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Woody species diversity and ecological characteristics of the Mawouon forest, in the Western Highlands of Cameroon

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Keywords

Phytodiversity;
Structure;
Life forms;
Phytogeographic types;
Mawouon Cameroon.

Abstract

This study was conducted to characterize the floristic, structural and ecological diversity of the Mawouon Forest in the Noun division (Western Highlands Cameroon). In total, 14 plots of 30 m x 100 m (3000 m²) were laid out. Within each, all individuals with a diameter ≥ 10 cm at 1.30 m in height were measured. A total of 2324 individuals belonging to 102 species, 78 genera and 35 families have been identified. The richest family was the Fabaceae (15 species) followed by Euphorbiaceae (12 species) and Moraceae (10 species). The most abundant family was the Rubiaceae (26.97%) followed by Euphorbiaceae (17.16 %) and Cecropiaceae (12.65%). The Shannon diversity index was 4.51 bits and the Pielou evenness index was 0.67. *Alchornea laxiflora* with 89.21% of important value index was most importance species followed by *Myrianthus arboreus* (89.03%) and *Polyscias fulva* (79.12%). The diameter structure shows a predominance of young individuals. The abundance of megaphanerophytes and mesophanerophytes reflects the adaptive plant strategies that correspond to the competitive strategy. The relative abundance of Guinean-Congolese domain species translates a great regeneration of species in this forest despite anthropogenic pressure.

Mots clés:

Phytodiversité ;
Structure ;
Types biologiques ;
Types phytogéographiques ;
Mawouon Cameroun

Résumé

Cette étude avait été faite pour caractériser la diversité floristique, structurale et écologique de la forêt de Mawouon dans le Département du Noun (Hautes Terres de l'Ouest Cameroun). Au total, 14 relevés floristiques de 30 m x 100 m (3000 m²) ont été réalisés. A l'intérieur de chaque relevé, tous les individus ayant un diamètre ≥ 10 cm à 1,30 m de hauteur ont été mesurés. Un total de 2324 individus appartenant à 102 espèces, 78 genres et 35 familles ont été recensés. La famille la plus riche en espèces était les Fabaceae (15 espèces) suivie des Euphorbiaceae (12 espèces) et des Moraceae (10 espèces). La famille la plus abondante était les Rubiaceae (26,97%) suivie des Euphorbiaceae (17,16%) et des Cecropiaceae (12,65%). L'indice de diversité de Shannon pour cette relique forestière était de 4,51 bits et l'équitabilité de Piélou était de 0,67. *Alchornea laxiflora* a eu la plus grande valeur d'importance (89,21%) suivie de *Myrianthus arboreus* (89,03%) et de *Polyscias fulva* (79,12%). La structure en diamètre montre une prédominance des individus jeunes. L'abondance des mégaphanérophytes et mésophanérophytes traduit les stratégies adaptatives des végétaux qui correspondent à la stratégie compétitive. L'abondance relative des espèces du domaine guinéo-congolais sur les autres types phytogéographiques traduirait une grande capacité de régénération des espèces dans cette forêt malgré les pressions anthropiques sur ces ressources.

Historic

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1. Introduction

Forests cover approximately 31 % of the planet lands and over 4 billion hectares [1]. In Africa, its occupy approximately 675 million hectares representing 17 % of the world forest area and 23 % of total area of the continent [1]. The Congo Basin Forests are the second largest tropical massive forest after the Amazonian Forest, with a total area estimated at about 200 million of hectares, nearly 91 % of dense humid Africa forests [2]. With an area of 22.5 million of hectares, Cameroonian forests represent 11 % of the Congo Basin Forests and 41.3 % of the national territory [3]. Cameroon ranks fifth among the richest African countries in biodiversity [4].

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Nevertheless, Cameroonian forests are undergoing net deforestation rates of 0.14 % and net degradation of 0.01 % per year [5].

