutes a threat to humanity[10]. This change that is at the origin of biodiversity loss is largely the result of population growth, which is inevitably accompanied by significant demands for cultivable land and economic and social needs. The case of the Mayo-Oulo Forest Reserve is a perfect illustration. Thus, woody plants and their biotopes are subject to pressure from biotic and abiotic factors that threaten their proliferation, even though they have not been studied in depth and are still useful[11,12]. This is what has yet preoccupied for decades, the international community strongly mobilized around the concepts of sustainable development, preservation of the environment and the fight against poverty. This testifies to the global awareness of the threat to our planet, due to current unsustainable production and consumption patterns.

In-depth studies are still commendable in this protected area which has no reference data to assess its level of biological diversity. This study falls within this framework with the objective of improving knowledge of the woody vegetation of the Mayo-Oulo Forest Reserve, which is subject to anthropic pressures, to provide basic elements for the implementation of sustainable management strategies. Specifically, it is a question of evaluating the floristic composition, diversity and structure of woody species in the Mayo-Oulo Forest Reserve.

MATERIALS AND METHODS

Study site: The study was conducted from November, 2021 to January, 2022 in the Mayo-Oulo Forest Reserve, located in the Sudan-Sahel zone of Cameroon. It is a Category VI protected area according to the International Union for Conservation of Nature (IUCN) and a Category II Technical Operational Unit (TOU) according to the Ministry of Forests and Wildlife of Cameroon. It follows the administrative division of the Mayo-Louti Department, Northern Region. It was created by Presidential Decree No. 82/455 of 20/09/1982. It is bounded to the North by the Bourha subdivision, to the South by the Basheo subdivision, to the East by the Guider subdivision and to the West by the Federal Republic of Nigeria (District of Mubi). It has an area of 1,271 km^2. The town of Mayo-Oulo is located approximately 150 km from Garoua, the capital of the Northern Region. The climate is of the Sudano-Sahelian type, characterized by two seasons of unequal length, a dry season from November to May, with changing temperatures and up to 38.5°C and a rainy season from June to October. The ferruginous soil, which results from leaching, is characterized by cuirassed sets, spliced kaolinite alterations and alluvial deposits. It is also sandy-clayey in places. The relief is occupied at 80% by mountain ranges and isolated mountains. It is covered with vegetation of several variants, the main ones being the tree/shrub savannah and steppe made up of different woody species: *Acacia albida*, *Ziziphus mauritiana*, *Tamarindus indica* and *Adansonia digitata*, the flood plains or swamps made up of *Vetiveria migratana*, *Echinochloa pyramidalis*, the grassy savannah of this formation contains, among others, *Caperonia palustris*, *Hibiscus asper* and *Sorghum arundinaceum*.

Data collection: Floristic surveys were conducted at 12 sites in the three villages near the forest reserve. At each site, the floristic inventory was done in square plots of 100 m side (10,000 m^2), equidistant of 500 m going from the inside to the outside of the forest reserve. A total of 36 plots were installed throughout the study area. In each plot, all woody plants encountered were identified and counted and their circumference measured at 1.30 m above the ground, with individuals smaller than 1.5 m considered as offshoots. Species identification was done on-site for some species and for others, samples were collected for later identification by the research team in the wildlife school herbarium using similarity traits. The botanical nomenclature used was that of the Angiosperm Phylogeny Group IV[13].

Data analysis: The data from the floristic surveys were used to evaluate floristic diversity through the specific richness and diversity in genera and families. The structure of the tree stand was evaluated using basal area, density, Shannon's diversity index and Pielou's equitability. Ecological parameters such as the relative frequency, relative dominance and relative density of each species. This method aims at obtaining their importance through the IVI (Importance Value Index)[14].

The basal area of the stand (G) is the sum of the sections of the tree trunks. Using the diameter of individuals, the basal area is given by the equation used by Adjonou *et al.*[15], which states:

$$G = \frac{\sum \pi d^2}{4}$$

where, d is the diameter at 1.30 m.

The stand density (D) corresponds to the number of stems per hectare according to the formula:

$$D = N/S$$

The diversity index of Shannon:

$$H = -\Sigma P \log_2 P$$

where, P is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N) is derived from Shannon[16].

Piélou's equitability index translates the degree of diversity reached concerning the theoretical maximum[17]. It is expressed by the following formula:

$$R = H/H'max = H/\log_2 S$$

Where:

H = Shannon index
H'max = Maximum diversity or the equi frequency
S = Species richness
R = Piélou equitability between 0 and 1

The importance value Curtis:

$$IVI (\%) = Fr+Dr+Gr$$

Where:

Fr = Relative frequency
Dr = Relative density
Gr = Relative dominance

The IVI varies between 0 and 300%.

The biological types adapted to tropical regions adopted include mesophanerophytes (Msph), microphanerophytes and nanophanerophytes (Nnph). The phytogeographic types adopted correspond to the major chronological subdivisions of Lebrun and Stork[18]. modified by White in 1986 and accepted for Africa. These were species with a wide geographical distribution: Cosmopolitan (Cosm), pantropical (Pan), paleo-tropical (Pal), species with a distribution limited to the African continent such as African multi-regional (PRA) and afro-tropical (At) and connecting species like Sudan-Zambezian (SZ).

Statistical analysis: The data collected in the field was processed and classified in an Excel spreadsheet to produce the histograms. The software Stat Graphics Plus 5.0 was used for the analysis of variance by the Duncan's Test at the 5% threshold to compare the significance level between the various parameters, while XLSTAT was used for principal components analysis (PCA) and the hierarchical ascending classification (HAC).

RESULTS

Floristic composition and specific diversity: A total of 2174 individuals belonging to 29 species, 24 genera and 14 families were inventoried. The most important families according to the importance value of families (FIV) in the reserve were Fabaceae (99.60%), Myrtaceae (56.87%), Combretaceae (41.17%), Rhamnaceae (27.21%) and Balanitaceae (15.02%) (Table 1).

