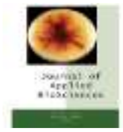

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Phytoecological markers of the Mpoh forest in the northern sector of the Léfini reserve, Congo

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ABSTRACT.
Objectives: The study aims to improve knowledge of the flora and structural parameters of the Mpoh forest in the northern sector of the Léfini reserve. This forest is subject to anthropogenic activities, the corollaries of which are the regression of woody stands and the expansion of those that adapt, as well as the rarity and even disappearance of certain species.
Methodology and results: The methodology involves three disjointed surveys of one hectare, positioned at random. Floristic data was collected on woody plants with dbh ≥10 cm. The 781 trees inventoried correspond to 53 species, 45 genera and 27 families. The biodiversity indices reveal *Heisteria parvifolia* as the marker of the environment, ahead of *Pentaclethra eetveldeana*, *Petersianthus macrocarpus* and *Pancovia laurentii*. The dominance of the endemic Guinean-Congolese element is evidence of a minor influence from neighbouring floristic regions, albeit within the Sangha River corridor. The majority of species are rare or even threatened with extinction according to the rarefaction index. In contrast, preferential species account for only 30.12% of the inventory, making this ecosystem less resilient. The structural parameters highlight a pauciflorous and paucispecific woody formation with a mesophilic and tropophilic affinity. The erratic pattern of the diameter structure is evidence of the impact of human activity on the environment. The high proportion of sarcochores, a sign of the high level of maturity reached by this ecosystem, marks the evolutionary duality of the trees and the agents of dissemination. Zoochory, and in particular endozoochory, which is closely linked to sarcochores, makes sarcochory the main means of dissemination.
Conclusion and application of finding: Despite recurrent human activities, the flora of the Mpoh forest is naturally little influenced by the intrusion of non-native species from the Guinean-Congolese centre of endemism, although they do evolve in the Sangha River corridor. The Mpoh forest, in the northern sector of the Léfini reserve, is a mesophilic tropophilic formation. This atypical ecosystem is particular facies within the dense rainforests of Central Africa.
Keywords: Congo, Léfini reserve, phytodiversity, structural markers, biodiversity index, forest stand.

INTRODUCTION

The world's forest ecosystems cover around 4 billion hectares, or almost a third of the world's land area (FAO, 2022). Forests are unevenly distributed across the planet, with the tropical portion comprising all wooded areas between the Tropics of Cancer and Capricorn (FAO, 2020). Tropical cover, which accounts for 44% of global forest cover, is a disjointed formation of three major basins: the Amazon, the Congolese and the Borneo-Mekong (CBD, 2010; Guéneau *et al*., 2012; UNESCO, 2018). The forest cover of the three tropical basins shows that 279 million hectares are used for timber production and 135 million hectares for a variety of uses (Guénau *et al*., 2012). Although heavily impacted by human activities, forests play an important role in conserving biodiversity and guaranteeing a range of ecological services to humanity (Doumenge *et al*., 2021; FAO, 2018; Gboze *et al*., 2020; Eba'a Atyi *et al*., 2022). The forests of the Congo Basin are no exception, providing a range of goods and services related to biological diversity, while making a diversified contribution to the economies of the countries of Central Africa (Tabuna, 1999; Tchatat and Ndoye, 2006, Kimpouni and Nguembo, 2018). In terms of ecosystem services, the forests of the Congo Basin are exceptional reservoirs of carbon sinks and thus play a vital role in regulating the continental and global climate system (de Wasseige *et al*., 2015; FAO, 2018; Eba'a Atyi *et al*., 2022; COMIFAC, 2023; WWF, 2023). Sustainable management of biodiversity is a global issue based on the economics of ecosystems. This sustainability is assessed through the costs generated by the destruction of ecosystems, the corollaries of which are the loss of ecological niches, the erosion of biodiversity and the benefits expected from conservation (N'dja Kassi, 2006). Protected areas worldwide cover 12.5% of the globe and their function is to contribute to the conservation of biodiversity by

(i) representing distinct natural communities in landscapes;

(ii) preserving the ecological processes that guarantee biodiversity, by maintaining viable populations; and

(iii) conserving sets of natural habitats that are fairly extensive and therefore resilient to large-scale disturbances and long-term changes (Mansourian *et al*., 2009; Stolton *et al*., 2020). As part of this dynamic, the Republic of Congo has set aside around 11% of its territory as protected areas, providing tangible and intangible goods and services to local populations and humanity (Poore and Sayer, 1993; UICN/PACO, 2012; Stolton *et al*., 2020). The Léfini reserve, classified as a critical site since 1968, is home to indigenous and local populations (Farron, 1968; Hecketsweiler, 1990). Despite its reserve status, this ecosystem is subject to ever-increasing anthropogenic pressure from year to year, to satisfy the daily needs (goods and services) of local residents. Man's many interventions, coupled with global climate change, are resulting in a decline in the populations of woody species, favouring the expansion of others that adapt to the new conditions, and also in the rarefaction, or even disappearance, of certain taxa in the long term (de Wasseige *et al*., 2015; Ahouandjinou, *et al*., 2017; Bita *et al*., 2017). Despite the ecological and socio-economic importance provided by the forests, the northern sector of the Léfini reserve is marked by a very low level of scientific knowledge. Very little information is available on phytodiversity and the ecological parameters governing the development of this ecosystem. This lack of data is a major handicap to the implementation of sustainable management policies. The aim of this study is therefore to improve knowledge of the flora of the forest islands in the northern sector of the Léfini reserve. This objective will be achieved by assessing the diversity of woody species and characterising the structure of the woody species.

MATERIALS AND METHODS

Presentation of the study site : The study site is located in Mpoh, more precisely on the Nsah-Ngo plateau, in the northern sector of the Léfini reserve. This reserve straddles the Pool and Plateaux prefectures (Figure 1), particularly between the sub-prefectures of Ngabé in the southern sector and Ngo in the northern sector (Hecketsweiler, 1990), and was created by decree no. 684 of April 14, 2008, amending and supplementing article 3 of decree no. 3671/CH of November 26, 1951, creating a hunting reserve known as "Léfini", thus instituting the name "hunting reserve", which does not exist in the current law (Goma Boumba *et al*., 2018). Originally covering some 400,000 ha (decree 3671/CH of November 26, 1951), its current area is 630,000 ha, following decree n°0046/MAEEFGR-CH-CN of January 7, 1963. The habitats and fauna are very similar to those of the adjacent Lesio-Louna gorilla reserve (UICN/PACO, 2012; Goma Boumba *et al*., 2018).

Climate: Mpoh is influenced by the climate of the Léfini reserve, which is of the Aw type (Köppen, 1936; Kottek *et al*., 2006; Beck *et al*., 2018). Climatic characteristics include rainfall of 1,600 to 2,100 mm/year and a temperature of around 25°C, with low annual thermal amplitudes and two alternating seasons (Samba, 2020). The dry season lasts from 1 to 3 months and is cool, with mild temperatures. The rainy season is longer, lasting from September to May, with rainfall slowing down in December and January (Figure 2).

Relief and hydrography: The Mpoh region has a flat topography with a difference in altitude of between 400 and 800 m. There is no permanent drainage on the Nsah-Ngoh plateaus. With the exception of the Nambouli River, some 18 km away, only a few marshes drain off rainwater on an exceptional and temporary basis (Schwartz, 1988).