The factors causing this deforestation are the slash-and-burn agriculture that would be responsible for more than 70 - 90% of the forest losses coverage and original carbon [5]. Several other threats such as extensive cultural practices, the over exploitation of non-timber forest products (NTFP) and infrastructure development weigh on these forests. The Cameroon's forests have long been doing many inventories [6-8]. The Western Highlands of Cameroon, considered as priority conservation sites, according to their transitional position between large humid forests and savannahs passing by the

forests of mountain feet and those in the middle of mountain, are still unlikely. These plants formation of the Western Highlands are continental biodiversity hot spots [9].

The West Region of Cameroon and especially the Noun area is characterized by mixed plant formations (forests, galleries forests, woody and shrubby savannahs). Due to the population increasing and the extension of land for agricultural activities, the natural forest formerly observed in large area is gradually reclaims under the human action, giving way to completely urbanized areas. These changes and predictions remain a major ecological concern [10]. In fact, the increasing trend in the current deforestation, especially in tropics, risks leading to the erosion of certain forest species not yet known [1]. In the West region of Cameroon, the strong and growing anthropogenic pressures exerted on forest relics could lead to a loss of species in forest still very little known; because these forests are subject to unprecedented anthropogenic pressures, threatening ecosystem services and human well-being. Due to this increasing human pressure on these forests threatened with extinction, it is now urgent to know the floristic diversity of highly anthropized ecosystems and determine their richness in Non-Timber Forest Products (NFTP), in order to implement and find a way to restore and sustain these resources which underpin climate regulation. The aim of this study was to characterize the floristic and ecological diversity of the Mawouon Forest in the Noum division (Western Highlands of Cameroon).

2. Material and methods

2.1. Study site

The Mawouon forest is located to 19 km from the Foumbot subdivision, Noun division in the West region of Cameroon. It is located between 5°27'00'' -5°29'30'' N and 10°44'30''-10°46'00'' E (Figure 1). The climate is tropical soudano-guinean type, with a long rainy season (mid-March - mid-November) and a short dry season (mid-November - mid-March). The annual average rainfall is 1950.1 mm and the annual average temperature is 17.09 °C. The relief is made up of an alternating of hills and valleys. The predominant soils are ferruginous, ferralitic and hydromorphic soils. The vegetation is characterized by the predominance of savannahs ecosystems with some patches of forest and galleries forests.

2.2. Methods

The field work was conducted during the rainy season on April 2017 in Mawouon's forest over an area of 4.2 ha. A total of 14 plots of 30 m × 100 m were done randomly to sample the floristic data and vascular plants. In order to identify most of the species, plots were established about 200 m away from each other. All individuals with diameter at breast height (DBH) ≥ 10 cm and their heights were recorded and measured. In each plot, herbs and epiphytes were not considered. Plants species were identified directly in the field using the flora [11, 12]; for other species, specimens were collected and compared to those available in the National Herbarium of Cameroon.