Table 1: Index of ecological importance value of families (%)

Families	NE	NG	Dr	Gr	Fr	FIV
Annonaceae	1	1	0.01	0.06	2.56	2.64
Apocynaceae	1	1	0.41	0.25	2.56	3.23
Balanitaceae	1	1	2.24	2.53	10.26	15.02
Combrétaceae	5	4	11.52	16.83	12.82	41.17
Ebénaceae	1	1	5.19	0.31	5.56	8.07
Fabaceae	9	7	36.22	50.55	12.82	99.60
Lamiaceae	1	1	0.15	0.06	2.56	2.78
Malvaceae	1	1	2.17	0.18	7.69	10.04
Méliaceae	1	1	5.05	2.34	10.26	17.65
Moraceae	2	1	2.93	0.25	5.13	8.30
Myrtaceae	2	2	29.25	14.80	12.82	56.87
Rhamnaceae	2	1	2.80	11.59	12.82	27.21
Rubiaceae	1	1	0.22	0.12	2.56	2.91
Sapotaceae	1	1	1.84	0.12	2.56	4.52
Total	29	24	100.00	100.00	100.00	300.00

NE: Number of species, NG: Number of genera, Fr: Relative frequency, Dr: Relative density, Gr: Dominance and FIV: Family importance value index

Table 2: Index of the ecological importance of families according to villages (%)

	Bangay Daba						Gouloum						Pologozom					
Families	NG	NE	Dr	Gr	Fr	FIV	NG	NE	Dr	Gr	Fr	FIV	NG	NE	Dr	Gr	Fr	FIV
Annonaceae	1	1	3.12	0.04	0.24	3.40	0	0	0	0	0	0	0	0	0	0	0	0
Apocynaceae	1	1	6.25	0.60	0.48	7.33	1	1	11.5	0.01	0.15	11.7	0	0	0	0	0	0
Balanitaceae	1	1	12.5	3.04	3.85	19.3	1	1	15.3	2.54	3.80	21.7	1	1	4.16	1.70	2.10	7.97
Combrétaceae	4	5	12.5	10.3	22.2	45.8	3	4	3.84	9.98	5.23	18.9	3	4	12.5	8.74	5.46	26.7
Ebénaceae	1	1	6.25	0.55	0.36	7.16	1	1	15.3	7.60	0.31	23.3	1	1	16.6	0.04	0.14	16.8
Fabaceae	7	9	12.5	36.8	34.4	83.7	6	8	15.3	44.8	65.5	114	7	9	4.16	48.3	58.2	110
Lamiaceae	1	1	3.12	0.22	0.12	3.47	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	1	1	3.12	0.90	0.12	4.15	0	0	0	0	0	0	1	1	12.5	0.05	0.14	12.6
Méliaceae	1	1	9.37	6.83	3.12	19.3	1	0	15.3	6.33	2.69	24.4	1	1	12.5	9.14	3.22	24.8
Moraceae	1	2	6.25	4.36	0.48	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	2	2	12.5	30.3	22.9	65.8	1	1	15.3	27.1	17.4	59.9	1	1	16.6	29.2	24.8	70.7
Rhamnaceae	1	2	9.37	3.13	11.3	23.8	1	2	15.3	1.33	4.44	21.1	1	2	16.6	2.35	5.61	24.6
Rubiaceae	0	0	0	0	0	0	1	1	3.84	0.34	0.31	4.51	1	1	4.16	0.32	0.28	4.77
Sapotaceae	1	1	3.12	2.73	0.24	6.10	0	0	0	0	0	0	0	0	0	0	0	0
Total	22	28	100	100	100	300	16	20	100	100	100	300	17	21	100	100	100	300

NE: Number of species, NG: Number of genera, Fr: Relative frequency, Dr: Relative density, Gr: Dominance and FIV: Family importance value index

According to the villages, the most dominant families following the values of the ecological importance index recorded in Table 2 show Fabaceae (83.7, 114 and 110%), Myrtaceae (65.8, 59.9 and 70.8%) and Combretaceae (45.8, 18.9 and 26.7%), respectively in the villages Bangay Daba, Gouloum and Pologozom.

Among the species, the most important according to the importance value index, the *Eucalyptus camaldulensis* (50.28%) which is the most dominant followed by some species with intermediate values: *Piliostigma thonningii* (38.48%), *Acacia albida* (27.21%), *Tamarindus indica* (22.87%), *Combretum glutinosum* (21.23%), *Ziziphus mauritiana* (19.74%) *Anogeissus leiocarpus* (15.29%), *Acacia seyal* (13.36%) and *Azadirachta indica* (12.46%) (Table 3).

The most dominant species based on their ecological importance index values were represented as follows in Table 4: *Eucalyptus camaldulensis* (65.1%), *Combretum glutinosum* (23.4%), *Tamarindus indica* (22.00%) and *Acacia albida* (21.8%) in Bangay Daba village, *Acacia albida* (62.27%), *Eucalyptus camaldulensis* (53.9%), *Piliostigma thonningii* (32.10%) and *Tamarindus indica* (28.5%) in Gouloum and *Eucalyptus camaldulensis* (61.9%), *Acacia albida* (58.5%), *Piliostigma thonningii* (28.1%) and *Tamarindus indica* (27%) in Pologozom.

