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Diversity and floristic composition of woody plants in the Mbalmayo Forest Reserve (Centre, Cameroon)

MSM. Caroline[1], MD. Liliane[1], NJ. Romain[*2], KYP. Christian[3]

[1]*Department of Plant Biology, Faculty of Science, University of Dschang, Dschang, Cameroon*

[2]*Institute of Agricultural Research for Development (IRAD), Yaoundé, Cameroon*

[3]*Ministry of Forest and Wildlife, West Regional Delegation for Forestry and Wildlife, Bafoussam, Cameroon*

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Abstract

Unlike other countries in the region, Cameroon is already experiencing very significant pressure on land, not only due to demographic factors but also related to the development of economic activities. This study focuses on the characterization of ligneous species in the Mbalmayo forest reserve. Trees having ≥10cm diameter at breast height (D.B.H) were identified and measured in 33 plots (250m x 20m). Species composition, structure, and conservation status of trees were assessed. Results of the study indicated that there were 129 tree species belonging to 100 genera and 33 families. The plot survey assessed the stem density, basal area, diversity indices and importance value index of the tree species having ≥10cm D.B.H. The stem density and basal area of the tree species were 122 stem ha^{-1} and 14.67m^2/ha while, diversity indices, i.e. Shannon-Wiener's diversity (2.59 bits), Simpson's diversity (0.87) and Pielou's evenness (0.85) indicated high diversity. The most abundant families are Fabaceae, Cecropiaceae and Combretaceae, while the most important species are *Gilbertiodendron dewevrei*, *Musanga cecropioides* and *Uapaca* sp. The structural composition based on D.B.H through reverse- J shaped curve indicated higher regeneration and recruitment but removal of trees of large growth classes. *Mansonia altissima*, *Pericopsis elata* and *Prioria balsamifera* are endanger species following IUCN category. This is a consequence of anthropogenic pressures from local populations characterized by illegal logging of timber and the establishment of fields. Maintaining the forest reserve status of this forest ecosystem will imperatively require the development of a management plan that takes into account the needs of all stakeholders.

***Corresponding Author:** Ngueguim Jules Romain ✉ njules_romain@hotmail.com

Introduction

Tropical forests are at the heart of international issues on climate change and biodiversity conservation. The Global Tree Search Database records over 60 000 tree species, of which over 20 000 are on the IUCN Red List and almost 8 000 are listed as globally threatened (IUCN, 2019).

A report by the FAO (2020) indicates that the global area of primary forests has shrunk considerably by more than 80 million hectares since 1990 due to anthropogenic and natural factors. This observation was the subject of discussions at the Rio Earth Summit, which suggested sustainable management, conservation and participatory management as useful options for reducing pressures and preserving forests. In such a context, the conservation of biodiversity has become an imperative for any society falling within the perspective of sustainable development and knowledge of the plant diversity of the species used by the populations is necessary to carry out adequate actions of conservation (Sèwadé, 2017).

In both developing and developed countries, poor people are more dependent on forest resources for their livelihoods such as food and medicine (leaves, roots, fruits, bark and seeds), fodder, shelter, energy, and income generation. Forests also provide other uses such as beautiful landscape, local climate improvement and genetic resources that contribute to forest biodiversity value chains (Zhang and Pearse, 2011; Ngueguim, 2013).

Forests play an important role in controlling the Earth's climate and biodiversity (Mandal *et al.*, 2013). In view of the foregoing, governments have an important role to play in the implementation of forest policies promoting the reconciliation between sustainable management of resources and an improvement in the level of lives of rural people (FAO, 2016).

Cameroon's forests cover an area of 22.5 million hectares, or 46% of the national territory (Ngomin and Mvongo, 2015). They are home to a remarkable diversity of flora and fauna that provide nearly eight million poor Cameroonians living in rural areas with most of their needs (Topa *et al.*, 2010).

These forests are also of significant importance in the national economy. However, they experience many exploitation pressures that emanate from a set of actors with divergent interests, which increases the threats and vulnerability of many species (Ngueguim, 2013). Cameroon's forests are considered today to be the most threatened in the Congo Basin (GFW, 2005) Thus, from 1994, Cameroon will adopt a new forest policy which takes into account international concerns in favor of forest conservation. Cameroon will also choose to convert 30% of its forest cover into a protected area.

The Mbalmayo forest reserve, located in the dense forest zone of Cameroon in an environment subject to strong land pressure with an area of 9700 ha, is therefore part of this forest conservation initiative. Following the growing urbanization and the pressure of local populations on the environment and resources, the government has continued to develop strategies to protect this forest massif against invasion by local populations.

Thus, over time, this reserve has undergone different phases of evolution both in its management and conservation. In 1995, a zoning plan for the reserve was validated by decree n°95/678/PM erecting part of the massif into a teaching forest for the National School of Water and Forests, while other areas were dedicated to the research vocation in which research institutes such as the International Institute of Tropical Agronomy (IITA) and the Agricultural Institute for Research and Development conduct their activities (Temgoua, 2007).

Many tropical forests are under great anthropogenic pressure and require management interventions to maintain the overall biodiversity, productivity, and sustainability (Kumar *et al.*, 2006). The majority of Cameroon's forests, including the reserves, are now threatened by degradation and advancing fragmentation due to the steady increase in local populations (Lawrence and Bierregaard 1997). Understanding tree composition and structure of forest is a vital instrument in assessing the sustainability of the forest, species conservation, and management of forest ecosystems (Kacholi, 2014).