Geology and soil: Mpoh is part of the Batéké Plateaux, evolving on the Batéké sandstone series. According to Boissezon and Gras (1970) and Denis (1974), the geological substratum is represented by sedimentary formations of Cenozoic (Tertiary) age, of a sandstone nature, where they form the polymorphous sandstone series or Batékés sandstone series. Depending on the author, this bedrock is either Upper Kalahari or the result of weathering of the schistosandstone system. According to Hecketsweiler (1990) and Boissezon *et al*. (1969), the soils at Mpoh (Léfini reserve) are impoverished yellow ferrallitic on sandy-clay material from the high plateaux.

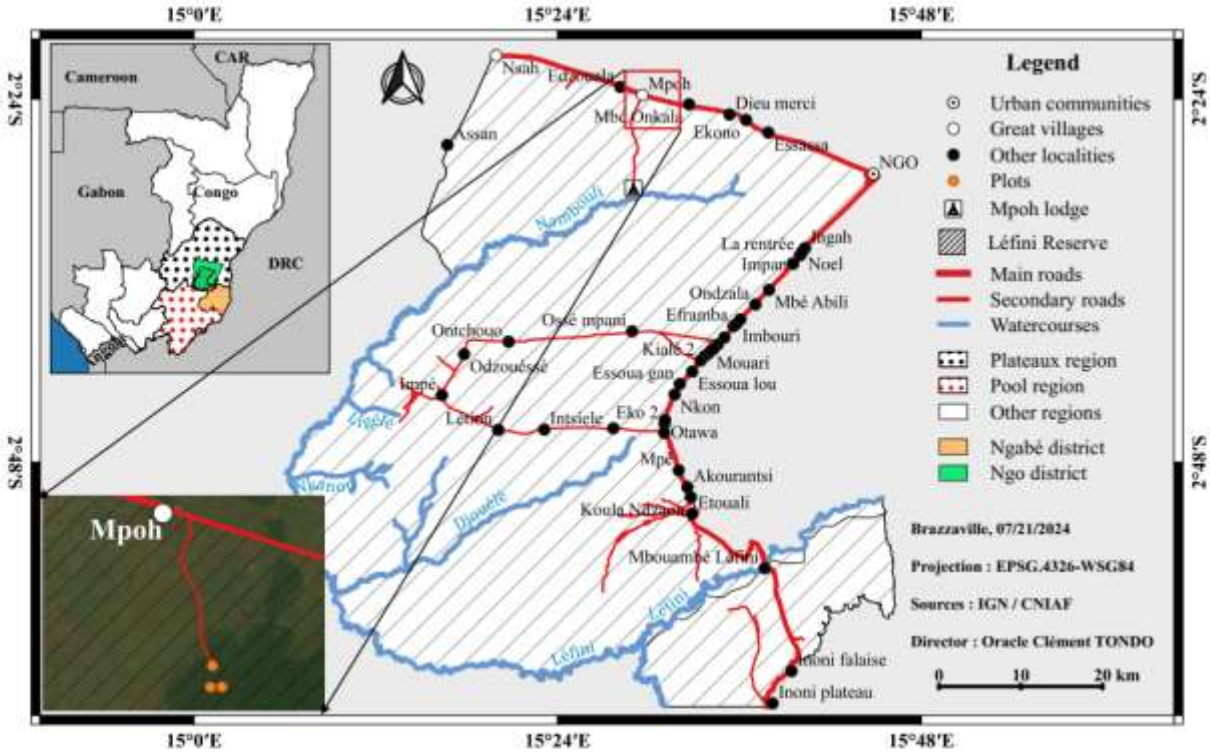

Figure 1: Northern sector of the Léfini reserve localisation

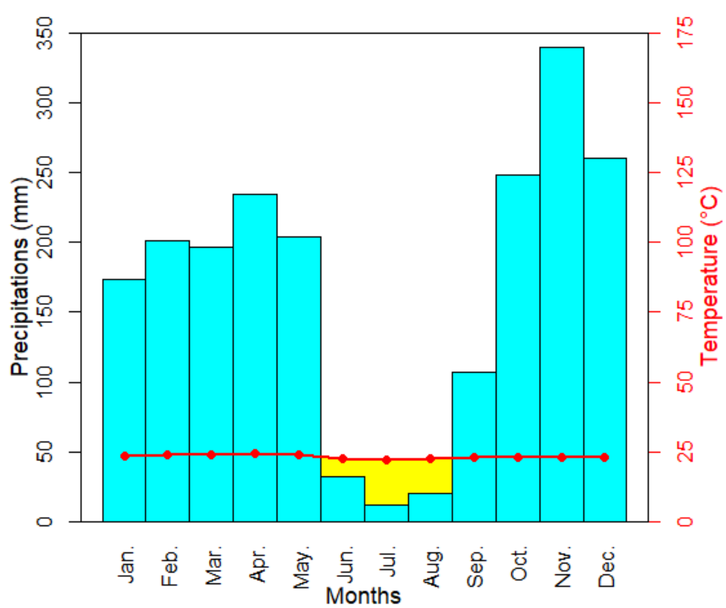

Figure 2: Djambala umbrothermal diagram, 2010 to 2020 (Source: ANAC data)

Vegetation: The vegetation of Mpoh can be divided into two main biomes, which are a mixture of forest and savannah (Makany, 1976). The mesophilic forest is frequently composed of *Millettia laurentii*, *Pentaclethra eetveldeana*, *Staudtia kamerunensis*, *Petersianthus macrocarpus* and *Trichilia heudelotii*.

Human populations and economic activities: The population of Mpoh is predominantly made up of the Téké ethnic group and indigenous Atswa populations (Bouquet, 1969). The opening up of overland communication routes has led to the arrival of foreigners (UNDP, 2016). In this village, the inhabitants mainly practice agriculture, gathering and hunting in its illegal form. Human constraints linked to agricultural activities are increasing exceptionally, following the introduction of the tractor as a means of production, the corollary of which is an increase in the areas affected. However, poaching pressure is high, encouraged by the proliferation of weapons of all kinds, weak surveillance and, above all, the proximity of the city of Brazzaville, which represents a very buoyant market (Ikamba-Nkulu and Tsoumou, 2009).

Materials: The biological material consisted of woody plants of dbh $\geq$ 10 cm present in the inventory system (Miabangana and Malaisse, 2020). Species identification was carried out in situ for the most common species and ex situ by consulting the IEC herbarium at IRSEN and reference works (Trees of the Sangha; Illustrated identification manual; Trees of Equatorial Guinea) for those that could not be identified in the field. The taxonomic ordination adopted is APG IV (2016) available on the "Tropicos" website and the nomenclature is in accordance with Lebrun and Stork (1991-2015) available on the "African Plant Database" website.

Data collection method: Data collection was carried out in three stages: (i) literature review, (ii) sampling, and (iii) floristic inventory.

Sampling and floristic inventory: Three georeferenced plots measuring 100 m x 100 m (1 ha) were set up in the Mpoh forest (Figure 1). Each plot was subdivided into 16 plots (sampling units) of 25 m x 25 m, i.e. 625 m^2 (Figure 3). The floristic inventory was carried out in the sampling units. All woody plants with dbh $\geq$ 10 cm were inventoried and identified (Dallmeier, 1992). Each tree measured was marked so that it could no longer be taken into account (Picard and Gourlet-Fleury, 2008).