Specific richness and floristic diversity of villages and the plots: Species richness varies from 19 to 28 species in the villages and from 19 to 21 species in the different plots in the reserve. The village Bangay Daba 28 species is richer in species than Gouloum 20 and Pologozom 19 species (Table 5). Plots T1 and T2 are richer in 20 and 21 species than plots T0 and T3, 19 species each (Table 6). Floristic diversity indices vary

Table 3: Ten dominant species according to the ecological importance value index (%)

Species	Dr	Gr	Fr	IVI
Acacia albida	11.08	9.80	6.33	27.21
Acacia seyal	5.12	1.91	6.33	13.36
Anogeissus leiocarpa	8.69	1.54	5.06	15.29
Azadirachta indica	5.05	2.34	5.06	12.46
Balanites aegyptiaca	2.24	2.53	5.06	9.83
Combretum glutinosum	2.13	12.76	6.33	21.23
Eucalyptus camaldulensis	29.22	14.73	6.33	50.28
Piliostigma thonningii	2.37	29.78	6.33	38.48
Tamarindus indica	15.80	0.74	6.33	22.87
Ziziphus mauritiana	2.07	11.34	6.33	19.74
Others	16.21	12.53	40.51	69.25

Dr: Relative density, Gr: Relative dominance, Fr: Relative frequency and IVI: ecological importance value index

Table 4: Ten dominant species based on the ecological importance value index according to villages (%)

	Bangay Daba				Gouloum				Pologozom			
Species	Dr	Gr	Fr	IVI	Dr	Gr	Fr	IVI	Dr	Gr	Fr	IVI
Acacia albida	5.79	11.1	4.93	21.8	9.30	19.9	33.4	62.27	7.84	21.8	28.8	58.5
Acacia seyal	5.79	6.98	2.28	15.1	9.30	2.28	2.85	14.4	7.84	3.05	2.80	13.7
Anogeissus leiocarpa	5.79	7.03	2.40	15.2	9.30	9.72	1.58	11.3	7.84	8.60	1.54	17.9
Azadirachta indica	4.34	6.83	3.12	14.3	9.30	6.33	2.69	18.3	7.84	9.14	3.22	20.2
Balanites aegyptiaca	5.79	3.04	3.85	12.6	4.65	2.54	3.80	11.0	5.88	1.70	2.10	9.68
Combretum glutinosum	5.79	2.26	15.4	23.4	4.65	0.03	0.79	5.47	3.92	0.04	0.84	4.80
Eucalyptus camaldulensis	5.79	30.3	22.8	651	9.30	27.1	17.4	53.9	7.84	29.2	24.8	61.9
Piliostigma thonningii	5.79	1.03	13.1	19.9	9.30	0.74	22.0	32.1	7.84	0.68	19.6	28.1
Tamarindus indica	2.89	14.1	1.08	22.0	6.97	20.1	1.42	28.5	5.88	19.7	1.40	27.0
Ziziphus mauritiana	4.34	2.04	10.8	17.2	6.97	0.23	3.96	11.1	7.84	0.30	4.76	12.9
Others	48.9	15.2	20.2	84.3	20.9	11.03	10.11	42.0	29.4	5.79	10.1	45.2

Dr: Relative density, Gr: Relative dominance, Fr: Relative frequency and IVI: Ecological importance value index

Table 5: Diversity index values according to villages

	Bangay Daba	Gouloum	Pologozom
S	28	20	19
H'	2.94	2.22	2.33
Q	0.88	0.74	0.79

S: Species richness, H': Shannon index and Q: Pielou equitability

Table 6: Diversity index values according to plots

	T0	T1	T2	T3
S	19	20	21	19
H'	1.21	1.97	2.15	2.33
Q	0.41	0.66	0.70	0.79

T0: Plot located in the center of the forest reserve, T1: Plot located 500 m from T0, T2: Plot located 500 m from T1 and T3: Plot located 500 m from T2, S: Species richness, H': Shannon index and Q : Pielou equitability

among villages and plots. The Shannon diversity indices and Piélou equitability were about 2.94, 2.22, 2.33 and 0.88, 0.74, 0.79, respectively for Bangay Daba, Gouloum and Pologozom. For the plots, T3 and T2 are the most diverse with Shannon index values of 2.33 and 2.15 and Pielou equitability of 0.79 and 0.70. Plot T0 is the least diverse with a Shannon index value of 1.21 and a Pielou equitability of 0.41. Pielou's equitability values of 0.41 and 0.79. The analysis of variance detects a significant difference between the species richness, Shannon index and Pielou equitability at the 5% threshold ($p = 0.000$), according to villages and plots.

Structural characteristics of the forest reserve stand: The reserve has an average density of 60.38 ind ha^{-1} for a basal area of 2.62 m^2 ha^{-1}. The trees have an average diameter of 6.73±8.80 cm and an average height of 3.42±3.44 m.

Table 7: Density and basal area of stand species

Species	D (ind ha^{-1})	BSA (m^2 ha^{-1})	Species	D (ind ha^{-1})	BSA (m^2 ha^{-1})
Acacia albida	12.72	0.46	*Ficus platyphylla*	0.02	0.00
Acacia hockii	0.75	0.09	*Ficus sycomorus*	0.08	0.00
Acacia seyal	1.58	0.10	*Gardenia aqualla*	0.11	0.00
Adansonia digitata	0.05	0.00	*Guiera senegalensis*	0.22	0.00
Anogeissus leiocarpus	1.13	0.22	*Hexalobus monopetalus*	0.05	0.00
Azadirachta indica	1.83	0.19	*Piliostigma thonningii*	10.77	0.02
Balanites aegyptiaca	1.97	0.70	*Psidium guajava*	0.02	0.00
Bauhinia rufescens	0.61	0.00	*Senna siamea*	0.38	0.04
Calotropis procera	0.13	0.00	*Tamarindus indica*	0.75	0.47
Cinera glomeratum	3.27	0.00	*Terminalia glaucescens*	0.63	0.00
Combretum collinum	1.27	0.00	*Vitellaria paradoxa*	0.05	0.02
Combretum glutinosum	3.86	0.02	*Vitex doniana*	0.02	0.00
Diospyros mespiliformis	0.16	0.06	*Ziziphus mauritiana*	4.12	0.02
Entada africana	0.05	0.00	*Ziziphus spina christi*	0.36	0.03
Eucalyptus camaldulensis	13.19	0.75			

