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Floristic composition and woody species diversity in Campo-Ma'an National Park, South Cameroon

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ABSTRACT

The lack of floristic data represents a fundamental obstacle to effective conservation planning and the long-term monitoring of vegetation change within the Campo Ma'an National Park (CMNP). The aim of this study is to characterize the ligneous flora of CMNP to ease management schemes for biodiversity conservation. Ligneous floral inventory was carried out in 115 sample plots of 25m × 25m. All standing and dead trees above 5cm were registered, name, diameter and height taken. The data from the inventory was processed, diversity indices and floristic parameters were calculated with Excel and Stata Softwares. The floristic inventory carried out in CMNP revealed a remarkably high level of woody plant diversity (232 Ligneous species) with a high stem density of 812 stems/ha, recorded in two main strates, mangrove (851 stems/ha) and tropical lowland evergreen forest (810 stems/ha) . Only 3.4% of species occupied more than 50% of the total area, *Diospyros simulans* was present in 82.6% of the total park surface area, *Strombosia pustulata,* (72.2%**)** and *Strombosiopsis tetrandra,* (66.1%). In total, 12.93% of species were classified as threatened according to the IUCN Red List, 0.86% endangered species, 7.76% vulnerable species and 4.3% near-threatened species. *Guibourtia tessmannii, Calpocalyx heitzii*, *Millettia laurentii*, *Drypetes preussii*, *Entandrophragma* spp., *Milicia excelsa* and *Afzelia bipindensis*, show signs of demographic vulnerability with the possibility of local extinction in the long-term. It was recommended that active silvicultural interventions, strict enforcement of harvesting bans of all threatened species, and strengthened anti-logging surveillance to preserve the high conservation value of the CMNP.

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INTRODUCTION

Tropical forests of the Congo Basin constitute the second largest continuous rainforest block in the world after the Amazon and are globally recognized for their exceptional biological diversity, ecological functions, and socioeconomic importance (World Bank, 2025). Ligneous flora encompassing all woody plant life forms including trees and shrubs which constitutes the structural and functional backbone of tropical forest ecosystems. In the tropical humid forests, ligneous species not only determine canopy architecture and microclimate but also provide critical ecosystem services, nutrient cycling, climate regulation, carbon sequestration and storage, hydrological stability, soil protection, and habitat provision for thousands of plant and animal species (Awoke, 2025; Apgaua, 2016).

Among the major forest ecosystems of the Congo Basin, the Campo Ma'an National Park (CMNP), covering 264 064 ha, occupies a strategic position. The Park occupies a unique phytogeographic transition zone between the Atlantic Biafran forests, characterized by oceanically influenced flora, and the wider Guineo-Congolian forest region, resulting in a distinctive assemblage of plant species. This transitional character, combined with the park's mosaic of terra firma forests, seasonally flooded forests, coastal vegetation, rocky outcrops, and mangrove fringes along the Ntem River and Ocean margin, generates exceptionally diverse ligneous flora. The CMNP is internationally recognized for its high floristic richness and ecological importance that contribute significantly to local livelihoods, biodiversity conservation, and ecosystem functioning, recognized globally as one of the 25 most biologically important areas on the planet (NPA, 2024; Brooks, 2004; Tchouto *et al.*, 2006).

Despite its ecological importance, Campo Ma'an National Park faces increasing anthropogenic pressures including illegal logging, agricultural expansion, infrastructure development, mining activities and petroleum exploitation in the adjacent offshore Kribi-Campo zone which generates edge effects and encroachment pressures on the parks vegetation. These disturbances if pronounced threatens forest structure, species composition, regeneration dynamics, and the survival of threatened species. Climate change further compounds these pressures by altering species distribution patterns, forest resilience, and ecosystem stability (Ordway *et al.*, 2019; Fobane *et al.*, 2024; Tchouto *et al.*, 2006). The Ligneous flora of the CMNP remains relatively underexplored compared to other Central African protected areas such as Korup National Park or the forests of the Dja Biosphere Reserve.

The majority of studies in regards to biodiversity conservation including all management plans of the CMNP focused essentially on wildlife species. Previous botanical inventories in the CMNP landscape, including the works of Tchouto *et al.* (2006), Kabelong *et al.* (2018), Todou *et al.* (2022) and subsequent surveys associated with the Campo Ma'an Technical Operations Unit (TOU Campo Ma'an), have documented hundreds of vascular plant species, with the woody component accounting for a large proportion of species richness and nearly all of the basal area and aboveground biomass. However, these efforts have often been geographically or taxonomically limited, focused on particular vegetation types or selected taxa, leaving substantial knowledge gaps regarding the park's full floristic composition, the spatial patterns of woody species distribution across habitat gradients and the structural attributes of different forest strata. This lack of systematic and comprehensive floristic data represents a fundamental obstacle to effective conservation planning, adaptive management, and the long-term monitoring of vegetation change within the park. Without such structural data, it is impossible to accurately estimate the biomass and carbon stocks of the park, assess the successional dynamics and evaluate the functional resilience of woody plant communities to ongoing disturbances (Fauset, 2012; Lewis, 2013). Equally problematic is the inadequate characterization of threatened species within the park's ligneous flora. The distribution ranges of many IUCN Red-Listed timber tree species across CMNP's landscape remain poorly mapped, their population densities within the park are largely unknown, and the degree to which the park's boundaries encompass viable populations of these species has never been rigorously assessed (Politi, 2021; BGCI, 2022).

Understanding the composition and structural organization of woody vegetation is essential for sustainable forest management and biodiversity conservation (Fobane, 2024). Furthermore, documenting threatened species distribution is critical for developing effective conservation strategies, monitoring ecosystem health, and supporting protected area management under increasing environmental pressures (Awoke *et al.,* 2025; Todou *et al.*, 2022).

The aim of this study is to characterize the ligneous flora of Campo Ma'an National Park, with particular emphasis on its floristic composition, distributional patterns, structural attributes, species diversity, and the distribution of threatened species to ease management schemes for biodiversity conservation.

MATERIALS AND METHODS

Presentation of the study area

The Technical Operation Unit (TOU) of Campo Ma'an covers 770 000 ha. At its core the Campo-Ma'an National Park (CMNP) covering a surface area of 264 064 ha and the first marine Protected Area in Cameroon, Manyange na Elombo-Campo (MANEC) at Ebodje covering a surface area of 110 300 ha. Agro industrial plantation (palm oil and rubber), forest exploitation units, subsistence farmland and fallows cover most of the non-protected area (Djoko *et al*, 2022).