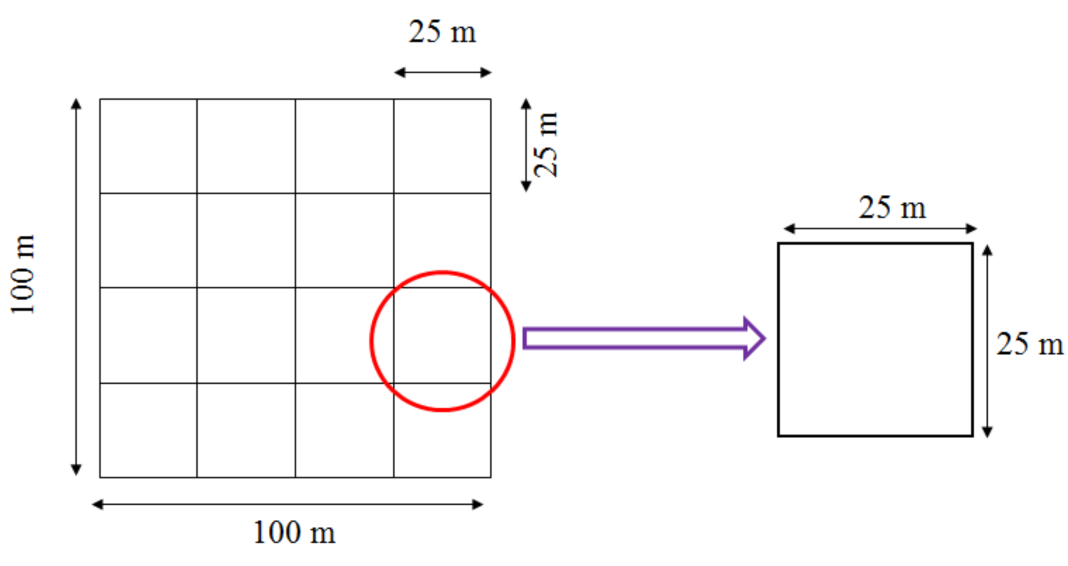

Figure 3: Sampling device

Expression of results

Structural parameters evaluated: 1. Density indicates the average number of individuals of the species per unit area. For the purposes of this research, it will be calculated per hectare (Rollet, 1993). Its formula is as follows:

$D = n / S$

n: Number of individuals of the species and S: plot area in ha

2. The basal area (BA) is the projection on the ground of the sum of the cross-sectional areas of all stems at 1.30 m per hectare. It is expressed in m^2/ha, and is obtained from the following formula:

$BA = \sum \pi di^2 / 4$

di: diameter of tree at chest height.

3. Frequency (F) refers to the number of surveys where the species is present in relation to the total number of surveys. Frequency expresses the presence or absence of the species.

F = (Number of plots where the taxon is present / Total number of plots) x 100

4. The basal area/density ratio, which provides information on the dynamics of diametric evolution and population structure, highlighting the least represented individuals while characterizing large-diameter taxa. It is an indicator of succession and ligneous evolution (Kimpouni, 2017).

R = BA/D

5. The species importance value index (IVI) is used to determine the most abundant species. This index provides information on the number of individuals, distribution and level of spatial occupation of trunk sections projected on the ground (Kimpouni, 2017).

IVI = RF + RD + RDo

With relative frequency (RF), relative density (RD) and relative dominance (RDo);

6. The Morisita index (Id) is a dispersion index equal to 1 for a random distribution, between 0.5 and 1 for a regular distribution and greater than 1 when the distribution is aggregative (Morisita, 1962).

$$Id = n\left(\frac{\sum X^2 - N}{N(N-1)}\right)$$

n: number of subplots; X: number of individuals per subplot; N: number of individuals of all plots.

7. The values of the dispersion index (Id) were subjected to the chi-square test (χ^2) for α = 5%, in order to verify if they are significantly different from 1 (random dispersion).

$$\chi^2\ (df = Q - 1) = (Q - 1)S^2/\bar{X}$$

with Q the number of plots, S^2 and $\bar{X}$ respectively the variance and the mean of the number of trees per subplot.

Biodiversity parameters

8. The Shannon Diversity Index (H') gives the number of species in an environment and quantifies the heterogeneity of biodiversity. The higher the index, the greater the diversity (Legendre and Legendre, 1998).

$H' = -\sum pi \ln pi$

Where pi = ni/n; ni = number of individuals in the species/family and n = total number of individuals.

9. The maximum diversity index (H'max) corresponds to the maximum diversity a community can achieve (Legendre and Legendre, 1998).

$H'_{max} = \ln(S)$

Where "S" is the total number of species

10. Pielou equitability (Eq) predicts the spatial distribution pattern of taxa in the stand. If its value tends towards 1, the species present in the stand have identical abundances, and towards 0 one species dominates the whole stand.

$Eq = H' / H'_{max}$

11. The species rarity index or Géhou et Géhou index expresses the rarity of taxa. Species with a value of less than 80% are considered preferential, very frequent and abundant. However, when the rarefaction index value is greater than or equal to 95%, these taxa are rare and therefore highly threatened with extinction (Piba *et al.*, 2015).

$Ri = [1 - ni/N] * 100$

Where Ri = rarefaction index of species i; ni = number of plots where it is found and N = total number of plots surveyed.

12. Jaccard's similarity coefficient: this index compares floristic similarity between plots.

$S(\%) = (C / A + B - C) \times 100$

Where A = number of species in the first survey, B = number of species in the second survey, C = number of species common to both surveys.

Ecological parameters

Leaf types: Leaf type (LT) describes the nature of the ecosystem. The types used are:

- Leptophyll (Lepto) < 0.2 cm²;
- Macrophyll (Macro): leaf area between 2 cm^2 and 20 dm^2;
- Microphyll (micro) from 2 to 20 cm²;
- Mesophyll (Meso) from 20 to 200 cm².

Types of diasporas: The types of diaspora (TD) adopted are those defined by Dansereau and Lems (1957) taken up by Lebrun (1960); Kimpouni *et al*. (2014):

- Ballochores (Ballo): diaspores expelled by the plant;
- Pterochores (Ptero): diaspores with aliform appendages;
- Sarcochores (Sarco): totally or partially fleshy diaspores.

Phytogeographical types: The phytogeographical types (PT) of the species inventoried are established according to the major subdivisions of White's African phytochorology (1979, 1986). According to this classification, the following are recognized:

Wide-ranging species:

- Afro-American (Afam): species distributed in tropical Africa and America;
- Afro-tropical continental (Aftr): found in several tropical African phytochories;

Link zone species:

- Guinean-Congolese-Zambezian species (GC-Z): species evolving in the Guinean-Congolese and Zambezian regions;
- Guinean-Congolese-Sudanese species (GC-S): species evolving in the Guinean-Congolese and Sudanese regions.

Endemic species of the Guinean-Congolese regional center of endemism:

- Guineo-Congolese species (GC): found throughout the center of endemism;
- Lower Guinean-Congolese species (BGC): found in the Lower Guinean and Congolese subcenters.

Statistical data processing: The various statistical treatments of the data are carried out using R software (v. 4.1.2.) with its RStudio interface (v. 0.99.903.), Past (v. 4.03.) and the Excel spreadsheet (v. 2016). The results are subjected to a one-factor ANOVA test to assess the significance of the results for the structure and biodiversity parameters at the $\alpha = 0.05$ probability threshold. These tests are applied only when the data follow a normal distribution after application of the Shapiro-Wilk normality test. If the data do not follow a normal distribution, a transformation is performed and normality is rechecked. For significant differences, Tukey's post hoc multiple comparison test is applied to clarify significance.