D: Density and BSA: Basal area

Stand structure of the forest reserve: Table 7 showed the highest species densities in the reserve were recorded in *Eucalyptus camaldulensis* (13.19 ind ha^{-1}), *Acacia albida* (12.72 ind ha^{-1}), *Piliostigma thonningii* (10.77 ind ha^{-1}) and *Ziziphus mauritiana* (4.12 ind ha^{-1}) and the lowest in *Vitex doniana*, *Vitellaria paradoxa*, *Psidium guajava* and *Ficus platyphylla* each with a density value of (0.02 ind ha^{-1}). *Eucalyptus camaldulensis* (0.75 m^2 ha^{-1}), *Acacia albida* (0.46 m^2 ha^{-1}), *Piliostigma thonningii* (0.02 m^2 ha^{-1}) and *Combretum glutinosum* (0.02 m^2 ha^{-1}) have the highest basal area values and the lowest in *Hexalobus monopetalus* (0.00 m^2 ha^{-1}), *Psidium guajava* (0.00 m^2 ha^{-1}) and *Entada africana* (0.00 m^2 ha^{-1}).

Stand structure of the forest reserve according to villages: According to the villages, the species with high density are *Eucalyptus camaldulensis* (15.82 ind ha^{-1}), *Combretum glutinosum* (10.66 ind ha^{-1}), *Piliostigma thonningii* (9.08 ind ha^{-1}) in Bangay Daba, *Acacia albida* (17.58 ind ha^{-1}), *Piliostigma thonningii* (11.58 ind ha^{-1}), *Eucalyptus camaldulensis* (9.16 ind ha^{-1}) at Gouloum and *Acacia albida* (17.16 ind ha^{-1}), *Eucalyptus camaldulensis* (14.75 ind ha^{-1}), *Piliostigma thonningii* (11.66 ind ha^{-1}) in Pologozom show in the Table 8. For basal area values, the largest are recorded for *Eucalyptus camaldulensis* (2.14 m^2 ha^{-1}), *Tamarindus indica* (1.06 m^2 ha^{-1}), *Acacia albida* (0.79 m^2 ha^{-1}), in Bangay Daba, *Eucalyptus camaldulensis* (1.82 m^2 ha^{-1}), *Tamarindus indica* (1.35 m^2 ha^{-1}), *Acacia albida* (1.33 m^2 ha^{-1}), in Gouloum and *Eucalyptus camaldulensis* (2.09 m^2 ha^{-1}), *Acacia albida* (1.56 m^2 ha^{-1}), *Tamarindus indica* (1.41 m^2 ha^{-1}) in Pologozom.

Principal component analysis of villages and species dispersion: The principal component variable (PCA) analysis (Fig. 1) shows that the three villages are positively correlated, in isolation, we admit that these villages are grouped into 2 sections. Section 1 constitutes all villages, section 2 includes Gouloum and Pologozom villages (Fig. 1a). With each other and the different species are also positively correlated with each other in three axes F1, F2, F1 and F2 of analysis have varied percentages, respectively 81.92, 17.53 and 99.46%. The species are grouped at the origin forming a cloud of points, this shows that the species are diversified in the different villages (Fig. 1b). Despite this, *Acacia albida*, *Piliostigma thonningii*, *Eucalyptus camaldulensis*, *Ziziphus mauritiana*, *Combretum glutinosum* and *Cinera glomeratum* show a very different scattering from the other species, these discrepancies are justified by their abundance, density and very high diversity in the different villages.

Rank-abundance dendrogram of species in the reserve: The characteristics of the three floristic groups present were specified at 55.93% metric dissimilarity: Euclidean distance (Fig. 2). Group 1 includes four species: *Acacia albida*, *Combretum glutinosum*, *Eucalyptus camaldulensis* and *Ziziphus mauritiana*. Group 2, which is the most important in terms of species, is composed of 24 species including *Acacia hockii*, *Acacia seyal*, *Adansonia digitata*, *Anogeissus leiocarpus*, *Azadirachta indica*, *Balanites aegyptiaca*, *Bauhinia rufescens*, etc. The third group consists of the species *Piliostigma thonningii*.

Diameter structure of the woody stand in the reserve: The distribution of individuals by diameter classes shows an "L" shape. The histogram below shows a strong representation of small-diameter trees in the lower-diameter classes and a rarity of large-diameter trees in the upper classes (Fig. 3).