It is located in the Ocean Division, South region of Cameroun between 2°10'N, 9°50'E and 2°25'N, 10°48'E (Fig. 1). Found within four Sub-Divisions, Campo, Ma'an, Nieté and Akom 2, representing the four sections of the CMNP. The climate is coastal equatorial characterized by two dry seasons and two rainy seasons. The mean annual precipitation is about 2500 mm (rainfall reduces from the coast towards the interior, around the coast, the community of Campo receives an average annual rainfall of 2800 mm, while Nyabissan, further inland, receives an average annual rainfall of 1670 mm). The mean temperature is 25°C. Hydromorphic and ferralitic soils are the most dominant types of soils. Hydromorphic soils are found within the valleys and lowlands, while ferralitic soils develop on acidic parent rocks and are generally yellowish or reddish. It comprise the Atlantic basin drainage system, many streams, river branches and swampy areas makes the area water rich. The dense Guineo-Congolese evergreen forest is the primary vegetation type, consisting mainly of old secondary forest, but patches of primary forest type still occur and the area has a high level of endemism and plant species diversity. There are about 2,297 vascular plant species and ferns of which 29 species are endemic to the conservation area. The area harbours threatened wildlife species, among which the forest elephant, lowland Gorillas, Mandrils, Leopards, Buffalos and Chimpazees (MINFOF, 2015).

Sampling procedure

The Mono specie mangrove forest and the highly diversify tropical rain forest are the two main forest types of the CMNP. Out of the 264 064 ha of the CMNP, the mangrove forest covers a surface area of only 2 354 ha and the remaining 261 710 ha by the tropical rain forest. Totally, 115 square sample plots (25m × 25m) were chosen randomly such that it geographically covered all the park as recommended by Pearson *et al.* (2005). The 25m × 25m sample plots used for this study are standard and effective size for estimating forest parameters, especially in tropical regions Silveira *et al.* (2022). Out of the 115 samples, 110 plots were inventoried in the tropical forest and 5 in the mangrove forest. The plots were pre-established in the laboratory and printed on a map with GPS coordinates before the field work, facilitated by the software QGIS. At least 4 km separated a plot from the other to efficiently cover the park. On the field, recce walks avoiding obstacle enable us attain most plots with the aid of a GPS Garmin 64s.

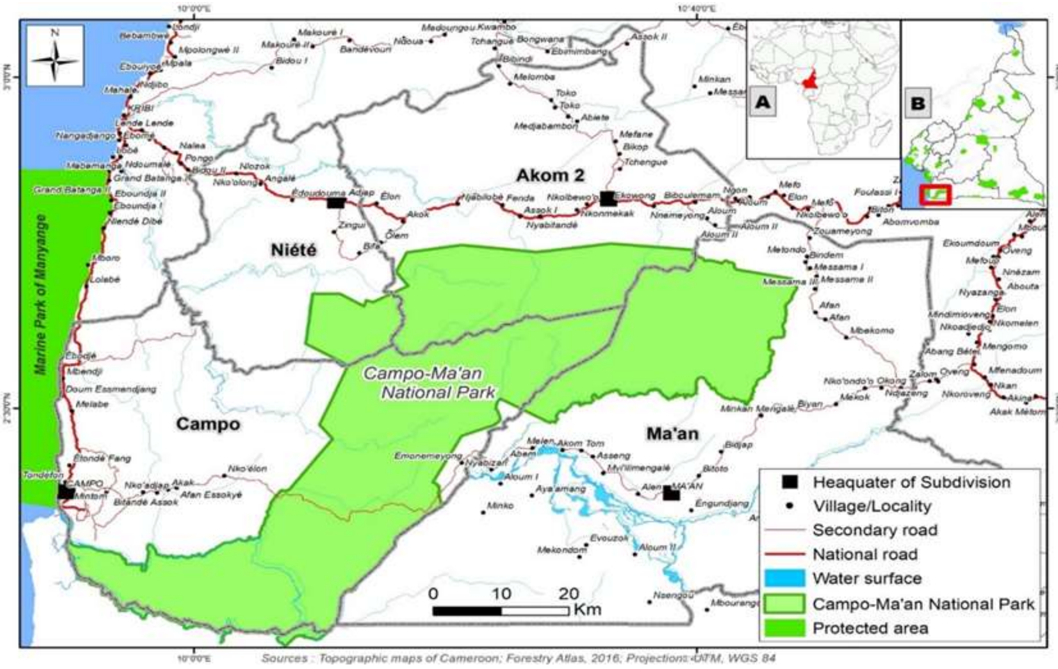

Fig. 1. Map of the technical operational unit of Campo Ma'an

Data collection

Data for this study was collected in two phases, the first from May 6 to June 11, 2024 in the sectors of Campo and Ma'an where inventories were carried out in 63 plots. The second phase was between the 31st January and the 20th of February 2025 where 52 plots were covered in the sectors of Niete and Akom 2. The inventory was done by a team of 7, the researcher (in charge of taking down data), an experienced botanist (identify ligneous flora species), an ecoguard/Ranger (security), a local guide, two porters and a cook.

Before counting, each plot was delimited with a lengthy meter tape, the plot number, locality, date, the GPS coordinates and the plot surface area were recorded.

In each plot, the stem diameter of all tree above 5cm were measured at 1.3 m above the soil surface using a diameter tape (most forestry measurements limited to a minimum diameter of 10cm results in the loss of most ecosystem vital information on trees and shrubs especially regeneration for adequate understanding of forest dynamics). For trees with many stems, each stem was taken separately. The diameter of high buttress roots were taken at 30 cm above the root. For mangroves, Diameters were measured 30 cm above stilt roots. The height of the tree was measured using a Suunto clinometer. The botanical species or local name of each tree was identified by the experienced botanist. All measurements within the plot was registered separately for big trees (DBH >30 cm) and for trees (5 cm < DBH ≤ 30 cm) within the plot by the researcher. All trees in the sample plot were wounded with a cutlass at the level of the trunk to be efficiently identified and this also helped avoid double counting.

Two species could not be identified on the field, the leaves, the back and a picture was brought to the national herbarium in Yaounde for identification.

Due to the complex growing nature of tropical forest species and some trees were shaded by other (or growing too close to each other), the all tree heights could not be accurately measured. Allometric equations with stem diameter developed by Djomo *et al.* (2010) was used to determine these heights.

