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Floristic Diversity, Stand Structure and Plant Life Traits in the Forest-Savanna Mosaic at Ndjole (Centre Cameroon)

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Abstract

With the aim of assessing floristic diversity, stand structure and vegetation ecology, the present work was carried out in the savanna mosaic forest of the locality of Ndjole (Centre Cameroon). A total of 30 floristic plots of 40 m × 40 m (1600 m^2) were delineated in the different ecosystems (forest, forest-savanna contact zone and the savanna). Within each plot, all individuals with a diameter at breast height ≥ 10 cm at 1.30 m were taken into account. ANOVA was used to compare the means of the diversity indices of the different ecosystems, and the DUNCAN test at 5% significance level (XLSTAT 2016) to separate these means. A total of 85 species belonging to 67 genera and 33 families were recorded. That is, 68 species in semi-caducifolia forest, 45 in forest-savanna contact zone and 18 in savanna. Urticaceae, Combretaceae, Apocynaceae, Myristicaceae and Euphorbiaceae are the most diverse families in the forest. On the other hand, in contact zones, the Euphorbiaceae, Fabaceae, Annonaceae and Moraceae families are the most diversified, while in the savannas, the Combretaceae, Fabaceae and Annonaceae families are the most diversified. Shannon's diversity index values (1.7 to 2.37 bits) reflect low specific diversity; Piélou's equitability (0.86 to 0.9) shows good distribution of individuals within species. The diametric structure of woody species shows an inverted "J" shape in all plant communities. This indicates a high regeneration potential characterized by a greater number of small trees than large trees. Mesophanerophytes and megaphanerophytes are dominant in forests and forest-savanna contact zones, and microphanerophytes in the savannas. Endozoochory is the main mode of diaspore dissemination. As regards the distribution of phytogeographical types, it shows the overall dominance of

Guineo-Congolese species in all plant communities. Our study provides detailed data on forest-savanna floristic and plant life traits in the mosaic and recommends further studies on the impact of environmental parameter variations on the forest encroachment into savanna.

Keywords

Mosaic, Communities, Dissemination, Regeneration, Diversity

1. Introduction

African tropical rainforests are terrestrial ecosystems with one of the highest and most complex biological diversities on the planet [1]. It is the second largest block of dense rainforest after Amazonia, and its Central African forests extend over six countries: Cameroon, Central African Republic, Democratic Republic of Congo, Republic of Congo, Gabon and Equatorial Guinea. They play an important global role in preserving biodiversity and storing carbon [2]. Its forests account for around 70 percent of the African continent's forest cover, nearly half of which are dense lowland forests [3]. Cameroon's forests belong to the vast Central African forest massif and represent around 11% of this massif [4].

Cameroon's forest ecosystems cover around 46.27% or 22.5 million ha of the national territory [5]. Cameroon is one of the Central African countries with high forest potential, with 22 million ha of dense rainforest. Forest-savanna mosaics rank among the country's most important forest categories, accounting for 9.4% of Cameroon's forest cover with an area of around 2,537,718 hectares [6].

Ecotones are transition zones between ecological communities, ecosystems or eco-logical regions [7]. Whatever the scale, transition zones generally cover vulnerable ecosystems that are relevant to the flow of organisms [8], with high biodiversity and the presence of rare species [9]. Transitions between forest and savanna show a wide variety of vegetation types, with different characteristics, floristic composition and ecosystem functions [10]. Throughout the tropical region, forest and savanna largely coexist as a mosaic at the landscape scale [11]. These two vegetation types differ not only in terms of tree density and vegetation structure, but also in species composition, with few species present in both ecosystems [12]. Its rich biodiversity is an important natural resource for food, medicine, timber and firewood for local inhabitants [13].

Knowledge on floristic diversity of an area can reflect the total resources and conservation status which have a key role for making conservation strategies and policies. Among the various ecological attributes of plant communities, floristic composition and ecological diversity are the most important ones that are influenced by a variety of biotic and abiotic factors [14].