Table 8: Density and basal area of species according to villages

	Bangay Daba		Gouloum		Pologozom		Mean	
Species	D (ind ha^{-1})	BSA (m^2 ha^{-1})	D (ind ha^{-1})	BSA (m^2 ha^{-1})	D (ind ha^{-1})	BSA (m^2 ha^{-1})	D (ind ha^{-1})	BSA (m^2 ha^{-1})
Acacia albida	3.41	0.79	17.58	1.33	17.16	1.56	12.72^{b}	1.23^{c}
Acacia hockii	2.08	0.03	0.08	0.00	0.08	0.00	0.75^{k}	0.01^{n}
Acacia seyal	1.51	0.49	1.50	0.15	1.66	0.21	1.56^{h}	0.28^{f}
Adansonia digitata	0.08	0.06	0.00	0.00	0.08	0.00	0.05^{u}	0.02^{m}
Anogeissus leiocarpa	1.66	0.49	0.83	0.65	0.91	0.61	1.13^{i}	0.58^{d}
Azadirachta indica	2.16	0.48	1.41	0.42	1.91	0.65	1.83^{h}	0.52^{e}
Balanites aegyptiaca	2.66	0.21	2.00	0.17	1.25	0.12	1.97^{g}	0.17^{h}
Bauhinia rufescens	0.58	0.00	0.66	0.00	0.58	0.00	0.61^{m}	0.00^{o}
Calotropis procera	0.33	0.04	0.08	0.00	0.00	0.00	0.14^{r}	0.01^{n}
Cinera glomeratum	6.00	0.03	1.91	0.00	1.91	0.00	3.27^{f}	0.01^{n}
Combretum collinum	1.33	0.05	1.08	0.00	1.41	0.00	1.27	0.02^{m}
Combretum glutinosum	10.66	0.16	0.41	0.00	0.50	0.00	3.86^{e}	0.05^{l}
Diospyros mespiliformis	0.25	0.03	0.16	0.51	0.08	0.00	0.16^{q}	0.18^{g}
Entada africana	0.08	0.00	0.00	0.00	0.08	0.00	0.05^{u}	0.00^{o}
Eucalyptus camaldulensis	15.82	2.14	9.16	1.82	14.75	2.09	13.24^{a}	2.02^{a}
Ficus platyphylla	0.08	0.14	0.00	0.00	0.00	0.00	0.03^{v}	0.05^{l}
Ficus sycomorus	0.25	0.16	0.00	0.00	0.00	0.00	0.08^{t}	0.05^{l}
Gardenia aqualla	0.00	0.00	0.16	0.02	0.16	0.02	0.11^{s}	0.01^{n}
Guiera senegalensis	0.66	0.00	0.00	0.00	0.00	0.00	0.22^{p}	0.00^{o}
Hexalobus monopetalus	0.16	0.00	0.00	0.00	0.00	0.00	0.05^{u}	0.00^{o}
Piliostigma thonningii	9.08	0.07	11.58	0.04	11.66	0.04	10.77^{c}	0.05^{l}
Psidium guajava	0.08	0.00	0.00	0.00	0.00	0.00	0.03^{v}	0.00^{o}
Senna siamea	0.25	0.09	0.33	0.10	0.58	0.19	0.39^{n}	0.13^{i}
Tamarindus indica	0.74	1.06	0.75	1.35	0.83	1.41	0.77^{j}	1.27^{b}
Terminalia glaucescens	1.08	0.00	0.41	0.00	0.41	0.00	0.63^{l}	0.00^{o}
Vitellaria paradoxa	0.16	0.19	0.00	0.00	0.00	0.00	0.05^{u}	0.06^{k}
Vitex doniana	0.08	0.01	0.00	0.00	0.00	0.00	0.03^{v}	0.00^{o}
Ziziphus mauritiana	7.50	0.14	2.08	0.01	2.83	0.02	4.14^{d}	0.06^{k}
Ziziphus spina christi	0.33	0.07	0.25	0.07	0.50	0.14	0.36^{o}	0.09^{j}
Mean	2.38^{a}	0.23^{b}	1.80^{c}	0.22^{c}	2.04^{b}	0.24^{a}	2.04	0.24

D: Density, BSA: Basal area, Numbers in a set of a column or rows with the same letter are not different at the 5% threshold

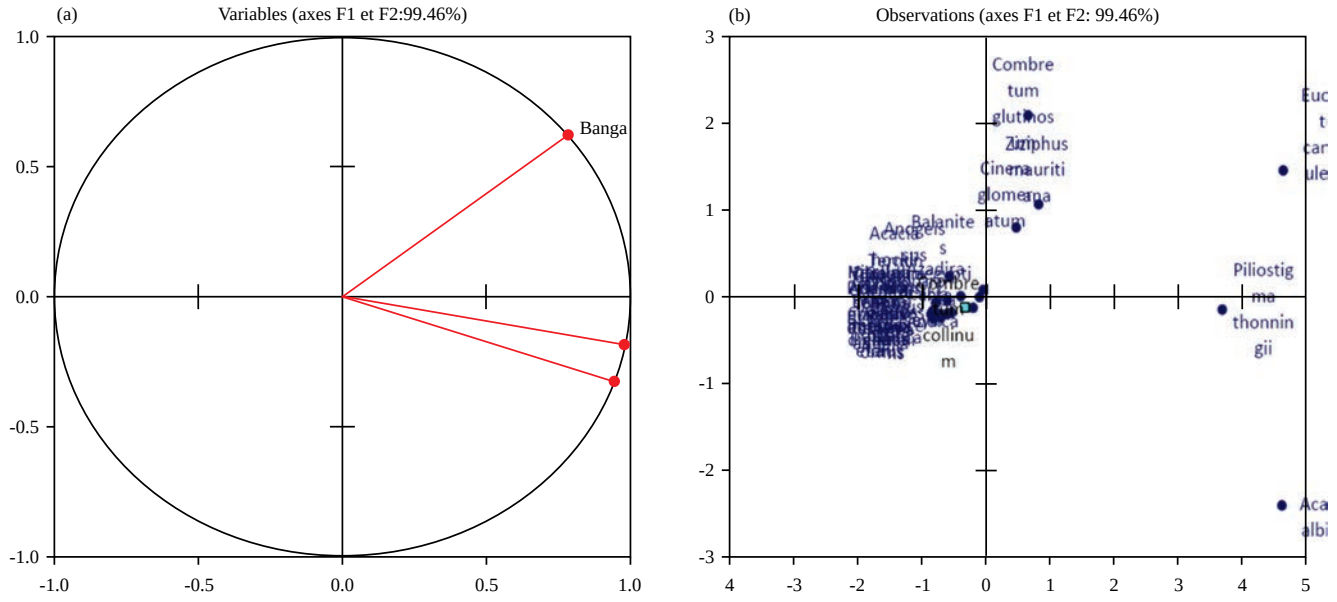

Fig. 1(a-b): Correlation between (a) Villages and (b) Species dispersal according to the principal component variable