Data analysis

After identification of species by the botanists, giving the common, pilot, commercial or scientific name, the species were then botanically classified using the Atlas of humid tropical species, example from Cameroon CIRAD (Guillaumet, 2010). *Gilbertiodendron brachystegioides* and *Canthium arnoldianum* were identified at the national herbarium in Yaounde.

All species in the 115 plots were recorded in the Microsoft Word Excel version 2016 software alongside the strates, GPS coordinates, names, diameter and tree height. The geographic field data was extracted from the GPS using Map Source software and the maps were created using Quantum GIS software version 2.18.11. Using the software Stata version 2016, biodiversity parameters were computed on the obtained data. The biodiversity parameters include the following: (computed with the aid of past studies of Douandji *et al*., 2025; IUCN, 2025 ; Fobane *et al*., 2024; Awoke *et al.,* 2025).

Indices of diversity

It indicates the manner in which individuals are distributed within species, genera and family in a plant community presented on a table for the two main stratums.

Frequency of species

Frequency, known as abundance or distribution, is the number of times a species appears in a plot. It provides information on the social behavior of a species and its distribution in space.

The relative frequency which is the ratio expressed as a percentage of the number of plots where the specie is present over the total number of plots. It is obtained from the following formula:

Relative frequency=[{(Frequency of a species (i)}/(Total frequency of species)] × 100

Species density

The density of a species is obtained by dividing the total number of stems belonging to that species by the surface area of the sampled area. In other words, it is the number of stems per hectare. It was calculated from the following formula:

$$D = n/S$$

Where, D: density (stems/ha); n: number of stems present on the sampled area and S: sampled area (ha).

Subsequently, the relative density (Rden) was obtained as follows:

$$RDen = \frac{\text{total number of individuals of a given species(i)}}{\text{total number of individuals in the sample unit}} \times 100$$

Diametric structure of species

Analyzing the diametric structure of the CMNP gives the possibility to determine if the studied population is in equilibrium or has been disturbed over time. The diameter of stems were classified in intervals of 10cm and presented on a histogram. Since the minimum diameter taken was 5cm, the first interval was between [5-10cm [(species with diameters of 10cm included in this interval), then [10-20[… [130-140cm[, and all species greater than 140cm.

Floral diversity of species

The Shannon index (H) measures the uncertainty as regards an individual taken at random belonging to a species in the sample unit. Uncertainty increases when richness and evenness decrease. The Shannon index increases with an increase in diversity. H>3.5, high diversity shows that individuals are partitioned in an even manner between all species. H is minimal (= 0) if all the individuals of the population have approximately a single and same species. It is calculated using the formula below:

$$ISH = -\sum (ni/N) \text{ Log2 } (ni/N)$$

Where ni is the number of species i and N the total number of species

Simpson's diversity index: This index (D) presents the probability that if two individuals taken randomly in a population studied belong to the same species. It measures the manner with which individuals are distributed between the species of a community or a sample unit. D increases as evenness decreases. This value is comprised between zero and 1. It is calculated using the formula below:

$$D = \sum (Ni/N)^2$$

Where Ni is the number of species i and N the total number of species

Pielou's equitability index: Equitability is an essential component of diversity since the abundance of one species statistically implies the rarity of other species. The Pielou equitability index allows for the measurement of individual distribution within species, hence determining specific richness. Pielou's Equitability ranges from zero to one. It goes to zero when practically all of the numbers are concentrated on a single species and to one when all species have the same abundance. It's calculated using the following formula:

$$EQ = ISH/Log2N$$

Where ISH= Shannon diversity index, N= total of species

Conservation status of plant species

The IUCN Red List enabled the classification of flora species inventoried according to their conservation status, Extinct (Ex), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC).

RESULTS

Ligneous floral composition in the Campo Ma'an national park

The floristic inventory in the 115 plots of 625 m² each lead to the counting of 5 839 stems, 266 in the mangrove forest and 5 533 in the tropical lowland evergreen rainforest. Analysis showed that globally 812 stems are found per hectare in the CMNP, 851.2 and 810.6 in the mangrove forest and Tropical lowland evergreen rainforest respectively.

A total of 232 ligneous species were identified from 174 Genera and 56 families. In the mangrove forest, five species from three Genera and three families were identified while 227 species from 171 Genera and 53 families from the Tropical lowland evergreen rainforest (Table 1).

Family diversity in the Campo Ma'an National Park

The classification of species from the inventory showed that 56 families were present in the CMNP. Fabaceae were the most represented in terms of number of stems, 802 (13.7% relative abundance), number of genera (33) and diversity of species, 43 (18.5% of the total number of species). Table 2 presents families with more than five species in the sample plots inventoried. The family Annonaceae had 7.7% of species and 9.5% of the total number of stems, Euphorbiaceae (6.9% and 10%), Malvaceae (5.6% and 3.1%), Meliaceae (5.2% and 2.9%), Rubiaceae (4.7% and 1.7%), Phyllanthaceae (3.4% and 1.4%), Apocynaceae (3.0% and 2.7%), Clusiaceae (3% and 0.8%), Irvingiaceae (3% and 2.7%), Sapotaceae (2.6% and 0.5%), Anacardiaceae (2.1% and 1.5%), Combretaceae (2.1% and 0.8%) and Strombosiaceae (2.1% of the species present and 11.4% relative abundance of the number of stems present). The remaining 42 families had less than two percent of the species present each in the CMNP.

In the mangrove forest, Rhizophoraceae was the dominant family, represented by one genus and three species, while Acanthaceae was represented by a single species.

Relative frequency of species in the Campo Ma'an National Park

Out of the 232 species recorded in the CMNP, eight (3.4%) were present in more than 58 (50 %) sample plots (Fig. 2). *Diospyros simulans* with the highest frequency was identified in 95 out of the 115 plots (82.6 %), *Strombosia pustulata* (72.2%), *Strombosiopsis tetrandra* (66.1%), *Coula edulis* (61.7%), *Dichostemma glaucescens* (61.7%), *Mareyopsis longifolia* (59.1%), *Homalium sp.* (52.2%) and *Eriocoelum macrocarpum* (51.3%). 28 species (12%) had a relative frequency between 50% and 20%, amongst which *Polyalthia suaveolens* (49.6%), *Enantia chlorantha* (46.1%), *Irvingia gabonensis* (33%), *Diospyros crassiflora* (26.1%) and *Cola ficifolia* (20%). In the relative frequency interval 20 to 10%, 42 species were identified (18%) such as *Lophira alata* (19.1%), *Erythrophleum suaveolens* (16.5%), *Cola lepidota* (14.8%) and *Panda oleosa* (10.4%). 51 species (22%) had relative densities between 10 and 5% and the remaining 44.3% (103) species had less than 5%.