RESULTS

Taxonomic and floristic data: The overall floristic inventory revealed 781 woody individuals corresponding to 53 species classified in 45 genera and 27 families (table 1). The Anova test applied respectively to the richness of families (p-value = 0.754) and species (p-value = 0.722) did not reveal any significant differences between the surveys. This observation from the Anova test (p-value = 0.373) also applies to the number of individuals per survey. These data authenticate a homogeneous floristic composition within the surveys of the northern sector of the Léfini reserve. Of the 53 species inventoried, *Heisteria parvifolia* is clearly preponderant, with 18.82% of

individuals.ha^{-1}. This taxon is followed by *Pentaclethra eetveldeana* with 13.32% individuals.ha^{-1} and *Petersianthus macrocarpus* with 12.04% individuals.ha^{-1}. Unlike *Myrianthus arboreus*, *Morinda lucida*, *Antiaris toxicaria*, *Entandrophragma candollei*, *Cola* sp., *Cola altissima*, *Tetrapleura tetraptera* and *Pterocarpus soyauxii*, which each account for just one individual.ha^{-1} , i.e. a contribution of 0.13%.
In the Mpoh forest, in the northern sector of the Léfini reserve, the number of individuals by family varies from 0.13 to 21% (Table 2). Fabaceae (21%) are best represented, ahead of Olacaceae (20.6%), Sapindaceae and Lecythidaceae (12%). However, the families with the fewest species are Simaroubaceae and Irvingiaceae with 0.13%. As for the number of species per family, values range from 1.88 to 15.1%, with the best represented being the Fabaceae (15.1%), followed by the Malvaceae and Meliaceae (9.43%). The least represented family's number 14, representing 26.32% of the inventory. These are Anacardiaceae, Annonaceae, Asparagaceae, Bignoniaceae, Burseraceae, Cannabaceae, Ebenaceae, Irvingiaceae, Lauraceae, Lecythidaceae, Passifloraceae, Phyllanthaceae, Sapotaceae and Simaroubaceae, with 1.88% each.

Table 1: Synopsis of taxonomic data

Plots	**Taxa.ha^{-1}**		**Number of trees.ha^{-1}**
	Families	**Species**	
R1	22 a*	37 a	236 a
R2	20 a	40 a	281 a
R3	20 a	34 a	264 a
Total	27	53	781
Average ± ES	20.67 ± 3.00	37 ± 1.73	260.33 ± 11.12

* Values followed by the same letter in the column are significantly non-different at the α = 0.05 threshold according to Tukey's post-hoc test.

Table 2: Floristic and ecological data for the Mpoh forest

N°	**Taxa**	**PT**	**TD**	**LT**	**Number of trees.ha^{-1}**			
					P1	**P2**	**P3**	**Average**
	Anacardiaceae				**1**	**2**	**0**	**1.00**
01	*Sorindeia ferruginea* Engl.	GC-Z	Sarco	Meso	1	2	0	1.00
	Annonaceae				**8**	**10**	**7**	**8.33**
02	*Anonidium mannii* (Oliv.) Engl. & Diels.	GC	Sarco	Meso	8	10	7	8.33
	Asparagaceae				**0**	**1**	**5**	**2.00**
03	*Dracaena arborea* (Willd.) Link	Aftr	Sarco	Meso	0	1	5	2.00
	Bignoniaceae				**6**	**1**	**0**	**2.33**
04	*Markhamia tomentosa* (Benth.) K.	GC	Ptero	Meso	6	1	0	**2.33**
	Burseraceae				**1**	**2**	**0**	**1.00**
05	*Canarium schweinfurthii* Engl.	GC	Sarco	Meso	1	2	0	1.00
	Cannabaceae				**5**	**5**	**1**	**3.67**
06	*Celtis tessmannii* Rendle	GC	Sarco	Micro	5	5	1	3.67
	Chrysobalanaceae				**8**	**4**	**14**	**8.67**

07	*Maranthes glabra* (Oliv.) Prance	GC	Sarco	Meso	7	3	13	7.67
08	*Parinari excelsa* Sabine	Afam	Sarco	Meso	1	1	1	1.00
	Clusiaceae				**3**	**4**	**2**	**3.00**
09	*Allanblackia floribunda* Oliv.	BGC	Sarco	Meso	2	3	2	2.33
10	*Garcinia sp.*	-	Sarco	Meso	1	1	0	0.67
	Ebenaceae				**5**	**6**	**0**	**3.67**
11	*Diospyros dendo* Hiern	BGC	Sarco	Meso	5	6	0	3.67
	Euphorbiaceae				**5**	**12**	**21**	**12.67**
12	*Macaranga barteri* Müll. Arg.	GC	Sarco	Meso	0	4	4	2.67
13	*Macaranga monandra* Mull.Arg.	GC	Sarco	Meso	2	6	8	5.33
14	*Macaranga spinosa* Mull. Arg.	GC	Sarco	Meso	3	2	9	4.67
	Fabaceae				**34**	**64**	**66**	**54.67**
15	*Albizia zygia* (DC.) J.F. Macbr.	GC	Ptero	Micro	0	2	2	1.33
16	*Dialium pachyphyllum* Harms	BGC	Sarco	Meso	3	10	4	5.67
17	*Millettia laurentii* De Wild.	BGC	Ballo	Micro	0	1	3	1.33
18	*Pentaclethra eetveldeana* De Wild. & T. Durand	BCG	Ballo	Lepto	18	38	48	34.67
19	*Pentaclethra macrophylla* Benth.	GC	Ballo	Lepto	1	1	2	1.33
20	*Piptadeniastrum africanum* (Hook. f.) Brenan	GC	Ptero	Lepto	11	11	7	9.67
21	*Pterocarpus soyauxii* Taub.	BGC	Ptero	Meso	0	1	0	0.33
22	*Tetrapleura tetraptera* (Schum. & Thonn.) Taub.	Aftr	Sarco	Lepto	1	0	0	0.33
	Irvingiaceae				**1**	**0**	**0**	**0.33**
23	*Irvingia gabonensis* (Aubry-LeComte ex O'Rorke) Baill.	GC	Sarco	Micro	1	0	0	0.33
	Lauraceae				**2**	**2**	**3**	**2.33**
24	*Beilschmiedia insularum* Robyns & R. Wilczek	BGC	Sarco	Meso	2	2	3	2.33
	Lecythidaceae				**19**	**44**	**28**	**30.33**
25	*Petersianthus macrocarpus* (P. Beauv.) Liben	GC	Ptero	Meso	19	44	28	30.33
	Malvaceae				**6**	**11**	**1**	**6.00**
26	*Cola altissima* Engl.	GC	Sarco	Macro	0	1	0	0.33
27	*Cola nitida* (Vent.) Schott & Endl.	GC-S	Sarco	Meso	2	0	0	0.67
28	*Cola sp.*	-	Sarco	Meso	1	0	0	0.33
29	*Grewia coriacea* Mast.	GC	Sarco	Meso	3	8	1	4.00
30	*Pterygota bequaertii* De Wild.	GC	Ptero	Meso	0	2	0	0.67
	Meliaceae				**7**	**7**	**8**	**7.33**
31	*Entandrophragma angolense* (Welw.) C. DC.	GC	Ptero	Meso	4	0	0	1.33

