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Contribution To The Study Of Flora And Vegetation Inongo Peat Bogs In The Concession Area Wildlife Works Carbon/Era-Congo In The Democratic Republic Of Congo

[Contribution A L'étude De La Flore Et De La Végétation Des Tourbières d'Inongo Dans La Concession Wildlife Works Carbon / Era-Congo En République Démocratique Du Congo]

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Abstract

A floristic, phytogeographical and phytosociological study of the vegetation in peatland areas was carried out between 2023 and 2024 in the Wildlife Works Carbon/Era-Congo concession at Inongo in the DRC. Direct observation, floristic inventory and field and laboratory identification methods were used. The concession covers an area of 301,100 hectares, lying between 17° and 18°20' East longitude and between 1° and 2° South latitude. All the species recorded belong to 90 genera and 46 families. Phytosociological surveys were carried out in two vegetation types: mature forests on hydromorphic soils and periodically flooded secondary forests. No species endemic to the region was found among the 121 species of the florarium studied. This study shows that the majority of species are dicotyledons or Magnoliopsida with 93.47% and 15.21% of Liliopsida, which together form the large representative group of Magnoliophyta (Angiospermae). Pteridophyta account for 6.52%, and Gymnospermae (Pinophyta) are completely absent. Most of the species are found in marshy areas, but a few (species) of them are transfuges from terra firma soils. These include Syzygium guineense, Bridelia ferruginea, Pterocarpus angolensis, Vitex madiensis, etc.

Key words: Era-Congo, peatland, flora, phytosociology, phytogeographic spectra.

Résumé

Une étude floristique, phytogéographique et phytosociologique de la végétation de zones à tourbières, a été réalisée entre 2023 et 2024 dans la concession Wildlife Works Carbon/Era-Congo d'Inongo en RDC. Les méthodes d'observation directe, d'inventaire floristique et d'identification sur terrain et au laboratoire ont été utilisées. Cette concession s'étend sur une superficie de 301.100 hectares, elle est comprise entre 17° et 18°20' de longitude Est et entre 1° et 2° de latitude Sud. L'ensemble des espèces répertoriées appartiennent à 90 genres et 46 familles. Les relevés phytosociologiques ont été réalisés dans deux types de végétation: forêts matures sur sols hydromorphes et forêts secondaires périodiquement inondées. Aucune espèce endémique pour la région n'a été décelée parmi les 121 espèces de la florule étudiée. Il se dégage de ceette étude que la majorité des espèces sont des dicotylédones ou Magnoliopsida avec 93,47 % et 15,21 % des Liliopsida qui, ensemble forment le grand groupe représentatif des Magnoliophyta (Angiospermae). Les Pteridophyta comptent 6,52 % et une absence totale des Gymnospermes (Pinophyta). La plupart des espèces sont des zones marécageuses, cependant quelques-unes (espèces) d'entre elles sont des transfuges de sols de terre ferme. Il s'agit des espèces comme Syzygium guineense, Bridelia ferruginea, Pterocarpus angolensis, Vitex madiensis, etc.

Mots clés: Era-Congo, zone à tourbière, flore, phytosociologie, spectres phytogéographiques.

1. Introduction

The mosaic distribution of vegetation due to slight micro-topographical and edaphic variations and the superimposition of plant communities of different natures, makes it particularly difficult to analyze the

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vegetation dynamics of the peatland zone in the Congo Basin, especially in the Democratic Republic of Congo.