Table 1. Ligneous floral composition in the Campo Ma'an National Park

Parameter	Mangrove forest	Tropical lowland evergreen rainforest	Total
Specie	5	227	232
Genera	3	171	174
Family	3	53	56
Number of individuals	266	5573	5839
Stem density (stem/ha)	851.2 ± 86.5	810.6 ± 194.6	812 ± 191.2

Table 2. Family diversity in the Campo Ma'an National Park

Family	Number of species	Abundance of species (%)	Number of genera	Specific quotient (E/G)	Number of stems	Abundance (%)
Fabaceae	43	18.5	33	1.3	802	13.7
Annonaceae	18	7.7	12	1.5	554	9.5
Euphorbiaceae	16	6.9	12	1.3	582	10.0
Malvaceae	13	5.6	8	1.6	181	3.1
Meliaceae	12	5.2	6	2	171	2.9
Rubiaceae	11	4.7	9	1.2	102	1.7
Phyllanthaceae	8	3.4	7	1.1	79	1.4
Apocynaceae	7	3.0	5	1.4	161	2.7
Clusiaceae	7	3.0	4	1.7	48	0.8
Irvingiaceae	7	3.0	3	2.3	158	2.7
Sapotaceae	6	2.6	6	1	31	0.5
Anacardiaceae	5	2.1	4	1.2	85	1.5
Combretaceae	5	2.1	4	1.2	48	0.8
Strombosiaceae	5	2.1	3	1.7	665	11.4
Total	232	100	171	1.4	5839	100

E: number of species, G: number of genera

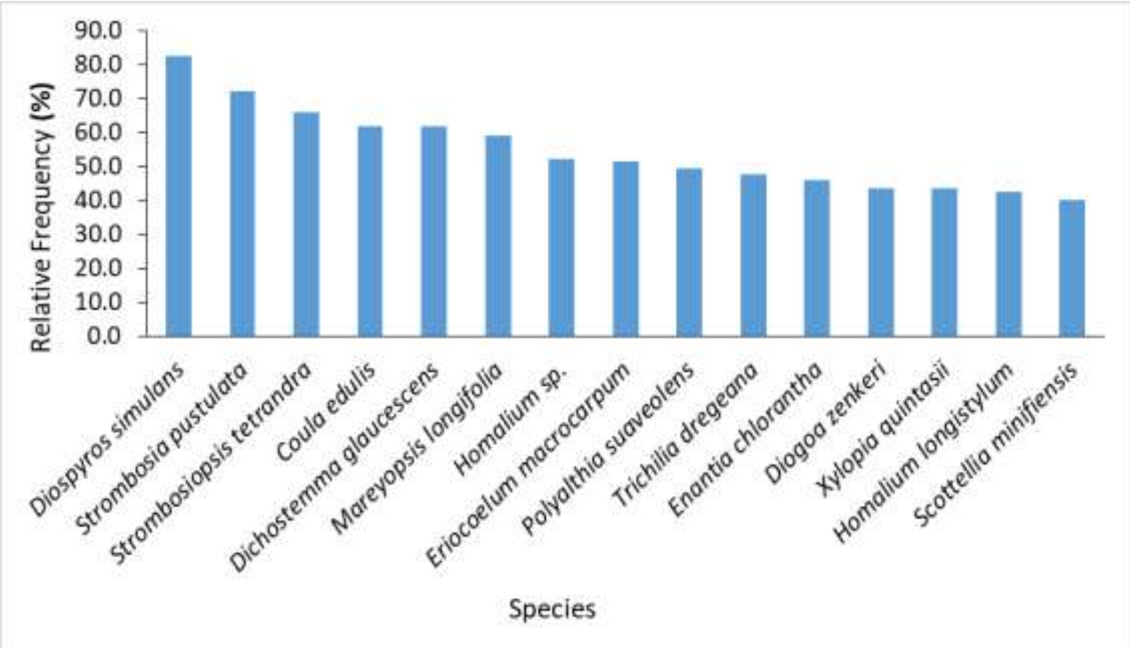

Fig. 2. Relative frequency of the lowland tropical forest species in the CMNP

The distinct ecological characteristics of the mangrove ecosystem resulted in a complete separation of species composition between the two habitats: no mangrove species were found in the inland tropical forest, and no inland forest species were recorded in the mangrove strata.

Only five species were recorded in the mangrove forest. *Rhizophora racemosa* was present in all 5 plots (100%), followed *Rhizophora mangle* (80%). *Rhizophora harrisonii* and *Avicennia germinans* inventoried in 3 plots (60%) and finally *Nypa fruticans* in two plots (40%).

Table 3. Density and relative abundance of tropical rainforest species in the CMNP

Scientific name	Number of stems	Number of plots	Specie density (stems/ha)	Relative abundance (%)
Strombosia pustulata	336	110	48.87±69.5	6.0
Diospyros simulans	319	110	46.40±38.9	5.7
Dichostemma glaucescens	304	110	44.22±58.9	5.4
Strombosiopsis tetrandra	149	110	21.67±23.1	2.7
Eriocoelum macrocarpum	146	110	21.24±24.9	2.6
Homalium sp.	144	110	20.95±31.1	2.5
Polyalthia suaveolens	143	110	20.80±36.2	2.5
Coula edulis	135	110	19.64±20.5	2.4
Mareyopsis longifolia	135	110	19.64±21.3	2.4
…	…	110	…	…
Total	5573	110	810.62±194.6	100

In the tropical lowland evergreen rainforest, *Diospyros simulans* had highest frequency (86.4%), *Strombosia pustulata* (75.5%), *Strombosiopsis tetrandra* (69.1%), *Coula edulis* (64.5%), *Dichostemma glaucescens* (61.5%), *Mareyopsis longifolia* (61.8%), *Homalium* sp. (54.5%), *Eriocoelum macrocarpum* (53.6%), *Polyalthia suaveolens* (51.8%) and *Trichilia dregeana* (50%). All other 217 species had less than 50% relative frequency.

Density and relative abundance of species in the Campo Ma'an National Park

Results of the inventory shown that there were 812.4 stems/ha in the CMNP, 25 species (10.8%) had more than 1% relative abundance.