32	*Entandrophragma candollei* Harms	GC	Ptero	Meso	0	0	1	0.33
33	*Entandrophragma sp.*	-	Ptero	Meso	2	3	2	2.33
34	Indéterminé 1	-	Sarco	Meso	0	2	0	0.67
35	*Trichilia monodelpha* (Thonn.) J.J. de Wilde	GC	Sarco	Meso	1	2	5	2.67
	Moraceae				**11**	**4**	**7**	**7.33**
36	*Antiaris toxicaria* Lesch.	GC	Sarco	Meso	0	1	0	0.33
37	*Treculia africana* Decne.	Aftr	Sarco	Meso	11	3	7	7.00
	Myristicaceae				**7**	**18**	**17**	**14.00**
38	*Coelocaryon preussii* Warb.	GC	Sarco	Meso	1	2	0	1.00
39	*Pycnanthus angolensis* (Welw.) Warb.	GC	Sarco	Meso	3	9	14	8.67
40	*Staudtia kamerunensis* Warb.	BGC	Sarco	Meso	3	7	3	4.33
	Olacaceae				**80**	**49**	**32**	**53.67**
41	*Heisteria parvifolia* Sm.	GC	Sarco	Meso	74	46	27	49.00
42	*Strombosia grandifolia* Hook.f.	GC	Sarco	Meso	6	3	5	4.67
	Passifloraceae				**0**	**0**	**3**	**1.00**
43	*Barteria fistulosa* Mast.	Aftr	Sarco	Meso	0	0	3	1.00
	Phyllanthaceae				**0**	**0**	**2**	**0.67**
44	*Bridelia micrantha* (Hochst.) Baill.	BCG	Sarco	Micro	0	0	2	0.67
	Rubiaceae				**2**	**0**	**1**	**1.00**
45	*Morinda lucida* Benth.	GC	Sarco	Meso	0	0	1	0.33
46	*Tricalysia sp.*	-	Sarco	Meso	2	0	0	**0 .67**
	Sapindaceae				**18**	**34**	**41**	31.00
47	*Blighia welwitschii* (Hiern) Radlk.	GC	Sarco	Meso	1	8	16	8.33
48	Indeterminé 2	-	Sarco	Meso	0	1	0	**0.33**
49	*Pancovia laurentii* (De Wild.) Gilg ex De Wild.	BGC	Sarco	Meso	17	25	25	22.33
	Sapotaceae				**3**	**1**	**0**	1.33
50	*Chrysophyllum africanum* A. DC.	GC	Sarco	Meso	3	1	0	1.33
	Simaroubaceae				**0**	**0**	**1**	**0.33**
51	*Quassia africana* (Baill.) Baill.	GC	Sarco	Micro	0	0	1	0.33
	Urticaceae				**4**	**0**	**4**	**2.67**
52	*Musanga cecropioides* R. Br.	GC	Sarco	Meso	4	0	3	2.33
53	*Myrianthus arboreus* P. Beauv.	Aftr	Sarco	Macro	0	0	1	**0.33**
Total					**236**	**281**	**264**	260.33

Structural characteristics

Density: The average density of the plots surveyed is 260.33 ± 13.12 trees.ha^{-1} and is supported by four taxa listed in descending order of contribution: *Heisteria parviflora, Pentaclethra eetveldeana, Petersianthus* *macrocarpus* and *Pancovia laurentii* (Table 3). These taxa with a density of at least 20 trees.ha^{-1} account for 52.37% of the inventory. The least represented species with no more than 1 tree.ha^{-1} are *Pterocarpus soyauxii, Tetrapleura tetraptera, Irvingia gabonensis, Cola altissima, Cola* sp., *Entandrophragma candollei, Antiaris toxicaria, Morinda lucida, Quassia africana, Myrianthus arboreus* and *Parinari excelsa*. The Anova test (p-value > 0.05) did not reveal any significant differences between the mean numbers of individuals within the surveys. As for Tukey's post-hoc test, with a threshold of α = 0.05, applied to densities highlights non-significant differences.

Frequency: Species frequency, refined to sampling units, varies between 0.2 and 0.94%. This frequency is supported by *Heisteria parvifolia* (0.94%). However, *Irvingia gabonensis, Antiaris toxicaria, Morinda lucida, Entandrophragma candollei, Pterocarpus soyauxii, Myrianthus arboreus, Tetrapleura tetraptera, Cola altissima, Cola sp.* and *Quassia africana* are the least represented with 0.2%.

Basal area: The average basal area is 25.45 ± 1.72 m².ha^{-1} , while it varies from 23.10 to 28.81 m².ha^{-1} per plot. This basal area is supported by *Heisteria parvifolia* at almost 50% (12 m².ha^{-1}). The Anova test revealed no significant differences between basal area values within the surveys following p-value > 0.050. Tukey's post-hoc test with threshold α = 0.05 also shows that basal area values do not differ significantly. The basal area value is low compared with known data from Central African dense forests, but incorporates the range of mesophilic and tropophilic formations.

Basal area to density ratio: The average plot basal area to density ratio was 0.099 ± 0.012 (Table 3). This structural parameter does not show significant differences between plots (Anova test: p-value > 0.050). However, this result indicates that the Mpoh forest is dominated by small-diameter woody species. As large-diameter trees are almost always cut for timber, this observation could only be supported by anthropogenic action.

Table 3: Overview of basal area, density and BA/D ratio

plots	Basal area (m².ha^{-1})	Density (trees.ha^{-1})	BA/D Ratio
R1	28.81 a	236 a	0.122a
R2	23.10 a	281 a	0.082 a
R3	24.45 a	264 a	0.093 a
Average ± ES	25.45 ± 1.72	260.33 ± 13.12	0.099 ± 0.012

*Values followed by the same letter in the column are significantly non-different at the α = 0.05 threshold according to Tukey's post-hoc test.

Diameter structure and land use: The 781 individuals were divided into 9 diameter classes, the most populous of which were classes 1 (33.3%), 2 (27.6%) and 3 (20.7%). However, classes 8 and 14 are the least represented with 0.12%. The number of individuals per diameter class decreases almost progressively with increasing tree diameter (Figure 4). Deficits or overcrowding in certain diameter classes are indicative of poor recruitment within the diameter classes. The erratic pattern of diameter structure curves reflects the functioning of a disturbed forest facies with poor regeneration. In fact, recruitment of individuals within diameter classes, and therefore from one class to another, is insufficient. This condition is one of the signs of anthropization of the flora in the forests of the northern sector of the Léfini reserve. Basal area is dependent on (i) the number of individuals and (ii) their dbh. In diameter classes where there is an accumulation of large-diameter trees, basal area is high (figure 4).