The flora and vegetation of many Congolese regions have been the subject of several floristic and phytosociological studies, notably that of the mountainous eastern region (Lebrun, 1947; Robyns, 1950a and b; Germain, 1952; Hauman, 1933; Léonard, 1962). These works relate to the flora of Albert National Park (Virunga), the vegetation of the alluvial plains south of Lake Edouard and the vegetation of the Ruzizi plain, as well as the study of the flora of the Ruwenzori western flank. In the south-east, we can cite Focan & Mullenders (1949), Duvigneaud (1953), Schmitz (1950, 1952, 1963), Mullenders (1954) and Malaisse (1997). This work covers the flora and vegetation of the Zambezi open forests (Miombo) and the Guinean-Congolese and Zambezi regional transition zone, as well as grassland formations. More recently, the work of Malaisse (1997) on the resources of the clear forests of Haut-Katanga completes the floristic and phytosociological aspects. In the Yangambi, Kisangani and Mbandaka regions of the central basin, work on flora and phytosociology has been carried out by Louis (1947), Léonard (1947, 1952), Germain & Evrard (1956), Dhetchuvi and Lejoly (1990) and others. In the latter region, floristic, ecological and phytosociological work continued after independence with researchers from the Universities of Kinshasa and Kisangani (Evrard 1968; Lubini, 1982; Mandango, 1982 and 1988; Nyakabwa, 1982; Mandango & Nyakabwa, 1988; Ntahobavuka & Nyakabwa, 1988; Nyakabwa, 1988; Mosango, 1990; Bebwa et al., 1990; Apema et al., 1994). This zone is one of the best floristically and phytosociologically known. In the South-West, the work of Devred (1954, 1956, 1957, 1958), Lubini & Mandango , Lubini (1990, 1997), Masens (1997), etc. is worthy of note. The work of these various authors relates to flora analysis, phytosociology and the use of plant genetic resources. Wetlands are complex, fragile and diverse environments. They are among the richest ecosystems on the planet, second only to tropical forests in terms of biological diversity and natural productivity (Pearce & Crivelli, 1994).

Tropical forests are at the heart of international issues concerning climate change and biodiversity conservation. As the second largest tropical forest ecosystem after Amazonia, the Congo Basin plays an important role in the continental and even global climate system. Africa's forests provide a livelihood for 60 million people who live in or near them (food, medicine, fuel, fiber, non-timber forest products). They also fulfil social and cultural functions. More indirectly, these forests help to feed the 40 million people who live in urban centers close to these forest estates (Nasi et al; 2011).

Carbon sequestration has often been described as one of the key services provided by tropical forests. Yet wetlands also have this capacity (Turpie et al., 2010). According to Chmura et al (2003), wetlands are the most important natural carbon sinks, provided they are in good health. Several processes are at work. Under anaerobic (oxygen-poor) conditions, peat is formed from dead plant material. Anaerobic conditions result from soil saturation, a situation in which the activities of aerobic bacteria are limited by the lack of oxygen. These organisms are therefore unable to decompose organic matter, including organic carbon, as they would under aerobic conditions.

The forests of the Democratic Republic of the Congo cover an estimated 155.5 million ha (including 99 million ha of dense rainforest), or 67% of the country's total land area of 2,329,374 km². They account for almost half of Africa's tropical rainforests. According to estimates by the United Nations system (UNPP, 2006), the aim of this study is to make a contribution to our knowledge of the peatland flora, the life traits of the various species that make up the floristic reservoir and the different plant assemblages of the periodically flooded marsh flora, in order to reduce the gaps and uncertainties concerning the floristic potential of peatland areas.

The overall objective of this research is to deepen scientific knowledge about peatlands in order to assess their current state by establishing their natural capital based on data on floral diversity in the Era-Congo concession in Inongo, with a view to providing useful information for effective management and rational use among the Bolia, Ntomba, and Basengele peoples.

The specific objectives derived from the general objective are to inventory and identify the plant species that predominate in the Inongo peatlands in the Era-Congo concession.

2. Material and methods

2.1. Study environment

The study was conducted from August 2023 to August 2024 within the Era Congo conservation concession, located in Mai Ndombe province, in the territory of Inongo. Covering an area of 301,100 hectares, this zone is located near Lake Mai-Ndombe, between longitudes 17° and 18°20' East and latitudes 1° and 2° South (Bwangoy, 2013).

Characterization by an Aw4 climate according to the Koppen classification, the site has an average temperature of around 30°C with little variation (around 1°C). In addition, annual rainfall exceeds 1,900 mm. The vegetation is mainly composed of two categories : dey forests and flooded or swamp forests. The latter constitue a substantial part of the territory, covering more than 45% of the total area of the concession (Bwangoy, 2013).