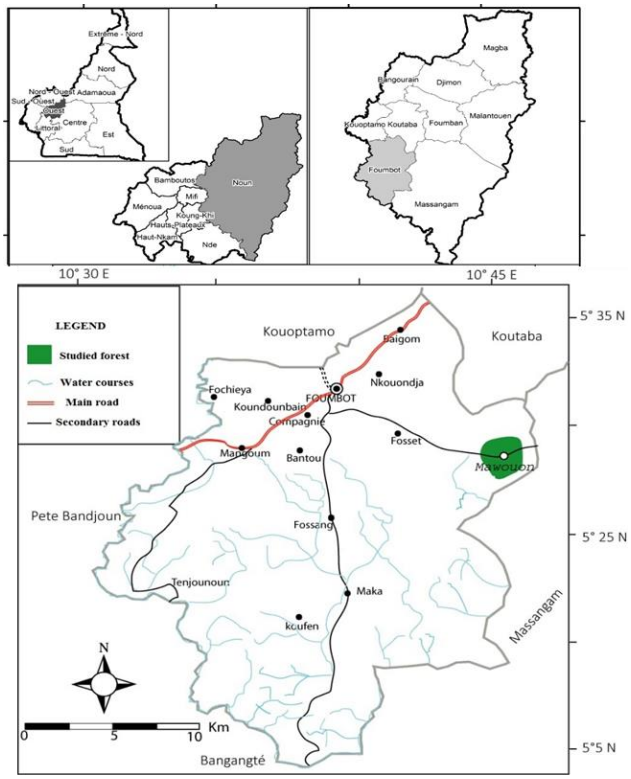


Figure 1 : Location of Mawouon's forest in the Foumbot subdivision

The taxonomic nomenclature adopted is the Angiosperms Phylogeny Group 3 (APG III).

Life form were determined and classified according to location of species in the vertical stratification of the ecosystem, indicate the ability of species to occupy space and seasons [13]. Phytogeographical distribution types characterized among other things, by the distribution pattern of vegetation and level of endemism of communities is likely to provide information about phytogeographic affinities, maturity and stability of the flora [14].

2.3. Data analysis

The species composition was described using the following parameters:

(i) The relative frequency (RFr) of species i is given by the formula: RF = (Ai/B) *100, where Ai=Number of plots containing the species i and B=total number of plots sampled.

(ii) Relative dominance (RDo) represents the recovery area for the species i of one population. It is given by the follow formula: RDo= $\pi Di^2/4$, RDo = relative dominance; Di = diameter at breast height of the specie i; π=3.14. (iii) Relative density (RDe) of species was calculated according this formula: RDe = Pi*100, where Pi=ni/N, ni is the number of individuals belonged to taxon i and N is total number of individuals of all sampled plots.

(iv) Relative diversity (RDi) is given by the formula: RDi = number of species of one family*100/ total number of species.

(v) Density (stems/ha) of each species were calculated according to this formula: D = ni/A where ni is the number of individuals belonging to species i and A is the area in hectares.

(vi) Basal area (BA) is given by the formula [15]: BA= $(\Sigma \sqcap Di)^2/4$, where D is diameter at breast height and S in m^2/ha.

(vii) Important Value Index (IVI) [16] is given by the relation: IVI= relative density + relative frequency + relative dominance.
(viii) Family Important Value (FIV) is given by the relation [15]: FIV= relative density + relative dominance + relative frequency.
Specific diversity of the site was described using the following indices: Shannon and Weaver [17] index is calculated according to the formula: H'= Σni/N log 2 ni/N. The equitability index of Pielou [18] is calculated according to the formula: Eq= H'/Hmax=H'/lnS. Simpson diversity Index (D):D = D=Σ (Ni/N)². Ni is total number of individuals of a specie i and N is total number individuals of all species.

3. Results and Discussion

3.1. Results

3.1.1. Floristic characteristics

In this study, 2324 individuals with DBH ≥ 10 cm belonging to 102 species, 78 genera and 35 families (APG III) were recorded. *Coffea arabica* (25.08%), *Myrianthus arboreus* (12.52%) and *Alchornea laxiflora* (10.62%) were the most abundant species. *Coffea arabica* (78.57%), *Alchornea laxiflora* (71.42 %), *Polyscias fulva* (71.42%) and *Voacanga africana* (71.42 %) were the most frequent species. The most dominants species were *Ceiba pentandra* (11.64 %), followed by *Lannea welwitschii* (5.82 %) and *Myrianthus arboreus* (5.08%) (Table I). The richest families in species were: Fabaceae (15 species), Euphorbiaceae (12 species), Moraceae (10 species) and Rubiaceae (8 species). Seventeen families were represented by a single species.
The Shannon-Weaver diversity index was 4.51 bits, the Pielou evenness index was 0.67 and the Simpson index was 0.1.