Notwithstanding the pressures exerted by the populations on the reserve, the impacts of these anthropogenic activities on the plant biodiversity within this natural environment remain poorly known. The aim of this study is to improve the knowledge on the floristic diversity, the composition and the structure of the vegetation of this reserve under the anthropogenic pressures, as a tool to help in the development of the site.

Material and methods

Presentation of the study site

The Mbalmayo Forest Reserve was classified in 1947, it covers an area of 9700 hectares, with its center situated at 3.24° latitude north, and 11.30° east longitude. It is characterized by a Guinean bimodal climate with an average annual rainfall ranging between 1600 mm and 1700mm.

The average annual temperature is about 23°C and the average relative humidity is 78%. It is situated at an altitude of 335 meters. The soils are ferralitic and strongly denatured. The natural vegetation of this zone is a transition between semi-deciduous forest and closed evergreen forest (Owana *et al.*, 2008). Administratively, the reserve is bounded to the West and North by the Nyong River, to the South by the So'o River, and to the East by the Mbalmayo - Ebolowa road.

Data collection methods

A total of 7 transects (variable length and 20 m wide) were laid throughout the study area (Fig. 2). About 16.5 ha of the site was sampled and each transect were divided into plots, sizes of 250×20 m, thereby given a total of 33 plots. Within each sample plot, all trees with diameter at breast height (DBH) ≥10cm measured at 1.3 m above the ground were identified, counted, and DBH-recorded. Along each transect, different types of land use were encountered. We can cite among others secondary forests, swamps, fields, fallow and cocoa plantation.

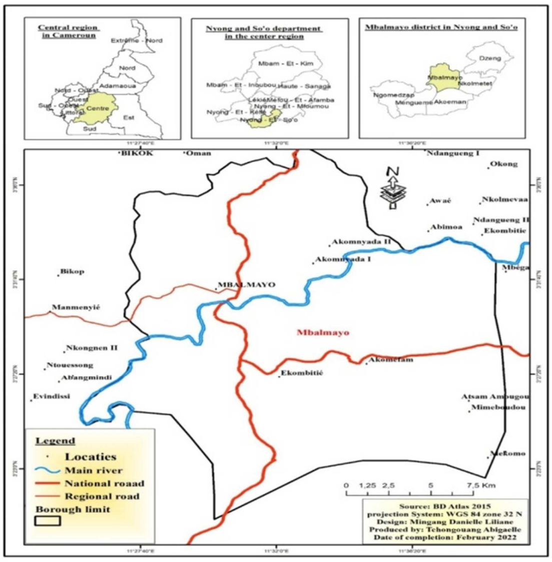

Fig. 1. Map of the study site.

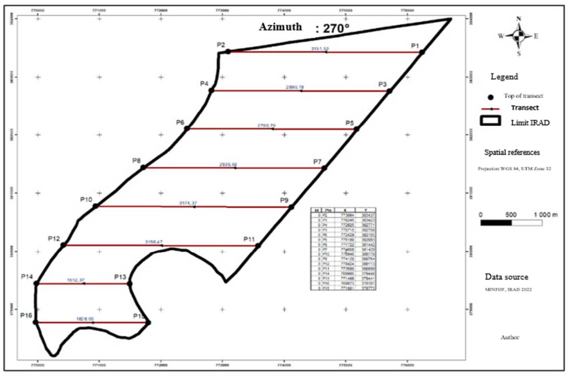

Fig. 2. Layout of transect for the inventory in the study area.

Analysis of field data

Species richness was expressed by the number of observed species in the forest. Shannon-Wiener's, Simpson diversity, and Pielou's evenness were calculated using the software Palaeontological Statistics (PAST) [Eq. No. 10, 11, and 12]. The forest structure was described in terms of tree density (stems/ha), basal area (m2 /ha), and size class distributions. The tree density was calculated using the number of individuals divided by sample area [Eq. No. 2] while the basal area was equal to the total cross-sectional area of all stems measured at breast height [Eq. No. 1]. Eleven tree size or DBH classes were formed, each arranged in 10cm intervals. The dominance of family and species was calculated based on Family Importance Value (FIV) and the Species Importance Value Index (IVI), which indicates the ecological importance of a tree species or family (Husch and Beers, 2003) [Eq. No. 9]. In order to quantify the importance of the types of land use, we have determined the density and the basal area of each type. The IUCN red list allowed us to determine the conservation status of the species inventoried. The IUCN red list is the most comprehensive global inventory of the conservation status of plant and animal species.

The data collected were subjected to statistical analysis using PAST version 4.10 and MS Excel 2017 version. The equations (Eq. No. 1-12) used to calculate the various biological parameters and diversity indices are summarized in Table 1.

Table 1. List of equations used for calculating phytosociological characteristics and biodiversity indices of the vegetation.