The mangrove forest had a higher density, 851.2 stems/ha. *Rhizophora racemosa* occupied most of this forest with a relative abundance of 77.8 % (662.4 stems/ha). *Avicennia germinans (*10.5%, 89.6 stems/ha), *Rhizophora mangle (*7.5%, 64 stems/ha), *Rhizophora harrisonii (*3.4%, 28.8stems/ha) and *Nypa fruticans (*0.8%, 6.4 stems/ha).

Table 3 illustrates the density and relative abundance of species in the tropical lowland evergreen rainforest. The density of this forest was evaluated at 810.6 stems/ha. *Strombosia pustulata* had averagely 48.9 stems/ha, 6% of the total number of stems. *Diospyros simulans* (46.4 stems/ha, 5.7%), *Dichostemma glaucescens* (44.2 stems/ha, 5.4%,), *Strombosiopsis tetrandra* (21.7 stems/ha, 2.7%), *Eriocoelum macrocarpum* (21.4 stems/ha, 2.6%), *Homalium* sp. (20.9 stems/ha, 2.5%), *Polyalthia suaveolens* (20.8 stems/ha, 2.5%), *Coula edulis* (19.6 stems/ha, 2.4%) and *Mareyopsis longifolia* (19.6 stems/ha, 2.4%). The remaining 218 species each exhibited a relative stem abundance of less than 2% in the tropical lowland evergreen rainforest.

Diametric structure of species in the Campo Ma'an National Park

Fig. 3 illustrates the distribution of species according to their diameter classes in intervals of 10cm in the mangrove forest, tropical lowland evergreen rainforest and the combine total for the CMNP. The results show that, the diametric structure of the park presents a decreasing exponential curve in the form of an inverted J-shape with the exception of the first class (5-10cm) because only half the number was counted in this class since species from 1-4cm were considered as herbaceous. As the diameter increased, the number of individuals decreases progressively. The diameter class [10-20[cm had the highest number of individuals, 2079 (35,6%) and the lowest was the diameter class >140cm (0.1%). The total mean diameter, 22.4±21.5cm, with 5cm and 172cm being the lowest and highest diameters respectively.

In the Mangrove forest, total mean diameter was 19.7±13.5cm with the highest, 74cm. The diameter class [10-20[cm had the highest number of individuals, 89 (33,4%) and the lowest was the diameter class [70-80[(0.1%).

In the inland forest, 22.5±21.9 cm was the mean diameter, The diameter class [10-20[cm had the highest number of individuals, 1990 (35,7%) and the lowest was the diameter class >140cm (0.1%).

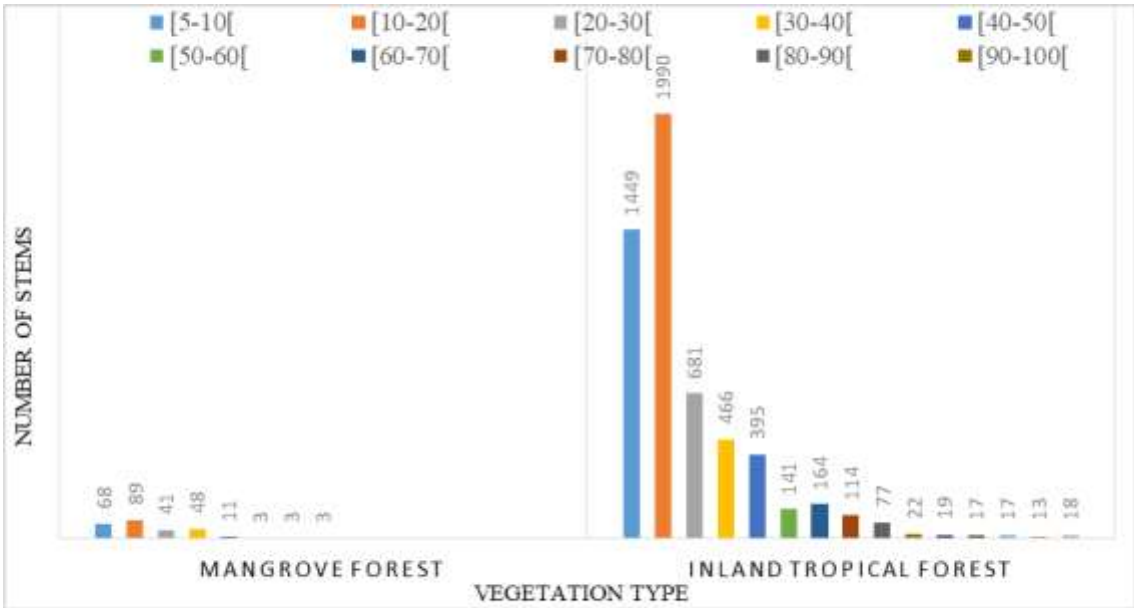

Fig. 3. Diametric structure of floral species in the CMNP

Table 4. Diversity indices in the Campo Ma'an National Park

Vegetation type	Diversity index		
	Shannon	Simpson	Evenness of Pielou
Tropical lowland forest	4.85	0.88	0.89
Mangrove forest	1.56	0.45	0.32

Floristic diversity in the CMNP: Simpson's, Shannon's and Pielou's equitability indices

Table 4 expresses the floral diversity in the mangrove and the tropical evergreen forest of the CMNP. In the tropical evergreen forest, the Shannon value (H') of 4.85 is greater than 3.5 (high diversity) indicating a very rich and diverse ecosystem. The Simpson diversity index (D') of 0.88 (close to 1) indicates high diversity, showing that if two individuals are chosen at random, they will belong to the same species due to the good distribution of individuals within species. J', the Pielou's evenness of 0.89 (close to 1) shows high evenness in the distribution of species, no specie strongly dominates.

In the Mangrove forest, the Shannon, Simpson and Pielou indices of 1.5, 0.45 and 0.3 showed than it was a less diverse ecosystem, largely dominated by the single specie *Rhizophora racemosa*.

Conservation status of species in the Campo Ma'an National Park

Out of the 232 species identified in the CMNP, two (0.86%) were endangered according to the IUCN red list of threatened species (*Guibourtia tessmannii* and *Millettia laurentii*), 18 species Vulnerable (7.76%) and 10 (4.3% of species) Near Threatened (Table 5). As such, 12.93 % (30 species) were threatened with extinction and 87.07% (202 species at a lower risk of extinction. No specie in the mangrove forest was threatened with extinction (all Least Concern). No specie was critically endangered in the CMNP.