In the Ndjole ecological zone, observations have shown that dense semi-caducifolia forest has been continuously colonizing periforest savannas for several decades, and that this transgression movement is certainly not recent [15]. Transition zones often receive little attention in biodiversity conservation strategies, although they can generate adaptive responses to environmental change [16]. The forest-savanna mosaic provides local communities with arable land, wild fruits and honey, bushmeat, firewood, building materials, water and grazing areas, among other regulatory and cultural ecosystem services [17].

Unfortunately, these forest-savanna mosaics have been severely fragmented, degraded and modified by human activities, such as slash-and-burn agriculture, unsustainable exploitation of wild resources and urbanization [18] [19]. Very few studies have been conducted on the characterization of forest-savanna mosaics in Cameroon, so it is therefore urgent to provide a good knowledge of the composition of the woody flora and other parameters. The goal is to highlight the floristic diversity, structure and ecology of vegetation in the forest-savanna transition zones in the locality of Ndjole.

2. Materials and Methods

2.1. Study Site

The study took place in the locality of Ndjole, commune of Yoko, located in the Mbam et Kim Division, Centre Region Cameroon, between latitude 5˚35'33" North and longitude 12˚18'57" East (**Figure 1**). The Yoko commune has a Guinean equatorial climate, with abundant rainfall spread over almost the whole year. The average annual rainfall is 1550 mm. The climate is marked by two dry seasons and two rainy seasons [20].

Soils are generally ferralitic, reddish in the savanna zones and blackish in forest zones. They are clayey, lateritic and clayey-sandy in places. Soil degradation is encouraged by erosion. The relief is dominated by the high rocky mountain range to the west of Yoko commune (Mont Fouiy), with an average altitude of around 1060 m, and the vast plains found in the savanna zones. These are low-lying areas, valleys located downstream of forests and steep hills that break up the monotony of the plains [21]. The hydrographic network is very dense. It is made up of numerous small, medium and large rivers. Flora and vegetation are characterized by savanna (tree savanna, shrub savanna, herbaceous savanna) and forest (dense forest and gallery forest). Forest vegetation is rich in various types of trees and non-timber forest products (NTFPs). Non-timber forest products include Djansang, Okok, wild mango and cola. Savanna vegetation consists of small trees, fodder species and aquatic forage found in lowlands and along watercourses. Forests and the savannas are exploited by the population for agriculture [22]. The fauna is diverse, comprising small animals, large animals, birds and reptiles. Agriculture is the main source of income for rural populations in the Yoko district. Agricultural practices are slash-and-burn in forest zones and bush fires in the savanna zones. Animal husbandry is very little developed, despite the fact that it is practiced by both men and women. Extensive livestock farming is characterized by small herds and roaming animals [22].