Table 1: Species with the highest values of relative frequency, relative dominance and IVI

Species	Relative Abundance	Relative Frequency	Relative Dominance	IVI
Coffea arabica	25.08	78.57	3.6	107.25
Myrianthus arboreus	12.52	71.42	5.08	89.03
Alchornea laxiflora	10.62	71.42	0.6	82.65
Voacanga africana	5.46	64.28	1.31	71.06
Rauvolfia vomitoria	4.38	64.28	0.77	69.44
Olax subsorpioidea	4.21	57.14	0.9	62.25
Ficus exasperata	3.52	50	1.14	54.66
Polyscias fulva	3.52	42.85	1.78	48.16
Prunus africana	1.03	42.85	4.17	48.05
Phyllanthus muellerianus	3.31	42.85	0.55	46.72
Tetrapleura tetraptera	0.98	42.85	2.21	46.05

3.1.2. Ecological importance indices

The ecological importance of species reveals that Coffea arabica is the most important species with an IVI of 107.25, followed by *Myrianthus arboreus* (89.03), *Alchornea laxiflora* (82.65) and *Voacanga africana* (71.06). These species are among the most abundant, the most frequent and / or most dominant (Table I).
The families with highest relative diversity values were the Euphorbiaceae (17.08%), Fabaceae (14.32%) and Cecropiaceae (12.65%). The most dominant families were the Fabaceae (18%), Moraceae (15%) and Malvaceae (9.97%). The ten most abundant families represented 84.59% trees of the sample. The most important families were the Fabaceae with a FIV of 47.03 followed by Euphorbiaceae (34.73) and Moraceae (34.51) (Table 2).

Table 2: Families with the greatest values of relative diversity, relative density, relative dominance and family important value (FIV)

Family	Relative diversity	Relative density	Relative dominance	FIV
Fabaceae	14.70	14.32	18	47.03
Euphorbiaceae	11.76	17.08	5.89	34.73
Moraceae	10.78	8.73	15	34.51
Rubiaceae	7.84	8.60	3.6	20.05
Cecropiaceae	2.94	12.65	0.39	15.98
Malvaceae	1.96	0.77	9.97	12.70
Apocynaceae	6.86	1.93	3.81	12.60
Meliaceae	4.90	5.07	2.19	12.16
Olaceae	0.98	8.73	0.91	10.62
Anacardiceae	2.94	0.77	4.81	8.52

3.1.2. Structure of woody vegetation of Mawouon forest

Diametral structure of woody-vegetation types

The distribution of individuals in diameter classes showed a structure in "L" shape. The greatest number of individuals were in the diameter class [10cm; 20cm[. The smallest proportions of individuals was observed in the diameter class [100 cm;⟶[(Figure 2). The maximum of DBH is 286 cm, this value was reached by 3 different trees. Mean diameter was 17.60 cm.

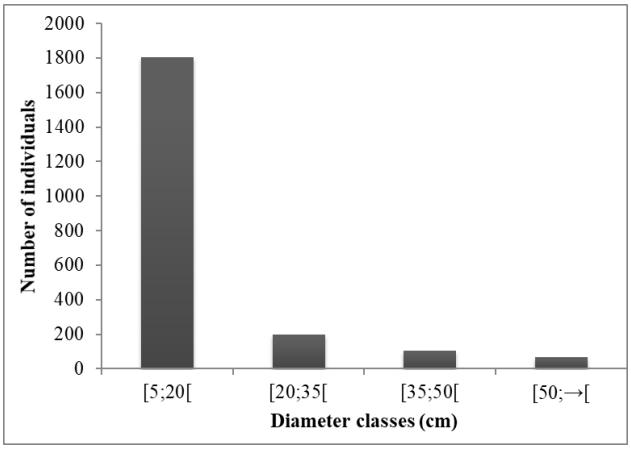


Figure 2: Distribution in diameter classes of individuals in the Mawouon forest

Vertical structure of Mawouon's Forest

The greatest number of individuals were in the lower height class [←; 15 m[while the stratum [25 m; 35 m[was the least represented (Figure 3). The distribution of individuals with respect to their height showed a structure in "L" shape. Only the species *Anthonotha macrophylla*, *Pterocarpus soyauxii*, *Dichrostachys cinera* and *Ceiba pentandra* had height higher than 35 m.