Amongst the threatened species, the most abundant and present in all sectors of the CMNP were *Irvingia gabonensis* (7.85 stems/ha), *Dacryodes igaganga* (6.98 stems/ ha), *Lophira alata* (5.67 stems/ ha), *Diospyros crassiflora* (5.09 stems/ ha), *Didelotia letouzeyi* (4.0 stems/ ha) and *Nauclea diderrichii* (1.87 stems/ ha).

The Endangered species *Guibourtia tessmannii,* was present in three out of the four but only 0.5 stems was present per ha. The least abundant species, present in only one sector, with a total average of 0.1 stem/ ha were *Millettia laurentii* (EN), *Drypetes preussii* (VU), *Entandrophragma utile* (VU), *Terminalia ivorensis* (VU), *Entandrophragma angolense* (NT) and *Milicia excelsa* (NT).

Table 5. Threatened species in the CMNP

CS	Species	Number of stems in each sector					Total stems in the CMNP/ ha
		Akom 2	Campo	Ma'an	Niete	Total stems inventoried	
EN	*Guibourtia tessmannii*	1	0	1	2	4	0.58
	Millettia laurentii	0	1	0	0	1	0.15
VU	*Afzelia bipindensis*	1	4	0	2	7	1.02
	Allanblackia kisonghi	0	1	1	0	2	0.29
	Anopyxis klaineana	3	3	0	1	7	1.02
	Baillonella toxisperma	19	1	0	0	20	2.91
	Calpocalyx heitzii	12	0	0	17	29	4.22
	Cordia platythyrsa	0	6	0	0	6	0.87
	Dacryodes buettneri	4	0	0	5	9	1.31
	Dacryodes igaganga	14	16	9	9	48	6.98
	Diospyros crassiflora	5	14	2	14	35	5.09
	Drypetes preussii	0	0	0	1	1	0.15
	Entandrophragma utile	0	1	0	0	1	0.15
	Garcinia kola	3	0	0	0	3	0.44
	Khaya ivorensis	3	5	1	0	9	1.31
	Lophira alata	10	24	2	3	39	5.67
	Nesogordonia papaverifera	3	0	0	3	6	0.87
	Pterygota beguaertii	2	21	4	0	27	3.93
	Pterygota macrocarpa	0	4	0	0	4	0.58
	Terminalia ivorensis	0	0	0	1	1	0.15
	Turreaenthus africanus	1	0	0	1	2	0.29
NT	*Cola argentea*	0	6	0	0	6	0.87
	Daniellia ogea	1	0	0	1	2	0.29
	Didelotia letouzeyi	4	10	4	10	28	4.07
	Entandrophragma angolense	0	0	1	0	1	0.15
	Guarea cedrata	1	2	0	0	3	0.44
	Guarea laurentii	1	0	0	1	2	0.29
	Irvingia gabonensis	19	30	2	3	54	7.85
	Milicia excels	0	1	0	0	1	0.15
	Mitragyna ciliate	3	6	2	0	11	1.60
	Nauclea diderrichii	4	6	1	2	13	1.89

CS=conservation status, EN=Endengered, VU=Vulnerable, NT=Near Threatened

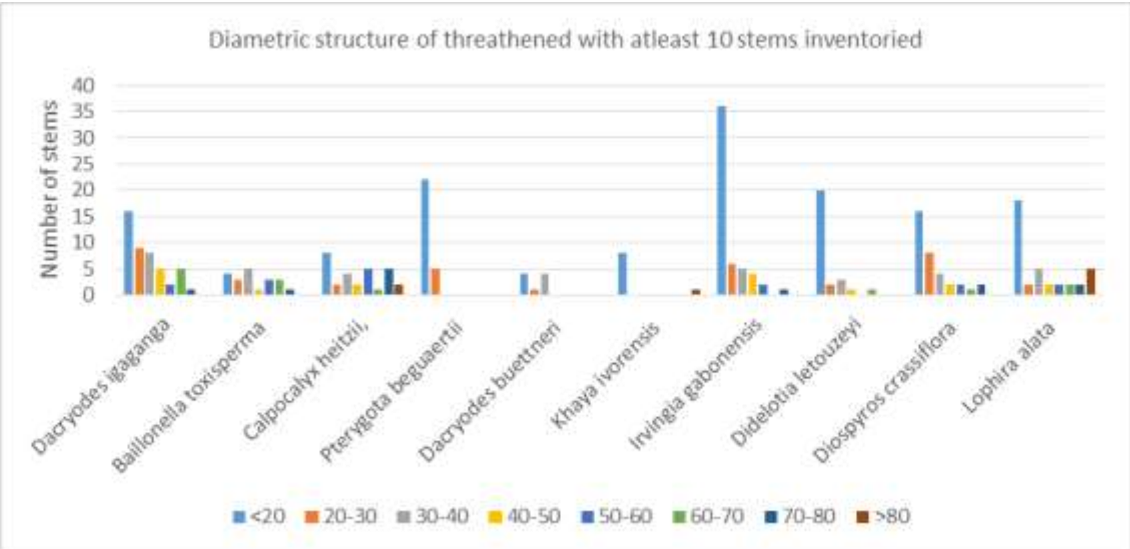

Fig. 4. Diametric structure of threatened species

The diametric structure of threatened species shows that all the four stems of *Guibourtia tessmannii* inventoried were above 40 cm, the seven trees of *Afzelia bipindensis* encountered had diameters between 21 to 108 cm (Fig. 4). Both trees of *Allanblackia kisonghi* had diameters above 30 cm, four out of the six stems of *Nesogordonia papaverifera* were above 60 cm. Four of the five stems of the genus

Guarea and all six stems of *Cordia platythyrsa* had diameters greater than 30 cm. Only four out of the 20 trees of *Baillonella toxisperma* were below 20 cm, amongst the 29 stems encountered for *Calpocalyx heitzii,* no stem had less than 10 cm and only seven stems were below 20 cm.

Threatened species with natural regeneration capacity included, *Pterygota macrocarpa* and *Pterygota beguaertii* where all 31 stems of the genus encountered had diameters between 5cm and 30 cm. The five stems of *Cola argentea* had diameters from 5 cm to 130 cm, five of the seven stems of *Anopyxis klaineana* had diameters below 20 cm. The nine stems of *Dacryodes buettneri* were between 14 to 40 cm. The diameters of nine stems of *Khaya ivorensis* were well distributed (from 5 cm to 108 cm). The diametric structure of the 54 trees of *Irvingia gabonensis*, the 28 stems of *Didelotia letouzeyi,* the 48 stems identified for *Dacryodes igaganga,* and the 35 stems of *Diospyros crassiflora* showed a decreasing exponential curve with most stems (43%, 57%, 25% and 23% respectively) in the range 10-20 cm followed by the interval 20-30cm (13%, 7%, 19 and 23% of stems) and 30-40 cm (9%, 11%, 17% and 11% of stems respectively).