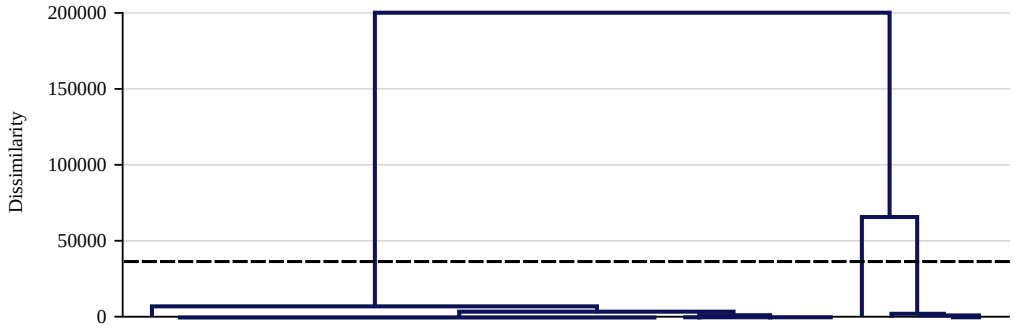

Fig. 2: Dendrogram of groupings of species encountered in the reserve

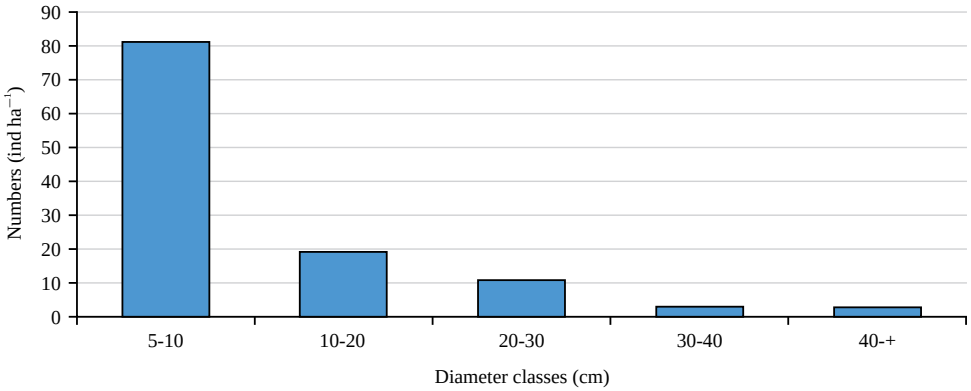

Fig. 3: Distribution of individuals by diameter classes

Diameter structure of the reserve's woody stand according to the villages: The distributions of individuals by diameter class also show an "L" shape in their entirety, depending on the village. The histogram shows a high representation of small-diameter trees in the lower-diameter classes and a rarity of large-diameter trees in the upper classes (Fig. 4) in all villages.

Vertical structure of the woody stand in the reserve: The distribution of individuals by height class shows an "L" shape. The representative histogram shows a strong representation of individuals of lower height in the lower height classes and a scarcity of tall trees in the upper classes (Fig. 5). The woody vegetation has fewer tall trees.

Vertical structure of the woody stand in the reserve according to the villages: Depending on the village, the distribution of individuals by height class presents an "L" shape. The characteristic histogram reveals a strong representation of individuals of lesser height in the lower height classes and a weak presence of tall trees in the higher classes (Fig. 6).

Spectrum of biological and phytogeographic types of the reserve stand: The spectrum of biological types (Fig. 7) shows that the woody flora of the forest reserve is dominated by microphanerophytes (62.06%) followed by mesophanerophytes (34.48%). Nanophanerophytes represent only 3.44% of biological types. The distribution of phytogeographic types (Table 9) showed that the woody flora is dominated by multi-regional species at 51.72% followed by pantropical species at 27.58%. The least represented phytogeographic types are paleo-tropical, afro-tropical and sudano-zambezian (SZ) species. Cosmopolitans are absent (Cosm). The analysis of variance detects a significant difference between the biological and phytogeographical types at the 5% threshold ($p = 0.035$).

Spectrum of biological and phytogeographical types of the reserve stand and according to the villages: According to the villages, the spectrum of biological types (Fig. 8) showed that the woody flora is dominated by microphanerophytes 57.14, 75 and 66.66% followed by mesophanerophytes 39.29, 25 and 33.33% in the villages of Bangay Daba and Pologozom, respectively. Nanophanerophytes are represented only in Bangay Daba with 3.57% of biological types. The