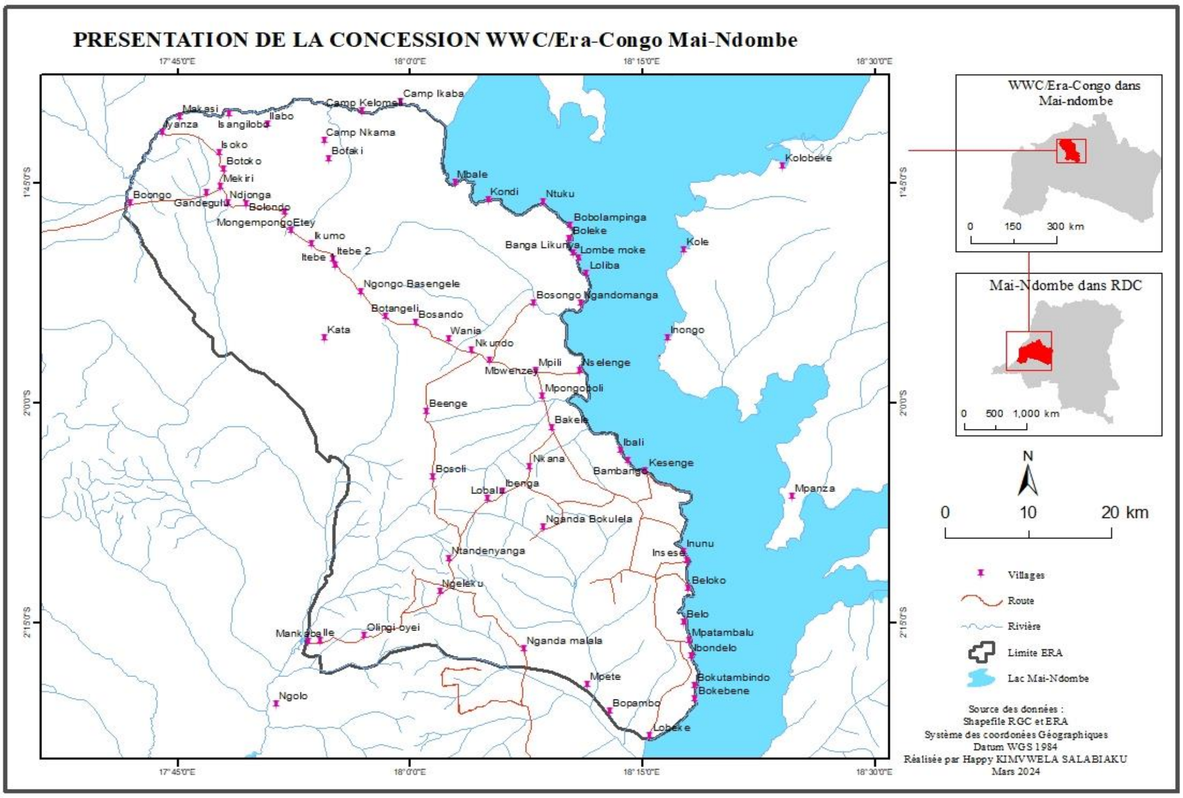


Figure 1. Location of the WWC / ERA - Congo concession in the DRC

2.2. Materials

The materials used for this work are biological materials and equipment:

2.2.1. Biological material

The research we carried out enabled us to identify specimens of 121 plant species that served as biological material.

a) Observation methods

We used direct observation methods: floristic inventories of peatland areas, collection and identification of samples in the field and in the laboratory, and statistical analysis of the data.

The observations enabled us to assess the structure and dynamics of swamp forests throughout the Era-Congo Inongo concession.

b) Botanical and wildlife data

Direct observations, interviews, and wildlife inventory reports

Interviews, direct observations of animals and fish from fishing activities in the peatlands, and consultation of wildlife inventory reports for the study area were used to characterize the wildlife.

c) Botanical inventory plots

Five permanent plots measuring 0.25 hectares, or 50 m x 50 m (for a total area of one hectare), were set up in a peatland stand. (Figure 2). The botanical inventory of the area consisted of identifying the families and species of characteristic plants (trees, shrubs, and Raphia) along these transects (OSFAC, 2023).