Lophira alata had an irregular shape but the diameter class 5-10 cm had the most number of trees (31%) followed by the class 10-20 cm (15%), with an exceptionally high number of stem above 80 cm in diameter (13%).

DISCUSSION

The floristic inventory carried out in Campo Ma'an National Park revealed a remarkably high level of woody plant diversity. A total of 232 ligneous species, belonging to 174 genera and 56 families**,** were recorded. Of these, 227 species (171 genera, 53 families) were found in the tropical lowland evergreen rainforest, while the mangrove forest contained only five species from three genera and three families**.** The high richness confirms that CMNP represents a biogeographical transition zone between Atlantic coastal forests and inland Guineo-Congolian forests. This results was similar to the 278 species from 177 genera and 52 families found in the Mount Nlonako tropical rainforest forest by Douandji *et al.* (2025). The CMNP is less diversed than the Dja Biosphere Reserve where 312 species belonging to 54 families and 213 genera were identified by Sonké and Couvreur (2014). The number of specie found in this study was superior to that of the dry Afromontane forests of northern Ethiopia reported by Kebede *et al.* (2013) which contained only about 108 woody plant species distributed among 52 families, less than half found in the CMNP. Ajonina *et al.* (2008) found out that in the Wouri estuary, six species from three families was distributed in the mangrove forest with a predominance of *Rhizophora* spp. Tropical lowland evergreen rainforest supports high species richness due to stable climatic conditions, high rainfall, and complex vertical structure, whereas the mangrove forest is naturally species-poor because of extreme environmental constraints such as salinity, tidal inundation, and anoxic soils, confirming that its low species richness is ecological.

Mean stem density in the CMNP was 812 ± 191 stems/ha**,** with 810.6 stems/ha in evergreen forest and 851.2 stems/ha in mangroves. These fall well within the range 600–900 stems/ha reported for intact Central African forests by Poorter *et al.* (2016). Logged forests in Cameroon typically show inflated stem densities dominated by small trees (>1,000 stems/ha), whereas heavily disturbed <500 stems/ha. Mangrove stem density values are consistent with those reported along the Cameroon and Gabon coasts, 700–1,200 stems/ha. The moderate stem density observed in CMNP suggests low anthropogenic disturbance and balanced recruitment, mortality dynamics. This supports the classification of CMNP as a structurally intact forest.

In the tropical lowland evergreen forest, 53 plant families were recorded. The most diverse and dominant family Fabaceae, accounted for 43 species (18.5%)**,** 33 genera**,** and 13.7% of total abundance. The family Annonaceae had 18 species and 9.5% of stems, Euphorbiaceae (16 species and 10% of stems), and Malvaceae (13 species and 5.6% of stems) which characterize the floristic background of typically dense humid forests Interestingly, the family Strombosiaceae, despite comprising only five species (2.1%), contributed 11.4% of the total number of stems, indicating strong numerical dominance by a small number this species. The high diversity and abundance of the family Fabaceae in this study is in accordance with the findings of other authors who carried out their research in the Congo basin forest. In the Mount Nlonako forest for instance Fabaceae was the most represented, dominant, and most diversified plant family at both zones with fewer number of species 26 species (Douandji, 2025). In the Mount Oku forest Fabaceae also dominated with 16 species identified only Momo (2009).

Doucet (2003) also had Fabaceae as the most important in the moist forest of Gabon. Fabaceae frequently dominate in the tropical Congo basin forest due to their ecological versatility and capacity to thrive across successional stages. They adapt to a broad range of climate and soil conditions, which could explain their abundance. Also, Plant species belonging to this family produce fleshy and succulent fruit organs, which are easily eaten and transported to other parts of the forest by animals, thus facilitating the dissemination of seeds (Chapman *et al*., 2016).

In the tropical evergreen forest of the CMNP, only eight species (3.4%) occurred in more than 50% of the plots. *Diospyros simulans* showed the highest frequency, being present in 82.6% of plots, followed by *Strombosia pustulata* (72.2%) and *Strombosiopsis tetrandra* (66.1%). The most abundant inland forest species were *Strombosia pustulata* (48.9 stems/ha; 6%), *Diospyros simulans* (46.4 stems/ha; 5.7%), and *Dichostemma glaucescens* (44.2 stems/ha; 5.4%). In the Mount Nlonako forest the most abundant species were *Strombosia grandifolia* and *Pycnanthus angolensis,* species that develop in an open canopy (Douandji, 2025). They differ from most abundant species in the CMNP because of few canopy opening favoring the development of *Diospyros simulans*.

The diameter-class distribution of woody species in CMNP followed a decreasing exponential (inverted J-shaped) curve, with the 10–20 cm diameter class containing the highest number of individuals (35.6%) and very few individuals in large diameter classes (>140 cm; 0.1%). The overall mean diameter was 22.4cm. The mangrove forest exhibited a lower mean diameter of 19.7cm and a truncated size distribution with the diameter class (10-20) cm having the highest number of individuals, (33,4%). NkKembi *et al.* (2021) found a similar results around the Deng Deng national park, were most of the specie were between 10-20 cm in diameter. This pattern is characteristic of undisturbed tropical forests, where continuous recruitment ensures a large pool of small and medium-sized individuals while large trees persist at lower densities (Doucet, 2003). Ouédraogo *et al.* (2012) reported in their findings that the large number of individuals in the diameter classes (10-20 cm) and (20-30 cm) constitutes a regenerative potential for woody vegetation. The presence of very large trees (>140 cm DBH), even at low frequencies, is ecologically significant, as these individuals contribute disproportionately to biomass, carbon storage, and habitat complexity. The presence of very large trees confirms long-term forest continuity.

Quantitative diversity indices confirm the exceptionally high floristic diversity of CMNP. The Shannon diversity index (H′ = 4.85) greatly exceeds the threshold of 3.5 typically used to indicate high diversity in tropical forests. Similarly, the Simpson index (D′ = 0.88), close to 1, indicates a low probability that two randomly selected individuals belong to the same species, while Pielou's evenness (J′ = 0.89) reflects a highly even distribution of individuals among species. Together, these indices indicate a species-rich, well-balanced ecosystem with no strong single-species dominance in the inland forest. Such diversity is commonly associated with high ecosystem resilience, efficient resource partitioning, and long-term ecological stability (Bita-Nicolae, 2025).