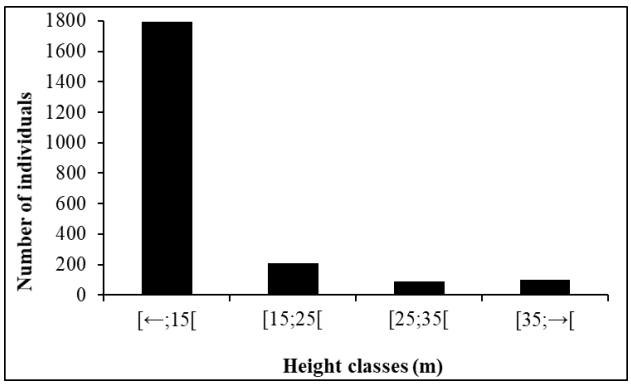


Figure 3 : Distribution of individuals according to height classes in the Mawouon forest

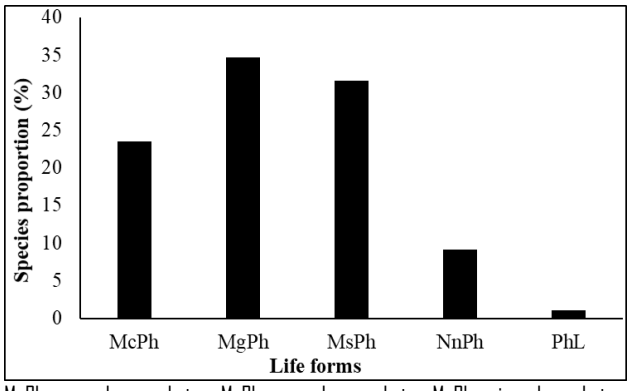
Density and basal area

In total, 2324 woody plants (DBH ≥10 cm) were recorded in 4.2 ha with mean density of 553.33 stems/ha. The species with high stem density were: *Coffea arabica* (25.08 stems/ha), *Myrianthus arboreus* (12.52 stems/ha), *Alchornea laxiflora* (10.62 stems/ha) and *Voacanga africana* (5.46 stems/ha). The average basal area was 29.15 m²/ha.

3.1.3. Life form and phytogeographic distribution of the Mawouon forest

Life Forms Spectrum

The detailed life forms spectrum of phanerophytes showed the preponderance megaphanerophythes (34 species, 34.69%) followed by mesophanerophytes (31 species, 31.63%) (Figure 4). The creeper phanerophytes were the least represented life form (1 species, 1.02%).

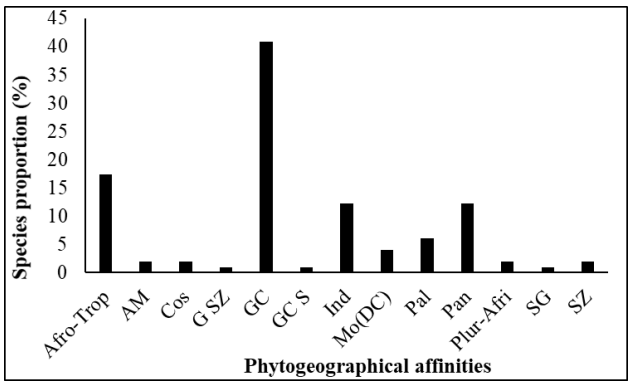


MgPh: megaphanerophytes; MsPh: mesophanerophytes McPh: microphanephytes; NnPh: nanophanerophytes; PhL: creeper phaneraphytes.

Figure 4 : Detailled spectrum of phanerophytes life forms in the Mawouon's forest

Phytogeographical distribution

The phytogeographical distribution showed a preponderance of Guineo-Congolian species (40 species, 40.81 %) by Afro-tropical species (17 species, 17.34 %) (Figure 5). The importance of african species showed that the flora conserved its identity. The lowest proportion of species with broad distribution indicated that the closing of this flora to external influences.