The phytosociological survey method developed by Braun-Blanquet (1932, cited by Belesi, 2009) was chosen for our study. Recognized for its rigor and ability to provide a detailed description of plant communities, it is particularly relevant in the Congo Basin. We adapted it to the specific context of the tropical forest in order to ensure an accurate understanding of the structure and dynamics of the vegetation.

d) Plot installation system

Figure 2. Plot layout according to Japan International Cooperation Agency FAO, 2019

Plot coding :

P1: first plot, P2: second plot, P3: third plot, P4: fourth plot, P5: fifth plot, B1,..., B9: blocks within a plot

2.2.2. Equipment

In all fields of science, there are certain tools appropriate for manipulation. The present study required the use of a number of tools for collecting botanical and other specimens:

- Corer;
- Canon camera;
- Garmin Dakota 20 GPS;
- Pruning shears ;
- Boots ;
- 100-meter ribbon;
- Pairs of wooden presses (41 x 29 cm);
- Newspaper wrappers (41 x 21 cm);
- Bags for transporting material in the field.

2.2.3. Biodiversity indices

Diversity indices, such as the Shannon index, the Pielou index, and the Simpson index, were used to analyze biodiversity in the various plots of the Era-Congo concession.

This index (H’) is calculated using the following formulas:

The Simpson index (D) is therefore the sum of the squares of the relative frequencies (pi) of individuals of each species and is expressed as:

$D = \sum (pi)^2$;

This expression of the Simpson index is a measure of dominance rather than diversity. When thinking in terms of diversity, (Danais, 1982) recommends calculating its reciprocal index 1 – D so that a high index reflects high diversity:

$1 - D = 1 - \sum (pi)^2$

In this study, we preferred the first expression because it is the most commonly used in phytosociology to determine the diversity of associations. We also used the reciprocal index. It allows us to identify the different groupings and associations present in our study area.

$H' = - \sum pi \log_2 pi$; where pi (between 0 and 1) is the relative frequency of individuals of species (i) in the grouping.

For phytosociological surveys, it is calculated based on the average coverage (ni) of each species. Thus, the relative frequency of species (i) will be:

$p_i=n_i/ (\sum N_i)$ (with $\sum$ Ni as the total coverage of all species).

This diversity index varies both according to the number of species present and according to the relative coverage of the various species. It is expressed in units of information per individual (or bits per individual).

This diversity index varies according to both the number of species present and the relative coverage of the various species. It is expressed in units of information per individual (or bits per individual).

Piélou's evenness index (1966)

Also known as “evenness” (sensu Piélou, 1966) or regularity (R) (sensu Frontier & Pichod-Viale, 1995), this index is relative diversity, i.e., the ratio of observed diversity H' to maximum observable diversity (H'max) with the same number of species. Relative diversity is therefore determined using the Shannon-Weaver index (H'):

$E(R) = H'/ \log_2 S$

where S is the total number of species or specific richness and $\log_2 S$ = H'max. Regularity then becomes:

$E(R) = H'/H'max$

In dense forests, regularity values commonly vary between 0.75 and 0.98 (Rollet cited by Kouka, 2000). It therefore varies between 0 and 1.

3. Results

3.1. Diversity indices based on plots in the Era-Congo concession

Data on spatial variations in diversity indices include species richness, overall abundance, dominance, and Shannon and evenness indices for each of the five plots, as shown in table 1.

Table 1. Spatial variations in different diversity descriptors in peatland areas

Indices	Era-Congo concession plots				
	P1. Ilee	P2. Botembo	P3. Mpongoboli	P4. Bombokili	P5. Nsanga
Taxa_S	114	112	112	112	115
Individuals	696	719	717	719	730
Dominance_D	0.01495	0.01627	0.01519	0.01572	0.016
Simpson_1-D	0.9851	0.9837	0.9848	0.9843	0.984
Shannon_H	4.424	4.376	4.411	4.395	4.396
Equitability_J	0.9342	0.9273	0.9348	0.9313	0.9264

Table 1 shows the spatial variations in several diversity indices for five plots during the two seasons.