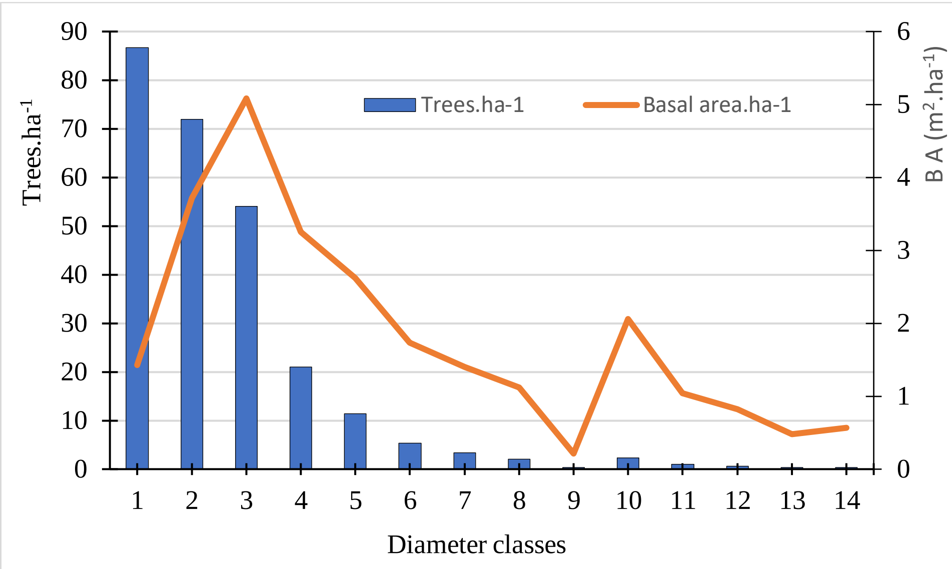

Figure 4: Trend in number of individuals and basal area

Morisita dispersion index (Id): This index, which provides information on the spatial distribution of species, reveals that the majority (81%) of taxa have a random distribution. Conversely, 19% of taxa (*Blighia welwitschii*, *Entandrophragma angolense*, *Grewia coriacea*, *Heisteria parvifolia*, *Macaranga barteri*, *Macaranga monandra*, *Musanga cecropioides*, *Pentaclethra eetveldeana*, *Pterygota bequaertii* and *Strombosia grandifolia*) have an aggregative distribution. The coexistence of two modes of taxon distribution within the Mpoh forest formation is the basis of floristic facies largely influenced by the distribution pattern, which in turn is dependent on several other factors, notably edapho-ecological.

Species Importance Value Index: The importance value index (IVI) of the species ranges from 0.37 to 46.51%. The most important species are *Heisteria parvifolia* (46.51%), followed by *Pentaclethra eetveldeana* (29.84%), *Petersianthus macrocarpus* (29.16%), *Pancovia laurentii* (21.24%) and *Piptadeniastrum africanum* (15.87%). However, less important species are *Tetrapleura tetraptera*, *Quassia africana*, *Cola* sp. and *Cola altissima*, with 0.37% (figure 5). *Heisteria parvifolia*, outranking *Pentaclethra eetveldeana* and *Petersianthus macrocarpus* by one and a half times, is the most important taxon according to the IVI and therefore the most representative of the Mpoh forests in the northern sector of the Léfini reserve.

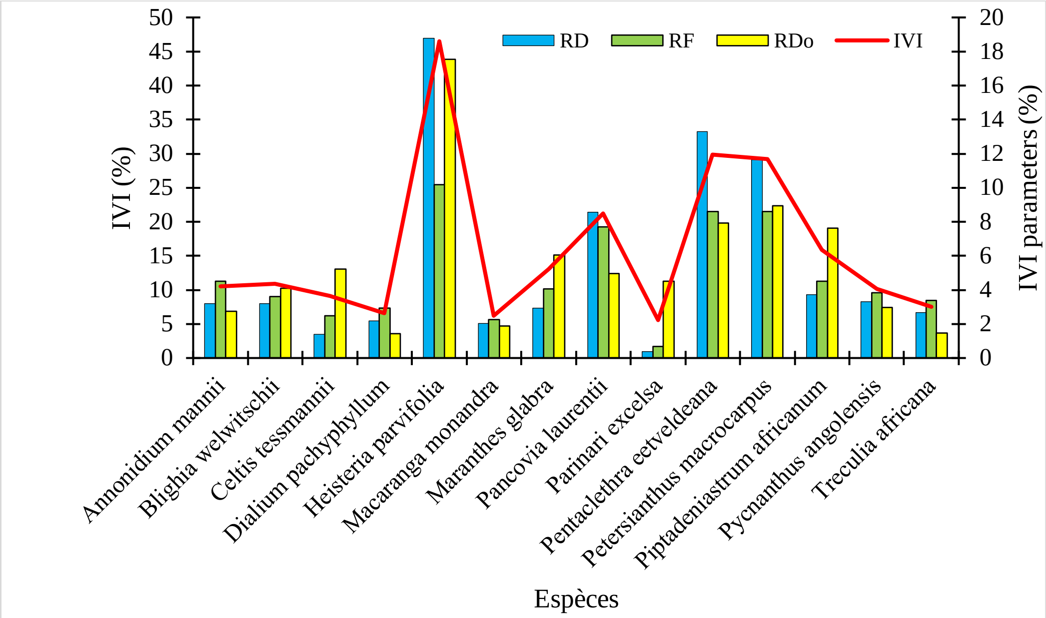

Figure 5: Evolution of IVI by species

Floristic diversity parameter

Floristic similarity coefficient and Biodiversity index: Jaccard's similarity coefficient ranges from 50 to 62.50%. At the 50% similarity threshold, there are no floristic differences between the plots. Shannon's biodiversity index ranges from 2.79 to 2.93, with an average of 2.88 ± 0.04. Maximum diversity (H'max) is equal to 3.61 ± 0.05. As for the equitability index, values range from 0.77 to 0.83, with an average of 0.80 ± 0.02. This range of biodiversity index values highlights the high degree of specific diversity in the Mpoh forest. In addition to this parameter, a homogeneous distribution of taxa is highlighted within this ecosystem (Table 4). Biodiversity parameters subjected to the Anova test, p-value > 0.050, reveal no significant differences between surveys.

Table 4: Comparative synopsis of biodiversity indices

Indices	**Shannon Index (H')**	**Maximum Diversity Index (H'$_{max}$)**	**Equity Index (J)**
P1	2.78 a*	3.61 a	0.77 a
P2	2.92 a	3.69 a	0.79 a
P3	2.93 a	3.53 a	0.83 a
Average ± ES	2.87 ± 0.05	3.61 ± 0.05	0.80 ± 0.02

*Values followed by the same letter in the column are significantly non-different at the $\alpha = 0.05$ threshold according to Tukey's post-hoc test.

Species rarity index (Ri): The rarefaction index shows that 69.81% of taxa in the Mpoh forest have an RI > 80%, and would therefore be considered rare. Among the taxa threatened with extinction in this ecosystem are a number of useful plants such as *Myrianthus arboreus*, *Cola nitida*, *Allanblackia floribunda*, *Grewia coriacea*, *Morinda lucida*, *Irvingia gabonensis*, *Canarium schweinfurthii*, *Chrysophyllum africanum*, *Coelocaryon preussii*, *Pterocarpus soyauxii*, *Entandrophragma* *candollei*, *Millettia laurentii*, etc. Conversely, 30.19% of taxa have an RI < 80% and are classified as preferential, i.e. frequent and abundant. Among these are *Heisteria parvifolia*, *Petersianthus macrocarpus*. *Staudtia kamerunensis*, *Pycnanthus angolensis*, *Anonidium mannii*, *Treculia africana*, etc. Notwithstanding the level of anthropization, ecological behaviour and the efficiency of the mode of dissemination would be factors to be taken into account in understanding the evolution of these taxa in the Mpoh forest. In addition, the socio-cultural value associated with certain taxa, such as *Petersianthus macrocarpus*, is not irrelevant to their influence.