Phytosociological attributes	Formula	Parameters unity	Equation no.	References
Basal area/ha (BA)	$BA = \frac{\sum \pi \times D^2/4}{\sum Area\ of\ all\ quadrats} \times 10000$	D= DBH in m Area in ha	1	Shukla and Chandel (2000), Chowdhury *et al.* (2019)
Density (D)	$D = \frac{a}{s}$	a = total no. of individuals of a species in all the quadrats s = total basal area in ha	2	Shukla and Chandel (2000)
Relative density (RD)	$RD = \frac{n}{N} \times 100$	n = Number of individuals of the species N = total no. of individuals of all the species	3	Misra (1968), Dallmeier *et al.* (1992)
Frequency (F)	$F = \frac{c}{b}$	c= total no. of quadrats in which the species occurs b = total no. of quadrats studied	4	Shukla and Chandel (2000)
Relative frequency (RF)	$RF = \frac{Fi}{\sum_{i=1}^{n}(Fi)}$	Fi = frequency of one species	5	Misra (1968), Dallmeier *et al.* (1992)
Abundance (A)	$A = \frac{n}{c}$	n, total no. of individuals of the species c = total no. of quadrats in which the species occurs	6	Shukla and Chandel (2000)
Relative Abundance (RA)	$RA = \frac{Ai}{\sum_{i=1}^{n} Ai}$	Ai = abundance of one species.	7	Shukla and Chandel (2000)
Relative dominance (D)	$D = \frac{\text{Basal area of one specie}}{\text{Total basal area}} \times 100$		8	Hosain *et al.* (2013a), Chowdhury *et al.* (2019)
Importance Value Index (IVI)	$IVI = RD + RA$		9	Dalmeier *et al.* (1992), Shukla and Chandel (2000)
Shannon-Wiener's diversity index (H)	$H = -\sum_{i=1}^{n} PilnPi$	H = Shannon-Wiener's diversity index; Pi = number of individuals of the species/total number of individuals	10	Shannon and Weaver (1963)
Simpson's diversity index (D)	$D = \sum_{i=1}^{n} Pi^2$	Pi = number of individuals of the species/total number of individuals	11	Simpson (1949)
Species (Pielou's) evenness index (E)	$E = \frac{H}{\ln(S)}$		12	Pielou (1963)

Result and discussion

Diversity and abundance of taxa

Woody species diversity and abundance in the study area are presented in Table 2. Based on the result, a total number of two thousand and five (2005) individuals were belonging to 129 tree species, 100 genera and 33 families. Shannon-weiner index of diversity (H'), Pielou's evenness index (E) and Simpson's index (D') of diversity had a value of 2.58, 0.85 and 0.87 respectively, as obtained during this study.

Table 2. Quantitative status of tree population and different diversity indices of tree species for forest reserve.

Category	Values
Numbers (dbh ≥ 10cm)	2005
Density (stems/ha)	122
Number of species	129
Number of genera	100
Number of families	33
Shannon-weiner index (H’)	2.58
Pielou’s evenness index	0.85
Simpson's index	0.87
Average diameter (cm)	31±24.05
Basal area (m²/ha)	14.67

Fig. 3 shows woody species distribution among families in the study area. The family of Fabaceae had twenty-six (26) species while Malvaceae and Meliaceae had 10 species each, Sapotaceae and Ulmaceae (6 species each), Anacardiaceae, Burseraceae, Euphorbiaceae and Annonaceae (5 species each) while Apocynaceae, Irvingiaceae, Moraceae and Phyllanthaceae had 4 species each, respectively.

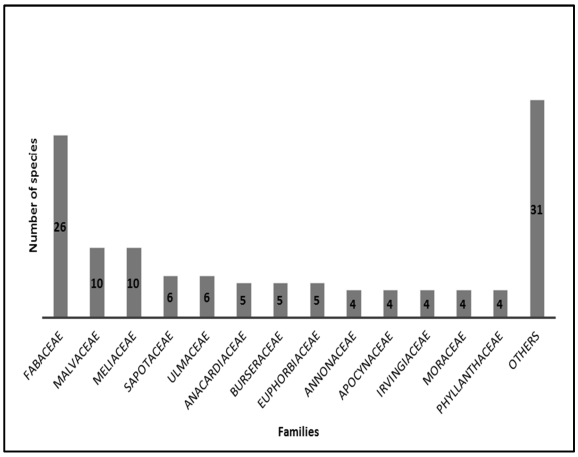

Fig. 3. Species Distribution among Families in the Study Area.

Frequency distribution of woody species and conservation status

The most frequent species in the study area are *Musanga cecropioides* (3.94%), *Terminalia superba* (3.02%), *Uapaca* sp. (3.02%), *Staudtia kamerunensis* (2.76%), *Erythrophleum ivorense* (2.37%) and *Macaranga* sp. (2.23%).

Table 3. List of tree species recorded with their local name, family, relative frequency (RF) and IUCN status (LC = Least Concern; Vu= Vulnerable; DD = Insufficient Data; EN = Endangered; CR = Critically Endangered).