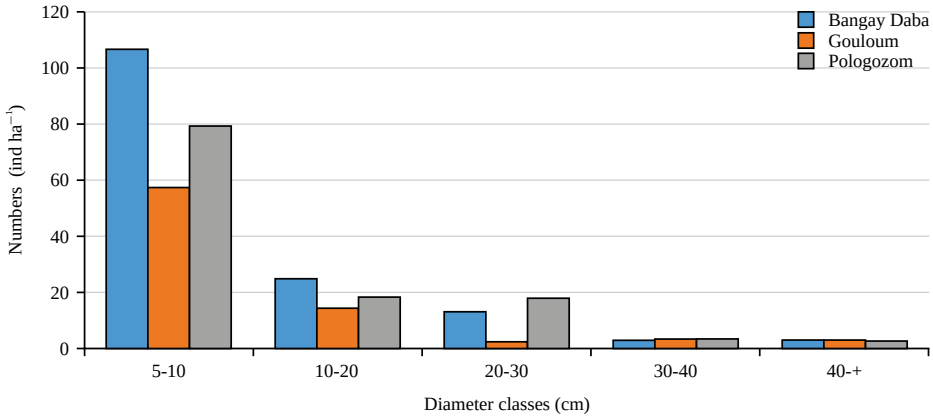

Fig. 4: Distribution of individuals by diameter classes according to villages

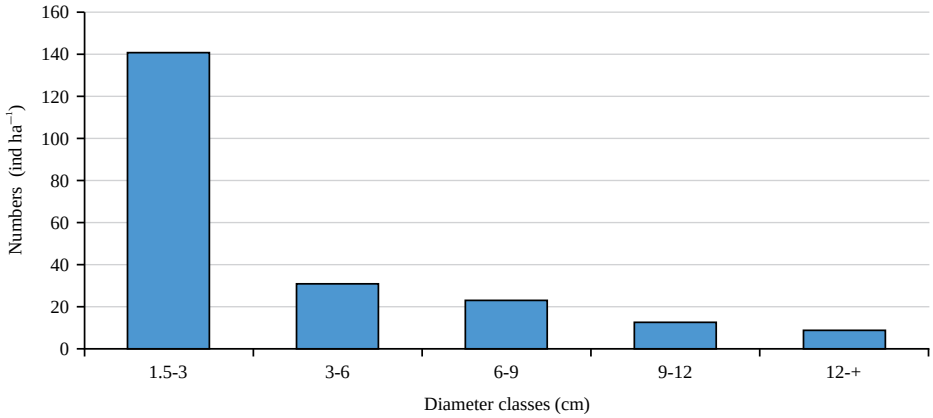

Fig. 5: Distribution of individuals by height classes

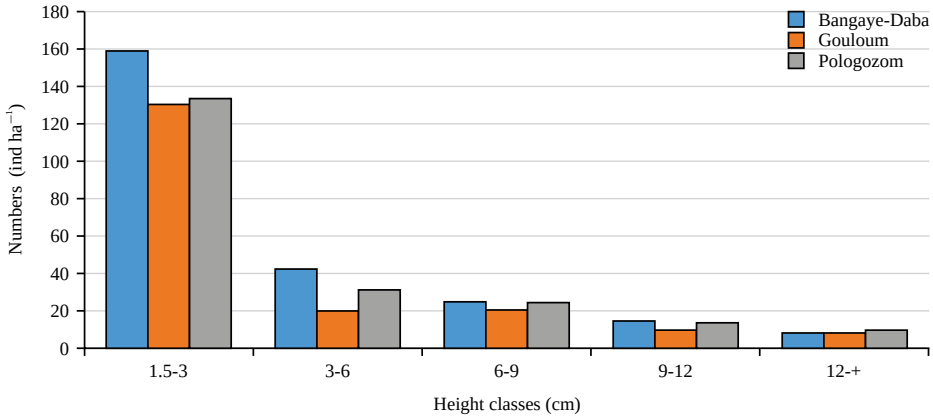

Fig. 6: Distribution of individuals by height classes according to villages

distribution of phytogeographic types (Table 10) showed the superiority of multi-regional species 50, 36.84 and 47.61% followed by pantropical species 28.57, 36.84 and 28.57% for the villages Bangay Daba, Gouloum and Pologozom, respectively. The least represented phytogeographic types are the paleo-tropical, afro-tropical and Sudan-Zambezian species. Cosmopolitan species are absent. The analysis of variance detects a significant difference between the biological and phytogeographical types at the 5% threshold ($p = 0.000$) according to villages.

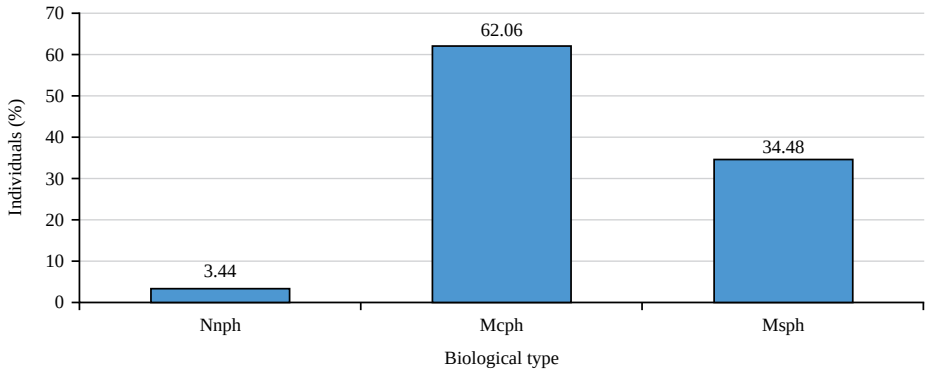

Fig. 7: Spectrum of biological types in the stand

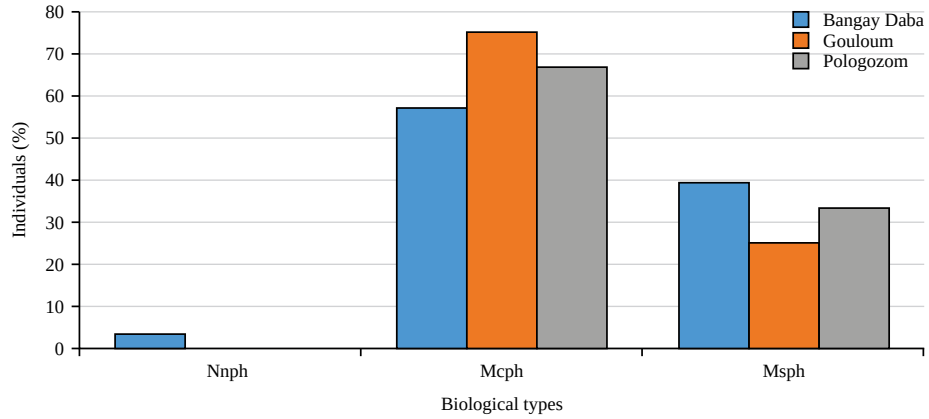

Fig. 8: Spectrum of biological types of the stand according to the villages

Table 9: Distribution of phytogeographic types in the reserve

Phytogeographic types		Numbers of species	Percentage
	Cosm	0	0.00
ELD	Pal	3	10.34
	Pan	8	27.58
	Total	9	37.93
EDLA	PRA	15	51.72
	At	1	3.44
	Total	16	55.17
EL	SZ	2	6.89
	Total	2	6.89

ELD: Widely distributed species, EDLA: Species with a distribution limited to the African continent, EL: Link species; At: Afrotropical, Cos: Cosmopolitan, Pal: Paleotropical, Pan: Pantropical, PRA: African multi-regional and Sz: Sudan-Zambezian