Cos: Cosmopolitan; Pal: Paleotropical; Pan: pantropical; AM: Afro-Malagasy; Afro-Trop: Afro-Tropical; Plur-Afri: Pluri-regional African; GC: Guineo-Congolian; SG: Sudano-Guinean, SZ: Sudano-Zambesian; Mo(DC): only in Cameroonian mountain, G SZ: Guinean and Soudano-Zambezian link species, GC S: Guineo-Congolian and Sudanian link species, Ind: Undeterminate.

Figure 5 : Spectrum of phytogeographic types of Mawouon's forest

3.2. Discussion

3.2.1. Floristic characteristics

The number of woody species, genera and families recorded was 102 species belonging to 78 genera and 35 families (APG III). These results were similar to those of Tiokeng et al. [19] who recorded a total of 91 species representing 85 genera and 47 families in the sacred forests in the Western Highlands of Cameroon. However, the studies of Noumo and Tiam [20] in of the Oku Sacred Forest in the North-West Cameroon found fewer number of species with 31 species belonging to 27 genera and 19 families. The study of Noumi [21] in the Kouoghap sacred forest of the village Batoufam (West Cameroon) found higher number of species with 252 species belonging to 186 genera and 82 families. In the same line, Tiokeng et al. [8] recorded 191 species representing 165 genera and 64 families in the Highlands of Lebialem (West Cameroon). The differences observed in these studies could be attributed to the number of plots in each study, the diameter at breast height (5 cm in some study and 10 cm in other), to the difference in the level of anthropogenic pressures such as agricultural activities and wood extraction. The high frequency of *Alchornea laxiflora*, *Polyscias fulva* and *Voacanga africana* could be explained by the climatic and edaphic conditions favourable for the installation of these species and that the anthropogenic pressures on these species are low. These High frequencies could also be due to the effectiveness agents of dispersion of their diaspores. The high abundance of Coffea arabica would be due to the fact that, two transects had crossed agroforestry relics made from coffee trees.

The value of the Shannon index obtained was high, indicating a high diversity of species in the Mawouon forest. This result was similar to those obtained by Tchouto et al. [16] in the humid forest of Campo-ma'an Forest (4.73 - 5.14 bits), Tiokeng et al. [8] in the Lebialem Highlands (2.97 - 5.80 bits), Noumi and Tiam [20] in the Oku Sacred Forest (2.60-3.97 bits) and Tiokeng et al. [19] in the Western Highlands of Cameroon (1.63-2.39 bits). This high diversity could be related to the fact that these forests do not seem to have known major disruptions. Pielou evenness index was high. This value means that the distribution of individuals across species is very equitable in the studied forest. The value of the Simpson index obtained in the Mawouon forest was low. Thus, the probability that

two individuals randomly selected belong to the same species is low. The high value of the Shannon-Weaver diversity index, the Pielou equitability index and the low value of Simpson index showed that this site was diversified [22].

3.2.2. Importance of species and families

The high ecological importance of *Myrianthus arboreus* is explained by its high number of' individual with large diameters. So, a species would be ecologically important, if it is numerically represented and the volume of wood of each individual also important. The Fabaceae was the most dominant family in this study. Gentry [23] remarks that the dominance of the Fabaceae in neotropic and in Africa is equal when only trees with a DBH > 10 cm are considered. The Fabaceae was also the most important family. This result is similar with those of Noumi [20], and Tiokeng et al. [8] in other tropical Cameroonian forests and Nangndi et al. [24] in the woody vegetation in the Sudano-guinean zone of Larmanaye, Chad. This family is also considered to be the one that characterizes the old forests [25].

3.2.3. Diametral and height structure of the Mawouon forest

The height and the diameters of the different woody species showed a structure in the form of an "L" shaped curve. It was found that a high proportion of stems of the woody species surveyed had smaller height and diameter indicating a good regeneration within the landscape. This structure results from anthropogenic pressures as wood collection and timber. According to Whitmore [26], the high densities of low diameter classes ensured the future of natural vegetation while the low densities of larger classes' trees resulted from natural selection. This stem class is in fact constituted of the seed-bearers which ensured the sustainability of the woody cover [24]. Similar results were found by Tiokeng et al. [19].