No.	Scientific name	Local name	Family	RF	IUCN status
1	*Afzelia bipindensis*	Doussié	Fabaceae	0,39	Vu
2	*Afzelia pachyloba*	Pachi	Fabaceae	0,26	Vu
3	*Albizia adianthifolia*	Saliemo	Fabaceae	1,84	
4	*Albizia ferruginea*	Iatandza	Fabaceae	0,26	Vu
5	*Alchornea cordifolia*	Aboé	Euphorbiaceae	0,26	LC
6	*Alstonia boonei*	Emien	Apocynaceae	1,45	LC
7	*Amphimas pterocarpoides*	Lati P	Fabaceae	0,53	LC
8	*Annickia chlorantha*	Moambé jaune	Annonaceae	0,26	LC
9	*Anonidium mannii*	Ebom afan	Annonaceae	1,58	LC
10	*Antrocaryon klaineanum*	Onzabili	Anacardiaceae	1,05	LC
11	*Antrocaryon micraster*	Onzabili m	Anacardiaceae	0,13	Vu
12	*Aubrevillea kerstingii*	Kodabéma	Fabaceae	1,31	LC
13	*Aucoumea klaineana*	Okoumé	Burseraceae	0,26	Vu
14	*Autranella congolensis*	Mukulungu	Sapotaceae	0,26	CR
15	*Awegue*	Awegue	N / A	0,39	
16	*Barteria nigritiana*	Mebenga	Passifloraceae	0,39	LC
17	*Berlinia bracteosa*	Abeum	Fabaceae	0,26	LC
18	*Berlinia grandiflora*	Abem ossoé	Fabaceae	0,26	LC
19	*Bombax buonopozense*	Kapokier	Bombacaceae	0,26	LC
20	*Bridelia grandis*	Ewolet	Phyllanthaceae	0,79	LC
21	*Canarium schweinfurthii*	Aielé	Burseraceae	0,66	LC
22	*Ceiba pentandra*	Fromager	Bombacaceae	1,05	LC
23	*Celtis adolfi-friderici*	Diana A	Ulmaceae	1,58	LC
24	*Celtis gomphophylla*	Odou	Ulmaceae	0,26	LC
25	*Celtis tessmannii*	Odou	Ulmaceae	0,13	LC
26	*celtis zenkeri*	Diana Z	Ulmaceae	0,13	LC
27	*Centroplacus glaucinus*	Elemekon	Euphorbiaceae	0,13	LC
28	*Chrysophyllum africana*	Longhi	Sapotaceae	1,31	LC

No.	Scientific name	Local name	Family	RF	IUCN status
29	*Chrysophyllum lacourtiana*	Abam	Sapotaceae	0,13	LC
30	*cola ballayi*	Abang	Malvaceae	0,13	LC
31	*Cola pachycarpa*	Cola du singe	Cecropiaceae	0,13	LC
32	*cola* sp.	Cola	Malvaceae	0,26	
33	*Cordia platythyrsa*	Ébé	Boraginaceae	0,26	LC
34	*Coula edulis*	Noisetier	Olacaceae	0,66	LC
35	*Croton oligandrus*	Ebin	Euphorbiaceae	0,13	LC
36	*Cylicodiscus gabunensis*	Okan	Fabaceae	0,13	LC
37	*Dacryodes buettneri*	Ozigo	Burseraceae	0,26	LC
38	*Dacryodes edulis*	Safoutier	Burseraceae	0,53	
39	*Dacryodes igaganga*	Assamingun	Burseraceae	1,45	Vu
40	*Desbordesia glaucescens*	Alep	Irvingiaceae	1,18	LC
41	*Detarium macrocarpum*	Allenélé	Fabaceae	0,53	LC
42	*Distemonanthus benthamianus*	Movingui	Fabaceae	0,92	LC
43	*Drypetes gossweileri*	Olelang	Putranjivaceae	0,26	Vu
44	*Duboscia macrocarpa*	Akak	Malvaceae	1,84	LC
45	*Entandrophragma angolense*	Tiama d'afrique	Meliaceae	0,13	Vu
46	*Entandrophragma candollei*	Kossipo	Meliaceae	0,79	Vu
47	*Entandrophragma cylindricum*	Sapeli	Meliaceae	0,53	Vu
48	*Entandrophragma utile*	Sipo	Meliaceae	1,58	Vu
49	*Eriocoelum macrocarpum*	Awonog	Sapindaceae	1,18	LC
50	*Erythrophleum ivorense*	Tali	Fabaceae	2,37	LC
51	*Erythroxylum mannii*	Landa	Erythroxylaceae	1,45	LC
52	*Ficus mucus*	Figuier	Moraceae	1,05	LC
53	*Funtumia elastica*	Mutondo	Apocynaceae	0,66	LC
54	*Gilbertiodendron brachystegioides*	Abeum	Fabaceae	0,26	LC
55	*Gilbertiodendron dewevrei*	Limbali	Fabaceae	0,79	LC
56	*Guarea cedrata*	Bossé C	Meliaceae	0,66	Vu
57	*Guarea thompsonii*	Bossé T	Meliaceae	0,39	Vu
58	*Holoptelea grandis*	Avep ele	Ulmaceae	0,39	LC
59	*Hunteria umbellata*	Ebam	Apocynaceae	0,13	LC
60	*Hylodendron gabunense*	Mvanda	Fabaceae	1,58	LC
61	*Irvingia gabonensis*	Mvanda	Fabaceae	1,71	LC
62	*Irvingia grandifolia*	Andok ngoé	Irvingiaceae	1,31	LC
63	*Isolona hexaloba*	Nding	Annonaceae	0,13	LC
64	*Khaya anthotheca*	Acajou ba	Meliaceae	0,13	Vu
65	*Khaya ivorensis*	Acajou	Meliaceae	0,26	Vu
66	*Klainedoxa gabonensis*	Eveuss	Irvingiaceae	0,66	LC
67	*Lannea welwitschii*	Kumbi	Anacardiaceae	1,05	LC
68	*Lophira alata*	Azobé	Ochnaceae	0,66	Vu
69	*Lovoa trichilioides*	Dibétou	Meliaceae	0,92	Vu
70	*Macaranga* sp.	Macaranga	Euphorbiaceae	2,23	LC
71	*Magnistipula tessmannii*	Ekom	Chrysobalanaceae	0,66	
72	*Mammea africana*	Boto	Clusiaceae	0,26	LC
73	*Mangifera indica*	Manguier	Anacardiaceae	0,26	DD
74	*Manilkara fouilloyana*	Nom adjap	Sapotaceae	0,13	LC
75	*Mansonia altissima*	Bété	Malvaceae	0,39	EN
76	*Margaritaria discoidea*	Ebebeng	Phyllanthaceae	0,66	LC
77	*Massularia acuminata*	Oyebe	Rubiaceae	0,13	LC
78	*Unknow*	Unknow	N / A	0,13	
79	*Microberlinia bisculata*	Alen élé	Fabaceae	0,39	EN
80	*Milicia excelsa*	Iroko	Moraceae	0,53	LC
81	*Musanga cecropioides*	Parasolier	Cecropiaceae	3,94	LC
82	*mussanga*	Mussanga	N / A	0,13	
83	*Myrianthus arboreus*	Ananas du singe	Cecropiaceae	1,31	LC
84	*Nauclea diderrichii*	Bilinga	Rubiaceae	0,26	Vu
85	*Nesogordonia papaverifera*	Kotibé	Malvaceae	0,13	Vu
86	*Omphalocarpum elatum*	Mebemengono	Sapotaceae	0,39	LC
87	*ondondou'ele*	Oudondo'u ele	N / A	0,92	
88	*Ongokea gore*	Angueuk	Olacaceae	0,13	LC
89	*Ormocarpum bibracteatum*	Enga'am	Fabaceae	0,66	
90	*Pachyelasma tessmannii*	Eyek	Fabaceae	0,79	LC
91	*Pancovia laurentii*	Nom ekom	Sapindaceae	0,53	
92	*Penthaclethra eetveldeana*	Ebaye	Fabaceae	0,26	