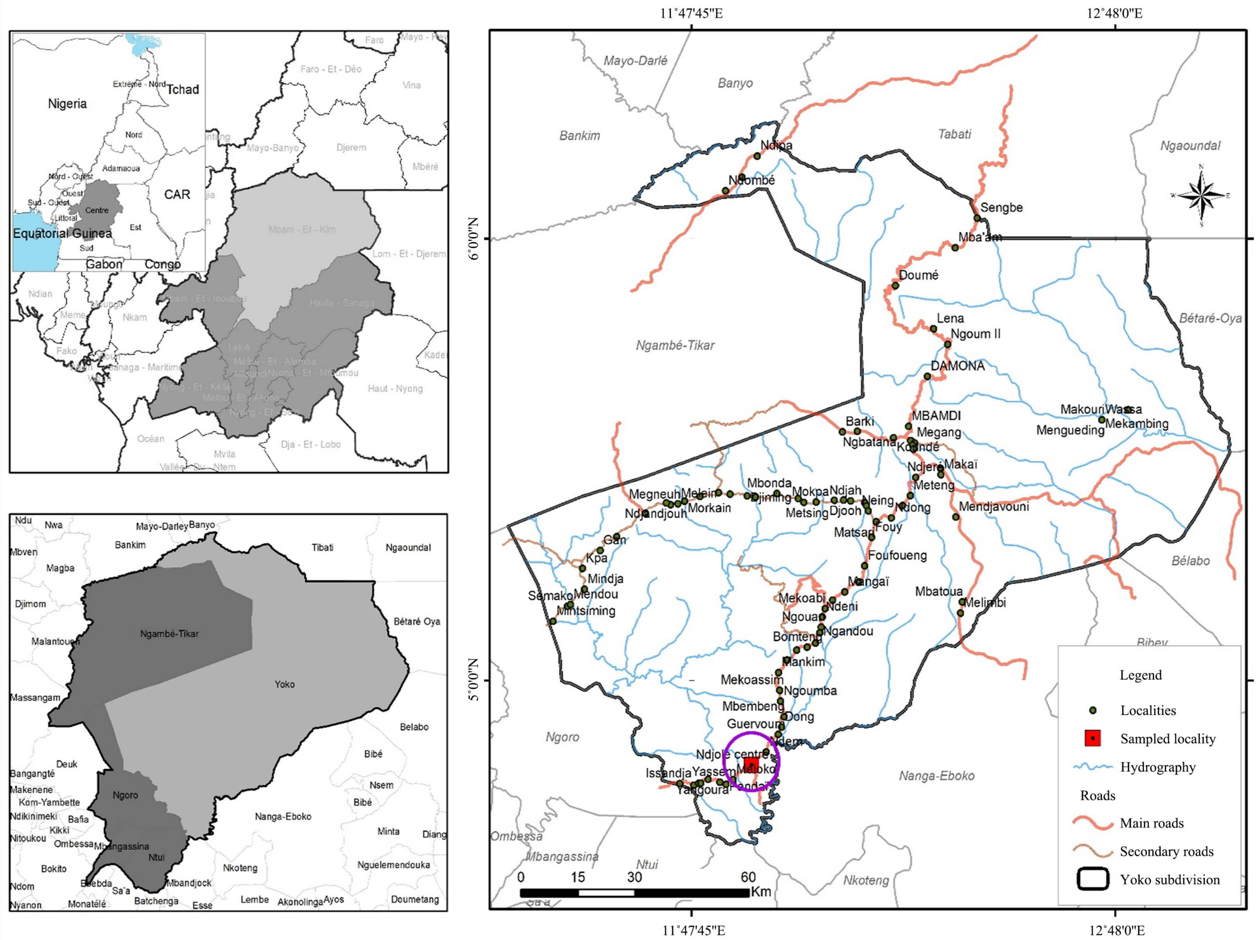

Figure 1. Location of the study area.

2.2. Methodology

Phytosociological surveys were carried out in three plant communities: forests, forest-savanna contact zones and the savannas. Quadrats of 40 m × 40 m, *i.e.* 1600 m^2, were installed at random in the different sites chosen, striving to integrate the different facies of the plant communities studied, various natural and anthropogenic conditions [14]-[23]. Thus, 30 quadrats were established in the Ndjole locality, representing a total of 48,000 m^2 (4.8 ha). For each tree, the diameter at breast height (DBH) ≥ 10 cm was measured at 1.30 m from the ground or 30 cm above the last trunk deformation using a diametric tape. Species identification was carried out in-situ and ex-situ. Several botanical works were used to identify species in the field, including Useful Trees of Gabon [24], Trees of Equatorial Guinea [25] and a Collection of plants names in ethnic languages of Cameroon [26]. Unidentified species were collected and compared with samples from the Yaoundé-Cameroon National Herbarium for identification. The classification system used was APG III.

2.3. Data Processing

The species composition was described using the following parameters:

- Frequency, also known as number of occurrences, is the number of times a taxon appears in a survey. It thus gives an idea of the social behavior of this taxon and its distribution in space.
- Species abundance corresponds to the number of individuals of a given species out of the total number of individuals in the sample. It is also expressed in terms of relative density. Relative density (Dr) is the number of plants of a species (or family) divided by the total number of plants and multiplied by 100.
- Taxon dominance is assessed by basal area. This takes into account the size of individuals, and highlights the taxa that occupy the most space in the vegetation. The relative dominance of a species is the ratio of its basal area to the total basal area, multiplied by 100.
- The Species Importance Value Index (IVI) is an indicator of the phytosociological importance of a species, within a particular community. This index was developed by Cottam and Curtis [27]. It is calculated according to the following formula,

$$\text{IVI} = \text{relative density} + \text{relative frequency} + \text{relative dominance}.$$