The P2_Botembo, P3_Mpongoboli, and P4_Bombokili plots have a taxonomic richness of 112, while the P5_Nsanga and P1_Ilee plots have a slightly higher richness with 115 and 114 taxa, respectively. This indicates that the P5_Nsanga plot has greater species diversity compared to the other plots.

The P5_Nsanga plot has the highest number of individuals (730), followed by the two plots P3_Mpongoboli and P4_Bombokili (719), which are relatively abundant in this edition. This suggests that the P5_Nsanga plot is the richest in terms of population, which may influence ecological interactions.

Dominance values are relatively similar between plots, with values ranging from 0.01495 to 0.01627. Lower dominance indicates a more equitable distribution of individuals among species. Plot P1_Ilee has the lowest dominance, which could indicate a better distribution of species.

Simpson_1-D index values range from 0.9837 to 0.9851, with plot P1_Ilee having the highest value and the others being very poorly represented.

The equitability_J values range from 0.9264 to 0.9348, with plot P3_Mpongoboli having the highest value (0.9348), which means that it has a more equitable distribution of individuals among species, a positive indicator for ecosystem health.

3.2. Floristic composition

The flora of the Era-Congo concession in the peat bog zones is rich and diverse in species. There are a total of 121 species belonging to 90 genera in 46 botanical families. The families with the highest number of species in peatland areas are Fabaceae (16 species), followed by Rubiaceae (8 species), Euphorbiaceae (5 species), Annonaceae (6 species) and Melastomataceae (6). Other families are very poorly represented. Hierarchy of the higher units making up the peatland florarium (table II)

Table II. Upper unit hierarchy

SYSTEMATIC GROUPS	FAMILIES		GENUS		SPECIES	
	Number	%	Number	%	Number	%
Pteridophyta	3	6,52	3	3,33	5	4,13
Pinophyta	0	0	0	0	0	0
Magnoliophyta	**43**	**93,47**	**87**	**96,66**	114	94,21
Monocots (Liopsida)	7	15,21	15	16,66	14	11,57
Dicots (Magnolipsida)	36	78,26	72	80	100	82,64
Total	**46**	**100**	**90**	**100**	**121**	**100**

This table shows the importance of each family in terms of number of species and genera. Table II shows that the majority of species are dicotyledons or Magnoliopsida, with 93.47% and 15.21% Liliopsida, which together form the large representative Magnoliophyta group (Angiospermae). Pteridophyta account for 6.52%, and Gymnosperms (Pinophyta) are completely absent. These species originate from the marshy zone, although a few are transfuges from dry land soils. These include Syzygium guineense, Bridelia ferruginea, Pterocarpus angolensis, Vitex madiensis and others.

3.3. Autoecological characteristics

For studies of the ecological spectra of peatland species, six parameters were taken into consideration: phytogeographical distribution, biological types, leaf size types and diaspore types, and phytosociological status.

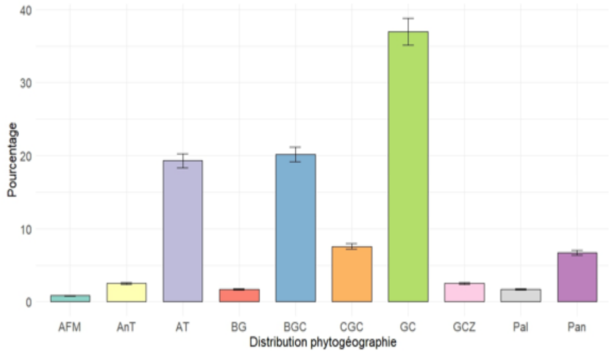


Figure 3. Phytogeographical distribution spectrum

Results on phytogeographical distribution, presented in figure 3, show that Guineo-Congolese species are the most numerous (36.97%), followed by Bas-Guineo-Congolese (20.16%), and Afro-tropical (19.32%). Centro-Guineo-Congolese and Pantropical species are relatively present in this section. The centesimal values of other phytogeographical types are very low.

3.4. Caractéristiques physiques des eaux des forages des forages des mini AEP de la Région de Maradi

The calculated values are shown in figure 4, which highlights the predominance of phanerophytes (Ph) with 64 species (53.78%), and the supremacy of mesophanerophytes (36.13%), with the others being very poorly represented.