In terms of distribution with respect to height of the stems, the structure showed a high number of individuals in the lower height class ([←,15] m). The high number of seedlings showed a good natural regeneration. The great number of individuals with height less than 15 m showed the influence of anthropogenic activities dominated by overexploitation of certain species such as firewood, timber and medicinal plants which contributed enormously to the height reduction of individuals. It is therefore imperative under these conditions to take measures that favour conservation and the sustainable management of these species [15].

The value stem density in the present study was similar to 532 stems/ha obtained by Gonmadje et al. [7] in the Ngovayang forest. This result was higher than the one (461 stems/ha) recorded by Sonké and Lejoly [27] in the dense forest of the Dja reserve and lower than the one (749 and 943 stems/ha) obtained by Tiokeng et al. [8] in the Lebialem Highlands and 926 stems/ha obtained by Tiokeng et al. [19] in the sacred forest of the Western Highlands of Cameroon. These differences in density would be due to abiotic factors (soil, rainfall and competition) which determine the diversity and structure of the vegetation in relation to the biotic parameters. Basal area was in relation to the individual diameter and the species density.

3.2.4. Life forms spectrum

The life forms spectrum gives valuable indications on the structure, physiognomy and adaptive community strategies [28]. It is synthetic and focuses on the degree of adaptation of plants at unfavourable periods (cold periods and drought periods) and to occupy vertical strata of vegetation. The considerable importance of megaphanerophytes and mesophanerothytes translate the adaptive strategies of plants which correspond to the competitive strategy.

3.2.5. Phytogeographical affinities

The geographical distribution of plant species depends on living conditions in the environment, the adaptation of plants in the area and reflects climate conditions. The high proportion of species of the Guineo-congolian region, would reflect a great maturity of this forest which seems little or not disturbed by human activity. The proportion of species to African regional distribution is higher than that of species with wide distribution. This reflects a low degree of alteration of local flora [29]. Also, the presence of Guineo-Congolian, Sudano-Guinean and Sudano-Zambezian species indicated that Mawouon forest is a crossroad of several flora [30], confirming the situation of Cameroon at the crossroads of several phytogeographic regions. It is located on the margins of the Guineo-Congolian region, which explains the importance of Guinean irradiations (39.79%) and between the oriental and zambezian domains of the Sudano-Zambezian region, explaining the presence of species in this region (2.04%). The relative high proportion of endemic species (4.08%) is a reflection of the originality of the Mawouon forest flora. On the basis of the new Phytogeographic map of Cameroon proposed by Letouzey [31], the Mawouon forest is part of the Guinean-Congolese region, more precisely in the Submontane level, located between 800 and 2200 m in the South and between 1200 and 1800 m in the North.

Conclusion

The Mawouon forest had a large number of woody species with a high diversity. The woody flora had a rich specific composition of 102 species belonging to 78 genera and 35 families. Dominant woody species were *Ceiba pentandra, Lannea welwitschii* and *Myrianthus arboreus*. The most importance species in terms of importance value index IVI were *Coffea arabica*, *Myrianthus arboreus, Alchornea laxiflora* and *Voacanga africana*. The Fabaceae, Euphorbiaceae and Moraceae were the most represented families. Structural parameters showed a very high proportion of individuals with small diameter and height. The megaphanerophytes constitute the most abundant life form. Guinean-Congolian species were the most preponderant phytogeographic types. The floristic potential and anthropogenic pressures on this forest showed the need for sustainable management of these natural resources for the benefit of future generations.

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Conflict of Interests
The authors have not declared conflict of interest.

Authors' contributions
JMN and JBWT collected data in the field and analysed the field data. JMN, JBWT and VFN drafted the manuscript. VFN supervised the work. All authors read and approved the final manuscript.

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