No.	Scientific name	Local name	Family	RF	IUCN status
93	*Penthaclethra macrophylla*	Mubala	Fabaceae	0,79	
94	*Pericopsis elata*	Assamela	Fabaceae	0,13	EN
95	*persea americana*	Avocatier	Lauraceae	0,66	LC
96	*Petersianthus macrocarpus*	Abalé	Lecythidaceae	1,31	LC
97	*Piptadeniastrum africanum*	Dabéma	Fabaceae	1,31	LC
98	*Polyscias fulva*	Nkog élé	Apiaceae	1,31	NT
99	*Pouteria aningeri*	Aningre	Sapotaceae	0,53	LC
100	*Prioria balsamifera*	Tola	Fabaceae	0,26	EN
101	*Psydrax subcordata*	Mvié ele	Rubiaceae	1,05	LC
102	*Pteleopsis hylodendron*	Ossanga	Combretaceae	0,92	Vu
103	*Pterocarpus soyauxii*	Padouk rouge	Fabaceae	2,10	Vu
104	*Pterygota bequaertii*	Efok ayous	Malvaceae	0,79	LC
105	*Pterygota macrocarpa*	Koto	Malvaceae	0,66	Vu
106	*Pycnanthus angolensis*	Ilomba	Myristicaceae	1,18	LC
107	*Ricinodendron heudelotii*	Ezezang	Euphorbiaceae	1,45	
108	*Scorodophloeus zenkeri*	Olom	Fabaceae	0,13	LC
109	*sp unknown*	Sp unknown	N / A	1,31	LC
110	*Staudtia kamerunensis*	Niové	Myristicaceae	2,76	LC
111	*Sterculia rhinopetala*	Lotofa	Malvaceae	1,58	
112	*Strombosia grandifolia*	Mbang mbazoa	Olacaceae	0,13	LC
113	*Syzygium rowlandii*	Bibolo	Myrtaceae	0,13	Vu
114	*Tabernaemontana crassa*	Étoan	Apocynaceae	2,10	
115	*Terminalia ivorensis*	Framiré	Combretaceae	0,79	LC
116	*Terminalia superba*	Fraké	Combretaceae	3,02	LC
117	*Tetrapleura tetraptera*	Akpa	Fabaceae	0,39	LC
118	*Treculia africana*	Etoup	Moraceae	0,39	LC
119	*Trema orientalis*	Aveeg	Ulmaceae	0,13	LC
120	*Trichilia welwitschii*	Ebangbemva ossoé	Meliaceae	0,13	
121	*Trichoscypha acuminata*	Amvut	Anacardiaceae	1,97	
122	*Trilepisium madagascariense*	Osomzo	Moraceae	0,79	LC
123	*Triplochyton scleroxylon*	Ayous	Malvaceae	1,05	
124	*Uapaca guineensis*	Assam	Phyllanthaceae	0,26	LC
125	*Uapaca* sp.	Rikio	Phyllanthaceae	3,02	LC
126	*Vernonia conferta*	Abéa	Asteraceae	1,18	LC
127	*Xylopia aethiopica*	Ekui	Annonaceae	0,92	
128	*Zanthoxylum gilletii*	Bongo H	Rutaceae	0,53	LC
129	*Zanthoxylum tessmannii*	Bongo T	Rutaceae	0,53	Vu

The conservation status of the species according to the IUCN red list indicates that 19.37% of the species are vulnerable (*Aucoumea klaineana, Entandrophragma angolense, Pterygota macrocarpa* for example), 60.46% are in the category of minor concern (LC) such as *Anonidium mannii*, *Dacryodes buettneri*, *Staudtia kamerunensis* and 3.1% in the category endangered (EN); *Mansonia altissima*, *Pericopsis elata* and *Prioria balsamifera* for example (Table 3).