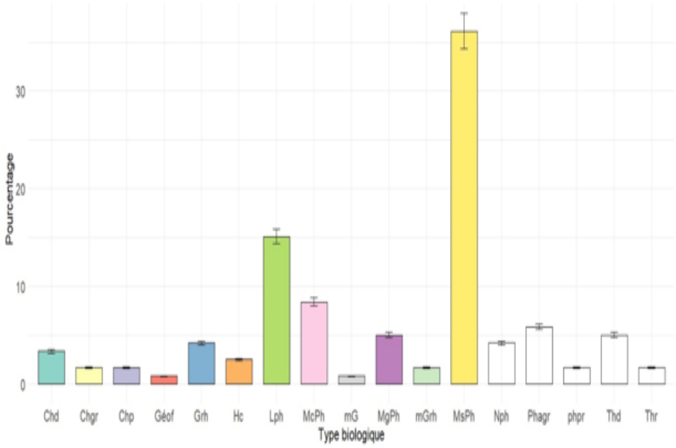


Figure 4. Spectrum analysis of floriculture biological types

3.5. Types of diaspore

In the peatland flora of the wetlands of the Era-congo concession, we have recognized the diaspore types represented in the following figure 5:

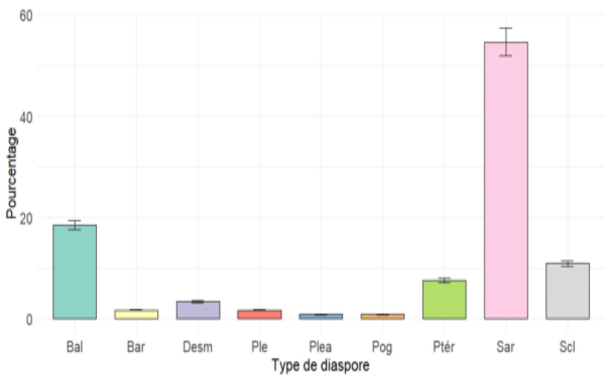


Figure 5. Spectrum analysis of diaspora types

The results of the diaspore type analysis in figure 5 confirm the predominance of sarcochore species (54.62%), followed by ballochores (18.48%) and a low representation of barochores (1.68%) and pogonochores (0.84%).

3.6. Leaf size types

With regard to the spectra of leaf size types for the flora of peatland species in the Era-congo concession in Mai-Ndombe province, figure 6 below illustrates the centesimal proportions for each category of leaf size types present.

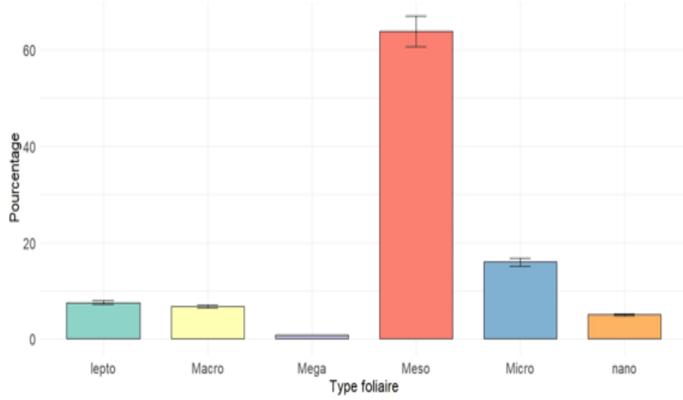
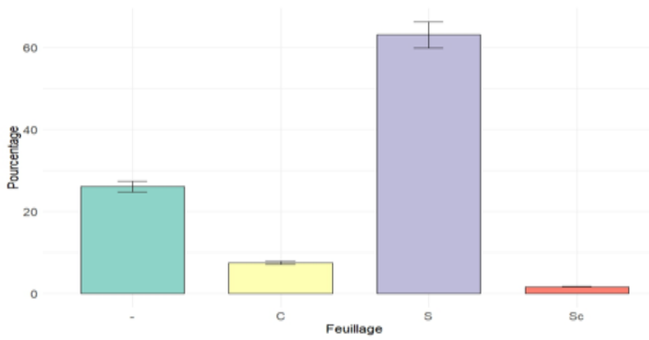


Figure 6. Spectra of leaf size types

This figure shows a high representation of mesophyll species (63.86%), microphyll species (15.96%) and leptophyll species (7.56%), and a low representation of megaphyll species (0.84%).