Ecological parameters

Types of diasporas: Analysis of the types of spread reveals four types of diasporas. Sarcochores (76%) outnumber pterochores (16%) by almost five to one, and ballochores (2%), which are the least represented, by 38 to one (figure 6). The weighted spectrum reveals that sarcochores (67%) dominate pterochores (18%) by almost 4 times, and ballochores are still the least represented at 0.5% (figure 6). These results, which highlight zoochore dissemination, in particular endozoochory, reflect a state of maturity acquired by this woody formation, symbolizing an evolutionary mutualism between the tree and the agent of dissemination.

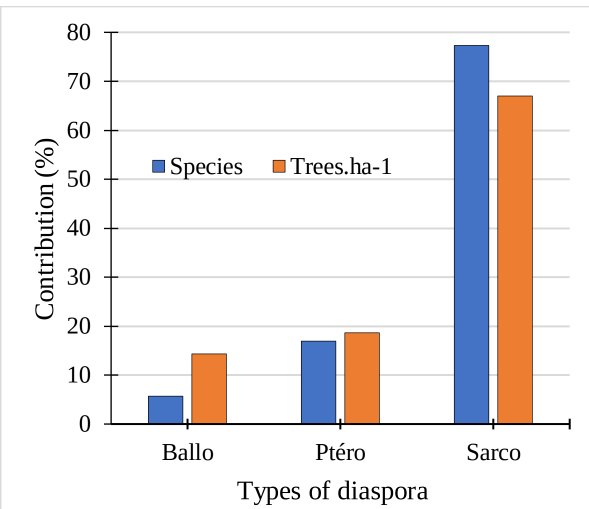

Figure 6: Spectra of diaspore types in the forest of the Léfini reserve
Legend: Raw spectrum (Species); weighted spectrum (Trees.ha^{-1})

Leaf types: Analysis of the crude spectrum of leaf types shows mesophylls (77%) to be 7 times more dominant than microphylls (11%) and macrophylls (4%), the least represented type, to be 19 times more dominant (Figure 8). As for the weighted spectrum, mesophiles (79%) clearly dominate leptophylls (17%) by 5 times, in terms of individuals inventoried. Macrophylls, with 0.5%, are the type least present in the Mpoh forest (Figure 7). The dominance of mesophylls is a sign of the maturity reached by this ecosystem.

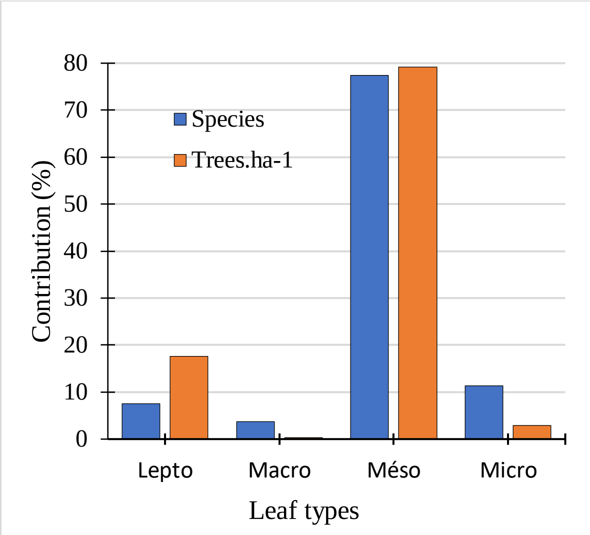

Figure 7: Leaf spectra of the Mpoh forest, Léfini reserve
Legend: Raw spectrum (Species); weighted spectrum (Trees.ha^{-1})

Phytogeographical types: Phytogeographic analysis of taxa in the Mpoh forest identifies six element types, of which Guinean-Congolese is predominant. The raw spectrum shows that Guinean-Congolese species (63%) dominate Lower-Guinean-Congolese (20%) by a factor of 3, and Afro-tropical (10%) by a factor of 6. Guinean-Congolese-Sudanese species are the least represented at 2% (figure 8). The weighted spectrum also shows a dominance of Guinean-Congolese taxa (64%), equivalent to twice that of Lower-Guinean-Congolese (30%). The least represented element is Guinean-Congolese-Sudanese, with 0.2% of individuals inventoried (figure 8). This analysis shows the dominance of the endemic Guinean-Congolese element and a minority representation of intrusion taxa. Like the Congolese flora, the flora of the Mpoh forest in the northern sector of the Léfini reserve remains pure, despite developing almost exclusively in the "Sangha River" corridor.

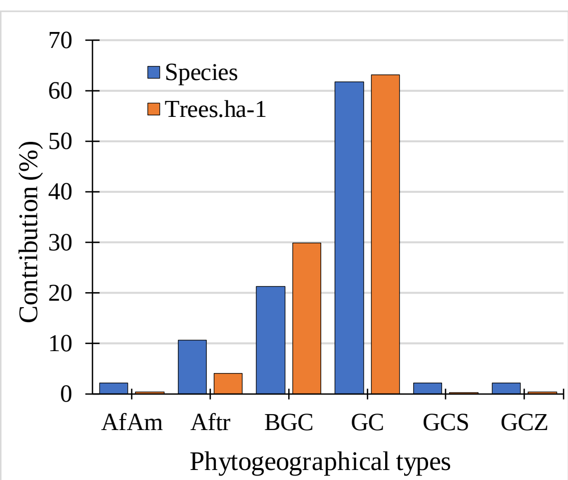

Figure 8: Spectra of phytogeographical types in the forest of the Léfini reserve
Legend: Raw spectrum (Species); weighted spectrum (Trees.ha^{-1})