Importance value indices of woody species and families

Important value indices (IVIs) provide knowledge on important species of the tree community in the reserve. The list of species and their IVIs for first 10 most important species are shown in Table 4. Based on IVI, the most important species where *Gilbertiodendron dewevrei* (IVI= 31.16), *Musanga cecropioides* (IVI= 16.64), *Uapaca* sp. (IVI= 10.65) while *Hylodendron gabunense* (IVI= 4.45) and *Erythrophleum ivorense* (IVI= 4.26) were the least ranked species among the first 10 species in the reserve.

Table 4. Ten most important species (stem diameter ≥ 10cm) recorded from the study area (RF: relative frequency; RD: relative dominance; RA: relative abundance; IVI: importance value index).

Species	RF	RD	RA	IVI
Gilbertiodendron dewevrei	0.79	20.84	10.32	31.16
Musanga cecropioides	3.94	5.57	11.07	16.64
Uapaca sp.	3.02	3.51	7.13	10.65
Terminalia superba	3.02	3.88	5.49	9.37
Staudtia kamerunensis	2.76	1.33	4.94	6.27
sp unknown	1.31	0.73	5.34	6.07
Pycnanthus angolensis	1.18	3.93	1.60	5.52
Macaranga sp.	2.23	0.93	4.19	5.12
Hylodendron gabunense	1.58	1.55	2.89	4.45
Erythrophleum ivorense	2.37	2.51	1.75	4.26

Table 5 represents the biological parameters of the most important families. The flora studied is mainly dominated by 05 ecologically important families. These include Fabaceae (FIV= 58.21), Cecropiaceae (FIV= 17.87), Combretaceae (FIV= 14.61), Phyllanthaceae (FIV= 12.60), Myristicaceae (FIV= 11.79).

Table 5. Ten most important families in the study area (RF: relative frequency; RD: relative dominance; RA: relative abundance; FIV: family importance value).

Family	RF	RD	RA	FIV
Fabaceae	6.79	36.51	21.70	58.21
Cecropiaceae	6.17	5.85	12.02	17.87
Combretaceae	4.94	7.08	7.53	14.61
Phyllanthaceae	5.56	4.37	8.23	12.60
Myristicaceae	5.14	5.26	6.53	11.79
Malvaceae	5.14	6.11	5.04	11.15
Euphorbiaceae	3.70	2.41	5.34	7.74
Anacardiaceae	4.73	3.78	2.79	6.57
Irvingiaceae	3.91	3.53	2.44	5.97
Meliaceae	4.94	3.10	2.74	5.84

Size class distribution

The tree size class distribution in the forest reserve (Fig. 4) exhibited negative exponential curve. About 56.06% of the recorded stems were in the first class [10-20[, and in the second [20-30[about (14.16%). Size classes whereas the midsize classes,]50.0-59.9]cm and]60.0-69.9]cm, were represented by 4.78% and 2.74% respectively. The maximum DBH value was 120cm recorded for *Antrocaryon klaineanum, Aubrevillea kerstingii, Bombax buonopozense, Ceiba pentandra* and *Gilbertiodendron dewevrei*, followed by 110cm recorded for *Antrocaryon klaineanum, Ceiba pentandra, Erythroxylum mannii, Gilbertiodendron dewevrei, Klainedoxa gabonensis, Lannea welwitschii, Prioria balsamifera* and *Pycnanthus angolensis.*

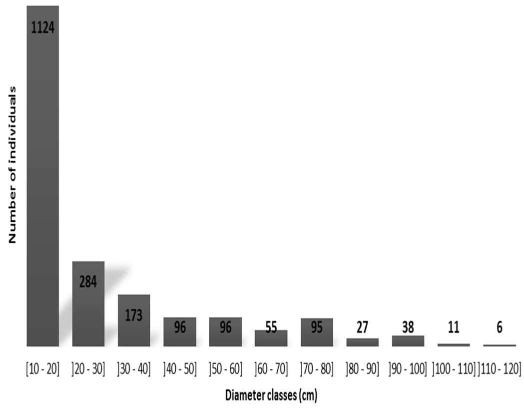

Fig. 4. Distribution of the number of individuals per diameter in the Mbalmayo Forest Reserve.

Tree density and basal area in land use types

Basal area and population density were high in secondary forests (10.46 m^2/ha and 86 stems/ha) and swamps (2.43 m^2/ha; 20 stems/ha) unlike cocoa plantations (0.76 m^2/ha; 4 stems/ha) and in the fields (0.20 m^2/ha; 4 stems/ha) which show low values (Table 6).

Table 6. Basal area and tree density by type of land use.

land use types	Average diameter (cm)	Basal area (m^2/ha)	Density (Number of Stems/ha)
Secondary forest	30.98 ± 24.37	10.46	86
Swamp	30.96 ± 24.14	2.43	20
Fallow	28.74 ± 23.13	0.82	8
cocoa plantation	42.79 ± 23.11	0.76	4
Field	23.17 ± 12.29	0.20	4

Table 7. Comparison of the floristic richness of the Mbalmayo forest reserve with other forest sites in Cameroon.