3.7. Foliage behaviour

With regard to the foliage behavior of the vegetation species studied, an analysis of figure 7 below reveals the predominance of evergreen species (63%) and semi-evergreen species (26.5%).



3.8. Phytosociological status of Mai-Ndombe peatland flora species

Figure 8 below shows the phytosociological status of the species studied in the context of this study.

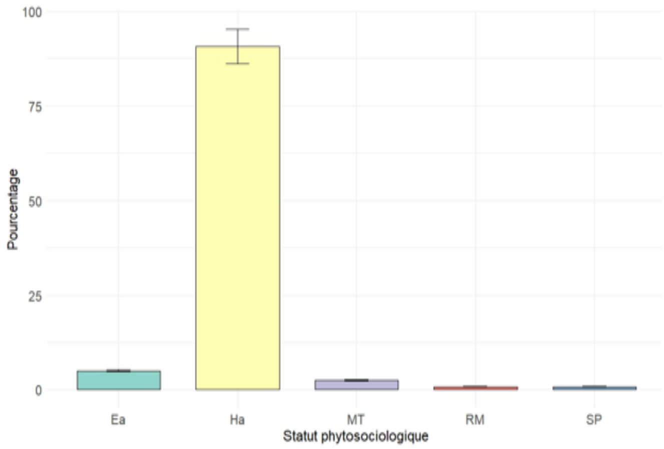


Figure 8 shows that Mytragyneatea (Halleetea) species dominate at 99.75%.

All other species are very poorly represented. However, the Erythrophleetea africanae are slightly better represented than the other species in the florarium.

4. Discussion

With regard to flora, the inventory carried out lists 121 different species belonging to 90 genera in 46 different families. These results are much higher than those reported by (Etepe, 2024 ; PIREDD Mongala, 2023 ; and Denis, 2023). The families best represented in terms of species in peatland areas are Fabaceae (16 species), followed by Rubiaceae (8 species), Euphorbiaceae (5 species), Annonaceae (6 species), and Meslastomataceae (6 species). In terms of species families, these results confirm those of (Etepe, 2025 and PIREDD Mongala, 2023) that the Fabaceae family is predominant in terms of species numbers. Other families are very poorly represented. This confirms our initial hypothesis that the Inongo peatlands, being wetlands that are still untouched, still retain their rich and diverse natural flora intact.

The dominance values are relatively similar between the plots, with values ranging from 0.01495 to 0.01627. Lower dominance indicates a more equitable distribution of individuals among species. Plot P1_Ilee has the lowest dominance, which could indicate a better distribution of species. These results confirm those of (Etepe. 2025) on the biodiversity index. The Simpson_1-D index values range from 0.9837 to 0.9851, with plot P1_Ilee having the highest value and the others being very poorly represented. The equitability_J values range from 0.9264 to 0.9348, with plot P3_Mpongoboli having the highest value (0.9348), which means that it has a more equitable distribution of individuals among species, a positive indicator for ecosystem health.

Among the most representative families, woody plants are found among the Fabaceae, Rubiaceae, and Euphorbiaceae. The predominance of these three families is also reported by several authors who have worked in the central basin of the Congo (Etepe, 2025; Dargie et al., 2019; Eba'a Atyi et al., 2022; IPCC, 2023).

These results confirm those of Lebrun & Gilbert (1954) and Evrard (1968), these species are dicotyledons or Magnoliopsida with 93.47% and 15.21% of Liliopsida which, together with the previous ones, form the large representative group of Magnoliophyta (Angiospermae). Pteridophyta account for 6.52% and there is a total absence of Gymnosperms (Pinophyta). This explains why the study area is swampy, although some of these species are transplants from dry land. This can be explained by the fact that the study area is swampy, so that the only forest species in this group is from dry land.