Of the 232 species recorded, 30 species (12.93%) were classified as threatened according to the IUCN Red List. This included two endangered species (0.86%), 18 vulnerable species (7.76%), and 10 near-threatened species (4.3%), while the remaining 202 species (87.07%) were of least concern. The number of threatened species was slightly less than that of the Essiengbot-Mbankoho forest reserve in Eastern Cameroon, where 3 Critically Endangered species, 5 species (0.58%) Endangered (0.96%), 32 Vulnerable species (6.14%), 18 Near Threatened species (3.45%) and 408 (78.31%) Least Concern species were recorded (Kengne *et al.*, 2022).

This slight difference might be due to the fact that this study considered all species present in the reserve while the present study analysed ligneous species greater than 5 cm. This proportion is higher than in many managed forests but similar to intact protected areas in Central Africa, for instance the percentage (12.93) of threatened ligneous species in the CMNP is far greater than 9.69% of threatened species in the Gari-gombo forest in Cameroon observed by Nyeck *et al.* (2024). Globally, the first Global Tree Assessment published in October 2024, updating the IUCN Red List, revealed that 38% of the world's tree species are at risk of extinction, with the IUCN Red List now including 166,061 species, of which 46,337 are threatened (IUCN, 2025).

The diametric structure of threatened species reveals a heterogeneous pattern of population. The abundance and diametric structure of threatened woody species recorded in Campo Ma'an National Park provide important insights into the conservation status, regeneration dynamics, and ecological resilience of the park's forest ecosystems. Species such as *Irvingia gabonensis*, *Dacryodes igaganga*, *Diospyros crassiflora*, *Didelotia letouzeyi*, and partially *Lophira alata*, displayed decreasing exponential (reverse-J shaped) diameter distributions with the majority of stems concentrated in the smallest diameter classes. *Pterygota macrocarpa*, *Pterygota beguaertii*, *Anopyxis klaineana*, and *Khaya ivorensis* showed more encouraging population structures, all 31 stems of the genus *Pterygota* were between 5 and 30 cm. The five stems of *Anopyxis klaineana* had diameters predominantly below 20 cm and the diameters of *Khaya ivorensis* were well distributed from 5 to 108 cm, reflecting a balanced population with individuals from all size classes. A reversed J-shaped size distribution is widely regarded as a proxy of population growth or dynamic equilibrium in forest tree populations, indicating the continuous recruitment of juveniles into the population, indicates active natural regeneration and a positive conservation signal for these threatened species within the CMNP (Kouamé *et al.*, 2022). In recent floristic assessments of Atlantic Biafran forests in southern Cameroon and Gabon, species of the genera *Dacryodes* were reported to exhibit strong regeneration in undisturbed forest stands but poor recruitment in logged forests, emphasizing the importance of protected areas such as Campo Ma'an for sustaining viable populations (Betti *et al.*, 2022). The findings of this study are consistent with reports from southern Cameroon, where abundant juvenile populations in protected forests have been attributed to effective seed dispersal by mammals and local community tolerance, thereby promoting regeneration success in protected landscapes (Hall *et al.*, 2003). This pattern suggests that these species possess sufficient regenerative capacity to maintain viable populations within the park under the current ecological conditions. In contrast, the restricted distribution and low densities of *Millettia laurentii* (EN), *Drypetes preussii* (VU), *Entandrophragma utile* (VU), *Terminalia ivorensis* (VU), *Entandrophragma angolense* (NT) and *Milicia excelsa* (NT), each present in only one sector at 0.1 stem/ha indicate particularly vulnerable local populations. The low density of this species (0.1 stem ha^{-1}), recorded in only one sector of the CMNP, is of concern because it reflects severe local rarity and may signal an elevated risk of local extinction under continued anthropogenic and ecological pressures.. Also, species such as *Guibourtia tessmannii*, *Afzelia bipindensis*, *Nesogordonia papaverifera, Calpocalyx heitzii, Allanblackia kisonghi*, and *Cordia platythyrsa* exhibited populations dominated by large-diameter individuals with very limited representation in smaller size classes. These results revealed a pronounced recruitment deficiency, suggesting that natural regeneration is inadequate to maintain the population, possibly due to the species' ecological requirements, seed predation, or past logging disturbances. Recent studies on forest dynamics increasingly interpret such truncated population structures as early warning signals of demographic decline, particularly in slow-growing hardwood species whose populations are highly vulnerable to recruitment failure and local extinction. Ageing population with little recent recruitment can be explained by the inherently slow growth rates of these species, past selective logging pressure in the park that selectively removed reproductively mature individuals, seed predation and dispersal limitation and the inherently low natural population densities of these species, which limit seed source availability and genetic diversity (Réjou-Méchain *et al.*, 2021).

Overall, the coexistence of high overall diversity with a significant proportion of threatened species underscores the conservation importance of CMNP.

CONCLUSION

The aim of this study is to characterize the ligneous flora of Campo Ma'an National Park, with particular emphasis on its floristic composition, distributional patterns, structural attributes, species diversity, and the distribution of threatened species to ease management schemes for biodiversity conservation.

The results confirmed a high woody flora diversity and stem density in the two main strates, Mangroves and tropical lowland evergreen forest of the Campo Ma'an national park. The great majority of species occupied less than half the surface area of the park. Globally, analysis of the diametric structure of stems showed an important successional dynamics marked by the remarkable number of small trees.

The evaluation of the conservation status of ligneous species reviled a large dominance of woody plant with Least Concern status and a low presence of threatened species. The majority amongst the threatened were species with a Vulnerable Status. The threatened woody flora of CMNP exhibits contrasting population structures ranging from healthy regenerating populations to ageing stands with limited recruitment, showing signs of demographic vulnerability with the possibility of local extinction in the long-term.

These findings confirm the critical conservation role of Campo Ma'an National Park as a refuge for threatened and non-threatened tropical tree species within the Congo Basin. The co-occurrence of both patterns within the same protected area underscores the ecological complexity of the CMNP and the need for species-specific rather than blanket conservation strategies.

To ensure the long-term persistence of threatened species and safeguard the high conservation value of Campo Ma'an National Park, it is essential to implement species-specific monitoring programmes, undertake active silvicultural interventions (including enrichment planting, seed collection, and nursery propagation for species with low densities and poor juvenile recruitment), strictly enforce harvesting bans within the Technical Operation Unit of Campo Ma'an, and strengthen anti-logging surveillance throughout the park.

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