Sites	Number of stems	Species (E)	Genera	Families	E/G	ISH	Authors
Mbalmayo Reserve	122	129	100	33	1.29	2.58	This study
Koupa Matapit [1]	-	124	97	47	1.28	2.72	Momo *et al.* (2018)
Douala-Edea [2]	-	103	89	56	1.16	3.56	Angoni *et al.* (2018)
Mangombe [3]	708	91	77	38	1.18	5.52	Ngueguim, 2013
Bidoo [3]	538	88	81	32	1.09	5.41	Ngueguim, 2013
Campo Ma'an National Park [3]	569	75	68	29	1.10	5.40	Ngueguim, 2013
Madhupur National Park in Bangladesh [4]	413±64	139	100	40	1.39	0.870±0.07	Rayhanur *et al.* (2019)
Boumba-Bek National Park [5]	440	247	169	51	1.46	6.24	Tajeukem *et al.* (2014)
Mengamé Gorilla Reserve [6]	341	304	191	49	3.37	6.75	Fongnzossie *et al.* (2008)
Ngovayang Forest Massif [7]	532 ±75	293	170	60	1.72	4.00 ±0.1	Gonmadje *et al.* (2011)

[1]Momo *et al.* (2018): Vegetation and functional spectra of the Koupa Matapit gallery forest (West-Cameroon).

[2] Angoni *et al.* (2018): Floristic composition, structure and threats of the vegetation of the coastal line of the Douala-Edéa Fauna Reserve.

[3] Ngueguim JR (2013): Productivity and floristic diversity of ligneous plants in dense forests of humid tropical Africa in Cameroon: site of Mangombe, Bidou and Campo.
[4] Rayhanur *et al.* (2019): Diversity and Composition of Tree Species in Madhupur National Park, Tangail, Bangladesh.
[5] Tajeukem *et al.* (2014): Vegetation structure and species composition at the northern periphery of the Boumba-Bek National Park, Southeastern Cameroon.
[6] Fongnzossie *et al.* (2010): The importance of habitat characteristics for tree diversity in the Mengamé Gorilla Reserve (South Cameroon).
[7] Gonmadje *et al.* (2011): Tree diversity and conservation value of the Ngovayang massif, Cameroon

Discussion

The results of floristic inventories show a specific richness of 129 species distributed in 100 genera and 33 families. The generic coefficient (1.3) and the diversity indices (H' = 2.58 bits, D = 0.87, E = 0.85) reveal the diversity of the study area. A low value (E/G ≈ 1) of the generic coefficient is indicative of a high diversity of vegetation (Evrard, 1968; Aké Assi, 1984), but does not provide information on the distribution of species between the different genera and families. Although Shannon-Wiener's diversity index is the most preferred index among the other diversity indices and values are between 0.0 and 5.0 with results generally in the range 1.5 to 3.5 and very rarely exceeding 4.5 (Deo *et al.*, 2016), the overall diversity index value of 2.58 for Mbalmayo Forest Reserve is equally considered high. Since a reserve with a diversity value (H') greater than two (H' ≥ 2) can be regarded as highly diverse in terms of species (Demies *et al.*, 2019), it implies that Mbalmayo Forest Reserve with a diversity of 2.58 harbours rich tree diversity and high species richness.

The reason for higher diversity values in the present study may be due to the protected status (Temgoua, 2007). Subsequently, more conservation efforts are urgently needed to buffer such a reserve from further degradation and habitat loss. The Shannon-Wiener diversity index indicates a rich community, made up of a large number of species with frequencies that vary little between species (Frontier & Pichod-Viale, 1993; Senterre, 2005). The general tree species evenness as a measure of equitability of species distribution in Mbalmayo forest reserve is 0.85. According to Ifo *et al.* (2016), such high a value of species evenness can be attributed to less competition for space among tree species in intact part of the reserve. The high value of Pielou's evenness (0.85) reveals the specific richness of the environment. According to Odum (1976) cit. Sonké (1998), ecosystems which have reached a level of maturity and which are not subject to disturbing constraints have a high equitability, of the order of 0.6 to 0.8, while ecosystems which are under stress have low equitability. This information could lead us to say that the disturbances in the forest sector studied in the Mbalmayo forest reserve remain weak and residual.

The value obtained for the generic coefficient is similar to that of Momo *et al.* (2018) in the Koupa-Matapit gallery forest with a value of 1.27. This specific richness is higher than that obtained by Angoni *et al.* (2018) during their work on the coastal line of the forest reserve of the Douala-Edea forest reserve (103 species). This difference could be explained by the fact that some ecological factors are favorable to the proliferation of species. Rayhanur *et al.* (2019) obtained a high generic coefficient (1.4) after their work in Madhupur National Park in Bangladesh. The specific richness is lower than that obtained by Tajeukem *et al.* (2014), who had a total of 247 species in their work on the periphery of Boumba-Bek National Park and those obtained in southern Cameroon by Fongnzossie *et al.* (2008) in the Mengamé Gorilla Reserve (307 species) and by Djuikouo *et al.* (2010) in heterogeneous forests on dry land in the Dja Faunal Reserve. The increase of human activities within the Mbalmayo forest reserve could explain this difference.

The most abundant species are, in decreasing order of importance, *Musanga cecropioides* (11.07%), *Gilbertiodendron dewevrei* (10.32%), *Uapaca* sp. (7.13%), *Terminalia superba* (5.49%), *Stautdia kamerunensis* (4.49%), *Macaranga* sp. (4.19%), *Hylodendron gabunense* (2.89%). They are dominated by pioneer species (*M. cecropioides*, *Macaranga* sp., *T. superba*) which are found in all types of land use. Processes such as the substitution of dead trees by dominated trees contribute to forest renewal mechanisms (Riéra, 1998). In disturbed environments, species can easily establish themselves and lead to a rapid increase in biodiversity; but such species do not become permanently integrated into the communities where they appeared. Thus, the maturity of the forest can lead to a reduction in species richness (Devineau, 1984; Chave *et al.*, 2003).