DISCUSSION

Floristic diversity analysis: A refined analysis of floristic diversity reveals that the Mpoh forest, in the northern sector of the Léfini reserve, is a paucispecific and pauciflorous formation (Lubini, 1997; Kimpouni, 2009; Rakotondrasoa *et al.*, 2013; Kimpouni *et al.*, 2017). This double marking would be a sign of affinity and/or belonging to mesophilic and tropophilic formations, a variant of Central African rainforests (Senterre, 2005; Kimpouni, 2009; Kimpouni *et al*., 2012, 2013a, b, c;). A refined analysis of the floristic composition, coupled with phytosociological data from known Congolese forests, supports Mpoh's classification as a Central African dense forest (Lebrun & Gilbert (1954). This classification concerns ecosystems at the edge of the evergreen forests of the Strombosio-Parinarietea, and especially the Gilbertiodendretalia order and the semi-deciduous Piptadeniastro-Celtidetalia forests of the Oxystigmo-Scorodophloeion alliance (Cusset 1989). The syntaxinomic classification recognizes three classes of ecological facies, namely: (i) the Mitragynetea; (ii) the Musangio-Terminalietea with the orders Musangetalia and Fagaro-Terminalietalia; the alliances Musangion cecropioides and Pycnantho-Fagarion; and (iii) the Strombosio-Parinarietela with the orders Gilbertiodendretalia and Piptadenio-Celtidetalia of the alliance Canarion schweinfurthii (Kimpouni *et al*., 2013c; Cusset 1989; Mosango 1991a, b; Van Asbroeck *et al*. 1997). This phytosociological analysis underpins the foundation of forest facies within this ecosystem and, ultimately, the irregular distribution of flora in this physiographic unit (Kimpouni *et al*., 2013c; Kimpouni, 2006; Kouka, 2001, 2006; Van Asbroeck *et al*., 1997; Mosango 1991a, b). This analysis highlights (i) the Piptadenio-Celtidetalia and Oxystigmo-Scorodophloeion on the one hand, and the *Canarion schweinfurthii*, and (ii) the Gilbertiodendretalia order of the Strombosio-Parinarietela, which would be weakly, marked, given the intrinsic trait of *Gilbertiodendron dewevrei.* The Mpoh forest is dominated in terms of floristic composition by Fabaceae, one of the outstanding families of Central African rainforest ecosystems (Kouka, 2006; Kimpouni, 2009; Kimpouni, 2017; Nangalire *et al*., 2017; Gueulou *et al*., 2018; Kimpouni *et al*., 2020; Miabangana and Malaisse., 2020). However, abundance-dominance analysis authenticates *Heisteria parvifolia* (Olacaceae) as the marker of this forest ahead of *Pentaclethra eetveldeana*. In addition to pedoclimatic factors, this specific characterization is dependent on anthropic actions, in particular the exploitation of timber, which is highly selective, and on factors intrinsic to the species. It should be noted that timber-harvesting operations degrade forest ecosystems. By focusing on just a few taxa, lumber milling encourages the development of non-bearing species to the detriment of those with high economic value. Concomitantly, the harvesting of non-timber forest products, especially generative organs, strongly modifies the structure of the forest and its canopy (Tchatat et Ndoye, 2006; Agbangla *et al*., 2015). Indeed, the degree of canopy openness is an asset for the development of the two dominant species (*Heisteria parvifolia* and *Pentaclethra eetveldeana*), which are semi-heliophilous and strict heliophilous, characteristic of disturbed forests whose growth is important in the presence of light (Hladick and Blanc, 1987). Despite their canopy behaviour, the fact that *Heisteria parvifolia* and *Pentaclethra eetveldeana* have no traditional use in the region means that anthropogenic pressure on their stands is very low. Another advantage, which argues in favour of their development, is the efficiency of their dissemination, a factor in the sustainability of forest stands (Kimpolo *et al*., 2021). This observation is strongly supported by statistical analyses and biodiversity indices. Ecological behaviour coupled with anthropogenic activities carried out in forest facies are responsible for the reduction in stands of certain taxa (Kimpouni *et al*., 2013a; Ngodo *et al*., 2017; Kouakou *et al*., 2018). Reserve status notwithstanding, the proximity and cohabitation of local residents places them in a position of vulnerability. Easy access to various forest products within easy reach is to the benefit of distant facies, with virtually no signs of harvesting. Unregulated extractivism often results in windthrows and gaps that encourage the establishment of pioneering heliophilous taxa, such as Macaranga spinosa and *Musanga cecropioides*, indicative of disturbed environments (Dupuy, 1998; Kengue *et al*., 2018). These anthropogenic practices can have negative effects on certain taxa, causing their rarity and being the cause of the large cohort of species threatened with extinction, within the Mpoh forest, of the northern sector of the Léfini reserve (Kimpouni *et al*., 2012).

Structural analysis: This ecosystem, dominated by mesophyll species, not only attests to the stage of maturity reached by the ecosystem, but is also a characteristic of dense tropical rainforests (Miabangana *et al*., 2016). In addition, the strong anthropogenic pressures suffered by this forest favour the development of heliophilous plants over the most ecologically demanding (sciaphilous), while at the same time imprinting the physiognomy of the original vegetation (Kimpouni, 2017; Miabangana, 2019; Taonda *et al*., 2021). Indeed, the selective cutting of small-diameter taxa favours the development of small-diameter individuals that recolonize and ensure the reconstitution of the environment after the opening of the canopy. Anthropogenic action notwithstanding, the Mpoh forest in the dense ombrophilous formations of the Congo Basin is a pauciflorous facies whose floristic affinities no longer need to be demonstrated (Kimpouni, 2009; Kimpouni *et al*., 2013c, 2019; Miabangana and Malaisse, 2020). This observation on structural parameters, particularly density, places it in the group of mesophilic and tropophilic formations (Puig, 2001; Guillaud, 2003; Kimpouni *et al*., 2012, 2013, 2014). In relation to data from dense tropical rainforests, recorded densities are far from integrating the range of known values (Ghate *et al*., 1998; Pascal, 2003). In addition to density, data on basal area and the ratio of basal area to density confirm the atypical nature of this facies within Central African rainforests, with their low values (Reitsma, 1988; Dupuy, 1998; Puig, 2001; Kimpouni *et al*., 2013a). The high proportion of small-diameter trees highlighted by the basal area/density ratio could be explained by the selective removal of large-diameter individuals, which gives the said ecosystem a trait of flora reconstitution after disturbance. Indeed, a disturbed ecosystem may recover its functioning long before the initial floristic composition is fully restored (Adiko *et al*., 2020). Lastly, this reflection is supported by the erratic pattern of the diametric structure, which shows poor recruitment within the diameter classes (Dupuy, 1998; Pascal, 2003; Miabangana and Malaisse, 2020). The reasons for the poor transition from one diameter class to another can be found in environmental disturbance (Peters, 1997; Puig, 2001; Sounon Bouko *et al*., 2007; Kimpouni *et al*., 2019).

Spatial distribution of flora: Although a refined analysis of the data confirms the existence of an underlying or even discrete gregariousness for certain taxa, the Mpoh forest ecosystem as a whole shows a random distribution. This distribution pattern could be based on the efficiency of diaspora dissemination, mainly ballochore, taxon ecology (intrinsic factors) or secondary dissemination (Janzen, 1970; Kumba *et al*., 2013). Intrinsic plant factors include ecological behaviour, edaphic factors, adaptability and intra- and interspecific competition (Pascal, 2003; Kumba *et al*., 2013; Kouadio *et al*., 2014). The dominance of sarcochores reflects a high degree of maturity acquired by this ecosystem and the evolutionary symbol of plant-disseminating agent mutualism (Puig, 2001; Beaufort, 2017; Adiko *et al*., 2020). The predominance of sarcochores confirms sarcochory, particularly zoochory (endozoochory), as the main mode of dissemination in the Mpoh forest, associated with a high floristic diversity of fleshy-fruited species (Reira *et al*., 1989; Sonke, 1998; N'dja Kassi *et al*., 2012; Ngueguim *et al*., 2016).

Phytogeographical analysis: Phytogeographical data for the Mpoh forest, in the northern sector of the Léfini reserve, reveal a preponderance of Guinean-Congolese endemics, both floristically and specifically. The basic Lower Guinean-Congolese element is well marked in the flora, reflecting the affinity of the Mpoh forest with the dense tropical rainforests of the Congo Basin, and more specifically with the Lower Guinean subcenter of endemism (White, 1979, 1986). The remarkable presence of Omni-Guinean-Congolese species really confirms that the forest in the northern sector of the Léfini Reserve is almost entirely free from the floristic influence of neighbouring regions (White, 1986). Like the flora of the Congo in general, despite developing in the "Sangha River" corridor, the flora of the Mpoh forest remains pure White (1979).

CONCLUSION

The Mpoh forest, in the northern sector of the Léfini reserve, is a mesophilic, tropophilic formation. This atypical ecosystem is particular facies within the dense rainforests of Central Africa. Despite recurrent human activities, the flora of the Mpoh forest is naturally little influenced by the intrusion of non-native species from the Guinean-Congolese center of endemism, although they do evolve in the Sangha River corridor. As such, this flora can be described as pure. The impact of human activity is such that the woody cohort is made up of small-diameter trees. This, coupled with the canopy's openness, which favours the development of pioneering heliophilous species due to strong light penetration, gives this ecosystem a state of perpetual vegetative reconstitution. However, the dominance of sarcochores is a tangible symbol of the high degree of maturity reached by this forest.

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