Table 10: Distribution of phytogeographic types in the reserve

		Bangay Daba		Gouloum		Pologozom	
Phytogeographic types		NE	P(%)	NE	P(%)	NE	P(%)
	Cosm	0	0	0	0	0	0
ELD	Pal	3	10.71	3	15.78	3	14.28
	Pan	8	28.57	7	36.84	6	28.57
	Total	11	39.28	10	52.63	9	42.85
ELDA	PRA	14	50	7	36.84	10	47.61
	At	1	3.57	1	5.26	1	4.76
	Total	15	53.57	8	42.10	11	52.38
EL	SZ	2	7.14	1	5.26	1	4.76
	Total	2	7.14	1	5.26	1	4.76

ELD: Species with wide distribution, EDLA: Species with distribution limited to the African continent, EL: Link species, At: Afrotropical, Cos: Cosmopolitan, Pal: Paleotropical, Pan: Pantropical, PRA: African multi-regional, Sz: Sudan-Zambezian, Ne: Number of species and P: Percentage

DISCUSSION

The floristic richness in the study area lists 29 species, 24 genera and 14 families. It has a poor floristic composition. This low floristic richness is largely due to anthropogenic pressures on the woody plants, which in some cases eliminates a species, genera, or family. It is lower than that obtained by some work done in the forests in North Cameroon[19-21] located in the same agro-ecological zone. The variability of the species richness of the woody stand in these different reserves would depend on abiotic conditions (nature and texture of the soil, interactions between species in each environment) and human activities.

The Fabaceae (99.60%), Myrtaceae (56.87%) and Combretaceae (41.17%) are the most important families according to the value of the Family Importance Index (FIV), this means that the area studied has a dry climate and could in part be explained by the mode of dissemination of these species. Fabaceae, some of which are forages, with zoochorous seeds disseminated by herbivores that consume them, Combretaceae are indeed characterized by their winged fruits easily disseminated by the wind. The Combretaceae observed can also be attributed to their ability to regenerate naturally by seedlings, by suckering and/or by stump rejections. All these families are composed of species that are notably resistant to the lack and insufficiency of rainfall, but also to the high-temperature characteristics of the study area. These results are in line with the work in other forests in tropical Africa[22,23].

The Shannon diversity index varies from 2.15 to 2.94 and the Pielou equitability from 0.41 to 0.79. These values mean that the area is less diverse, with a few species making up the flora. This shows low diversity, which is due to human activities and the vagaries of the climate. The result obtained is comparable to the results of work carried out by others in similar areas[24-26].

The dendrometric characteristics of the reserve, population density and basal area are equal to 60.38 ind ha^{-1} and 2.62 m^2 ha^{-1}, respectively. This shows that the area is poor individuals per hectare and also the surface area occupied at the base of the trunk. These low density and basal area would be due to factors abiotic, soils, precipitation and competition that determine the density and growth of the vegetation about biotic parameters, agricultural clearing, anarchic removal of wood exerted on the woody plant on the forest reserve by the riparian populations[27-29]. According to Tchobsala and Mbolo[30], Tchobsala *et al.*[31], demographic growth accompanied by certain modes of exploitation leads to pressure on the land with a consequent disturbance of the environmental balance.

The distribution of individuals by diameter and height classes shows an "L" structure characterized by a digital superiority of individuals from small diameter or height classes to large ones. This demonstrates that the flora is made up of individuals of small height and diameter and also ensures that the renewal capacity of the woody stratum is possible with the proportion of future stems. These results were in line with those of Tchobsala *et al.*[10,32], Sinsin[33] and Kodji *et al.*[34] where they state that this was considered as an index of vegetation degradation hence the loss of its specificity.

Biological types are dominated by microphanerophytes and mesophanerophytes. They characterize the plant formations at low individual heights and justify that the forest reserve is in the middle of the sudano-sahelien region. Mbaiyetom *et al.*[35] and Jonathan *et al.*[36] also shows the same results. These results supported the statement of Schmidt *et al.*[37], that biological types reflect vegetation structures and multiple environmental conditions but also varied environmental conditions. Tchobsala *et al.*[38] also pointed out the high representation of mesophanerophytes and microphanerophytes and justified that the studied area is savannah.

Phytogeographic types in the reserve studied, are represented by species with a multi-regional distribution followed by pantropic are dominant. This means that the reserve has undergone changes in its specific composition. These results were comparable to those of Sinsin *et al.*[39] and Tchobsala and Adamou[40], who record the dominance of these phytogeographic types in the Ngaoundéré area. This result confirmed the statement of Sinsin *et al.*[39] that the phytogeographic types provide information on changes in plant cover and the high proportion of species with wide distribution is an index of disturbance and indicates that the flora is losing its specificity. This study is a contribution to sustainable management, providing basic data for the development of conservation strategies and sustainable management of forest resources. The recommendation is aimed at two poles: Firstly, the reserve's residents must be concerned about future generations in the management of the forest resources and secondly, decision-makers are called upon to set up rational and sustainable land management policies based on our forestry results. The limitation of this study is that it did not address local use by residents and the state of regeneration of woody plants in this reserve and did not include a soil survey.

CONCLUSION

This study of the Mayo-Oulo Forest Reserve show that woody vegetation is disturbed by pressures of various human and climatic, based on floristic inventories, an essential element for knowledge of the flora and to apprehend the area's potential. The results show a poor floristic diversity, with a dominance of the Fabaceae families and the low diversity index with biological and phytogeographical types characterizing savannahs. Extending the study on local use by residents, the state of regeneration of woody plants and the soil to better define its characteristics and propose palliative measures for this threatened protected area.

SIGNIFICANCE STATEMENT

The study of the floristic characteristics, diversity and structure of the woody vegetation of the reserve has contributed to improving the knowledge by highlighting its floristic composition. The result of this study shows that the forest reserve is floristically poor and, as a result of human pressures. it supplied basic data for the development of conservation strategies and sustainable management of forest resources.

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