There are also many timber species (*Gilbertiodendron dewevrei*, *Duboscia macrocarpa*, etc.) whose numbers have been considerably reduced by illegal logging. The high specific richness of the *G. dewevrei* surveys can be explained by the environmental conditions favorable to the regeneration of the species present and the difficulty of access to its environments located near the Nyong River, which limits disturbances.

In forest ecological studies, IVI indicates the ecological importance of a species in a community. IVIs also indicate dominance of species in mixed population and give a knowledge about important species and their composition in a forest reserve (Siraj and Zhang, 2018). IVI enables prioritizing species for conservation interventions such that species with lowest IVIs might benefit from conservation and management interventions. Tree species such as *Gilbertiodendron dewevrei*, *Musanga cecropioides* and *Uapaca* sp. are species with high IVIs and constitute the dominant species in the Mbalmayo forest reserve. Some of these species recorded with high IVIs are multipurpose in nature and are valued by many communities in Africa for fuel and timber. According to Asigbaase *et al.* (2019), such trees with high IVIs have more ecological advantage and require less conservation management efforts. This implies that conservation measure should be shifted to trees with low IVIs. Species with low IVIs that are enlisted under IUCN Red list as threatened or endangered species and that need to be considered for special conservation interest are *Mansonia altissima*, *Microberlinia bisulcata*, *Pericopsis elata* and *Prioria balsamifera*. This observation defines the ecological significance and the urgency needed in developing mechanisms for the restoration and conservation of Mbalmayo Forest Reserve. The ecologically most important families are Fabaceae, Cecropiaceae, Combretaceae, Phyllanthaceae, Myristicaceae, Malvaceae, Euphorbiaceae. These families are known to contribute significantly to restoring the plant biodiversity of degraded environments (Zapfack *et al.*, 2002; Kengne *et al.*, 2018). In general, one of the fundamental characteristics of African dense forests is their great richness in Fabaceae and Euphorbiaceae (White, 1986; Xiao *et al.*, 2010; Chazdon *et al.*, 2010).

The population structure varied among the tree species because of poor forest management that has exposed the trees to illegal harvesting. The reverse 'J-shape' diameter distribution indicated healthy recruitment potentials; the lower class diameter tree stands could develop into mature trees and replace the old ones in the future if proper conservation efforts are sustained. Thus, this structure is typical of a natural forest (Ogana and Gorgoso-Varela, 2015). The lack of large trees may have been intensified by illegal logging. This is a feature of tropical forests where the stand structure is usually an inverted J shape and small trees (DBH < 10cm) account for about 80% of species diversity (Rollet, 1974; Gentry *et al.*, 1987; Tchouto *et al.*, 2006; Ngueguim *et al.*, 2018).

The 2005 individuals listed have a density of 121 stems/ha. This density is much lower than that observed by several authors such as Sonké (2005) in the forests of the Dja Reserve in south-eastern Cameroon (512 trees/ha), van Gemerden (2004) in the forest formations of southern Cameroon (523 and 532 trees/ha), Tajeukem *et al.* (2014) at the periphery of Boumba-Bek National Park (439 stems/ha) and Nguetsop *et al.* (2015) in the Bangang forest in western Cameroon (749 stems/ha). This low density can be explained by anthropogenic disturbances which deplete the forest in valuable species which are generally recruited among the large trees and shifting agricultural practices on slash and burn which clear large areas of forest.

Conclusion

This study made it possible to improve knowledge on the floristic composition and the structure of the vegetation of the forest reserve of Mbalmayo. The population studied is rich and diversified with 129 species distributed in 100 genera and 33 families. The flora consists mainly of pioneer species that rebuild forest gaps such as *Terminalia superba*, *Macaranga* sp., *Musanga cecropioides*, *Celtis mildbraedii*, *Alstonia boonei*, *Albizia adianthifolia*, *Petersianthus macrocarpus*, *Margaritaria discoidea*. The stand is quite diverse as shown by Shannon's diversity indices (2.57 bits), Pielou's evenness (0.85) and Simpson's diversity index (0.87). The structure of the vegetation presents the regular form generally observed in tropical forest which shows a preponderance of small stems. Anthropogenic pressures have made the studied forest compartment a forest mosaic with the density and the average diameter of the trees highly variable between the different types of land use. The highest values of density and basal area are observed in secondary forests (86 stems/ha and 172.61 m^2/ha) and the lowest in fields (4 stems/ha and 3.39 m^2/ha) and fallow land (8 stems/ha and 13.53 m^2/ha). This study contributes to the generation of information for decision-makers in charge of the environmental policy and management of this protected area.

Recommendation(S)

- Considerable management options that limit continuous degradations such as enforcement of environmental laws and tree enrichment planting should be undertaken to restore particularly the status of trees in the reserve;
- To meet the demand of local users, locally preferred species should be promoted to balance the species composition of other ecologically importance species;
- In order to preserve the functions and restore the floristic and structural potential of this classified forest in the permanent forest estate, it would be important to proceed with the development of a management plan which takes into account all the stakeholders involved.

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