The flora of the DRC has been studied by many authors, including Lebrun (1947); Duvigneaud (1949); Germain and Evard (1956); Mandango (1982); Lubini (1982, 1995, 1997, 2001); Belesi et al. (1996, 1998, 1999); Belesi (2006, 2007) cited by Belesi (2009); Belesi (2011, 2016); and Habari (2009). However, these various studies did not cover the entire country and obtained diverse results depending on the areas surveyed.

Analysis of the phytogeographic distribution of the species recorded revealed that the species listed are widely distributed throughout the world. The results on phytogeographic distribution show that Guineo-Congolese (36.97% of species), Lower Guineo-Congolese (20.16% of species), Afro-tropical (19.32% of species), and finally pantropical (6.72% of species) species are widely distributed throughout the world. The other species are very poorly represented, particularly Guineo-Congolese-Zambesian species (2.52% of species).

The calculated values highlight a predominance of phanerophytes (Ph) with 64 species, or 53.78%, in this flora, with mesophanerophytes (36.13%) being the most common; the others are very poorly represented.

These results confirm those obtained by (Etepe, 2024; Denis, 2023; Raunkier, 1934; Huntington, 2006; Dargie et al., 2019; Eba'a Atyi et al., 2022; GIEC, 2023) with the predominance of phanerophytes. Previous studies have reported results comparable to those of this study, such as those conducted by Evrard in 1968 on the ecological characteristics of forest stands on hydromorphic soils in the central Congolese basin and Lubini in 1982 and 1997, respectively, on the mesic and post-cultivation vegetation of the Kisangani and Tshopo sub-regions (Upper Zaire) and on the vegetation of the Kisangani National Park (Upper Zaire). 1997, respectively, on the messicole and post-cultural vegetation of the Kisangani and Tshopo sub-regions (Upper Zaire) and on the vegetation of the Luki Biosphere Reserve in Mayombe (Zaire).

The results of the analysis of diaspore types confirm a predominance of sarchore species (54.62%), followed by ballochore species (18.48%) and a low representation of barochore (1.68%) and pogonochore (0.84%) species.

Our study reveals a strong representation of mesophyll species (63.86%), microphyll species (15.96%), and leptophyll species (7.56%) and a low numerical representation of megaphyll species (0.84%).

With regard to the foliage behavior of the species of vegetation studied, the analysis shows a predominance of evergreen species (63%) and semi-evergreen species (26.5%).

5. Conclusion

The aim of the work carried out on the floristic inventory of peatland areas in the Wildlife Works Carbon/Era-Congo concession, Inongo territory, Mai-Ndombe district (Mai-Ndombe province) was to identify plant species specific to peatland areas, with a view to providing useful information for resource conservation and utilization. Peatlands are particularly fragile environments, sensitive to changes in the climatic and hydrological conditions that are at the root of their development. The heritage value of these ecosystems, due to the richness and biodiversity of their flora, has aroused worldwide interest in the face of climate change.

The inventory reveals 121 species belonging to 90 genera in 46 different botanical families. The families with the highest number of species in peatland areas are Fabaceae (16 species), followed by Rubiaceae (8 species), Euphorbiaceae (5 species), Annonaceae (6 species) and Melastomataceae (6). Of the five species-rich families in the DRCongo, our peatland florarium at the Wildlife Works Carbon/Era-Congo concession in Inongo includes four.It should be noted that mosses and ferns appear to be sparsely represented.

These species play a very important role in the daily lives of the inhabitants of Inongo and the surrounding villages. Poverty is a direct cause of deforestation and environmental degradation. It offers a wide range of opportunities for human activities for the local population. However, the utilitarian value of the species inventoried, in terms of their sustainability and conservation, is not a major concern in the region.

Degradation of vegetation cover, whether anthropogenic or natural, leads to the release of more carbon into the atmosphere than is used by the vegetation during photosynthesis. Conversely, when forest ecosystems are well managed, they act as carbon sinks.

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Conflict of Interest statements

There are no conflicts of interest to declare, as the study was conducted independently.

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F.L.L. participated in data analysis and interpretation.
R.L.S. contributed to data mapping and interpretation.
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