Specific diversity of the site was described using the following indices:

- Shannon diversity index (H') is the most commonly used index in the literature. It expresses diversity by taking into account the number of species and the abundance of individuals within each species. It is expressed in terms of the proportions of each species. H is maximal when all individuals are equally distributed among all species [28]. The Shannon diversity index increases as diversity increases [29].

$$H' = -\sum\left(n_i/N\right)\log_2\left(n_i/N\right),$$

with n_i = number of species i, N = number of all species; ISH is expressed in bits.

- Pielou Equitability (EQ) corresponds to the ratio between observed diversity and the maximum possible diversity of the number of species (N). Pielou Equitability varies from 0 to 1. It tends towards 0 when almost all species are concentrated in a single species. It is 1 when all species have the same abundance. A low Equitability represents a high importance of a few dominant species [30]. Its formula is as follows:

$$\text{EQ} = \text{ISH}/\log_2 N.$$

- Simpson's diversity index measures the probability that two randomly selected individuals in the sample belong to the same species [31]. It measures the way in which individuals are distributed between the species of a community. Its formula is as follows:

$$D = 1 - \sum n_i/N$$

where n_i = number of species i, N = total number of species;

- Sorensen's index of similarity (K) is used to assess whether two sites to be compared floristically belong to the same plant community or not. For K

values > 50%, the two sites compared belong to the same plant community. For those below 50%, we conclude that the two areas compared belong to different plant communities. Sorensen's coefficient of similarity is:

$$K = \left(2c/\left(a+b\right)\right)\times 100\,;$$

a = Represents the number of species in plot 1; b = Represents the number of species in ploot 2; c = number of species common to both plots.

Structural parameters

This was determined by the distribution of individuals by diameter class, density and basal area in each land-use type. Trees and shrubs were divided into diameter classes of 10 cm amplitude, and distribution histograms were developed to characterize the diametric structure of the vegetation.

- Species density

The density of a species is the number of individuals of that species per hectare. It is evaluated by the formula $N = n/S$ (with N: density (number of stems/ha), n: number of stems present on the surface considered, S: surface considered (ha).

- Basal area

The basal area of a tree is the surface area occupied by the stem, measured on the bark at 1.30 m from the ground. It is expressed in m^2/ha. The basal area of a species is the sum of the basal areas of all the individuals of that species, expressed per hectare. The total basal area is the sum of the basal areas of all the individuals present on the surveyed area.

Functional spectrum of vegetation

To characterize vegetation types, observations were made based on characteristics related to biological type, diaspore type, dispersal mode and phytogeographical distribution.

- The various biological types obtained in the course of this work are defined according to Raunkiaer [32] classification, adapted to tropical regions by numerous authors [33] [34] [35].
- Diaspore types and their seed dispersal modes were determined in the field by observations on the species and other sources. The diaspore types of species are taken from Senterre [36].
- The phytogeographical elements of the species in our study area were obtained from information on the distribution of species contained in the various floras and from the work of several authors [14]-[37].

ANOVA was used to compare the means of the diversity indices of the different ecosystems and see if there was a significant difference, and the DUNCAN test at the 5% significance level was used to separate these means using XLSTAT Software.

3. Results

3.1. Floristic Composition

A total of 933 individuals with stem diameter at breast height (DBH) of ≥10 cm representing 85 tree species, 67 genera and 33 families were recorded in all plant communities. Among these families, the Urticaceae family is the most represented in the forest (**Figure 2(a)**). It is followed by the Combretaceae, Apocynaceae, Myristicaceae, Euphorbiaceae, Malvaceae and Anacardiaceae families. On the contact zone, two families (Euphorbiaceae and Fabaceae), *i.e.* 9.09% of total families, are present in all plots, corresponding to a relative frequency of

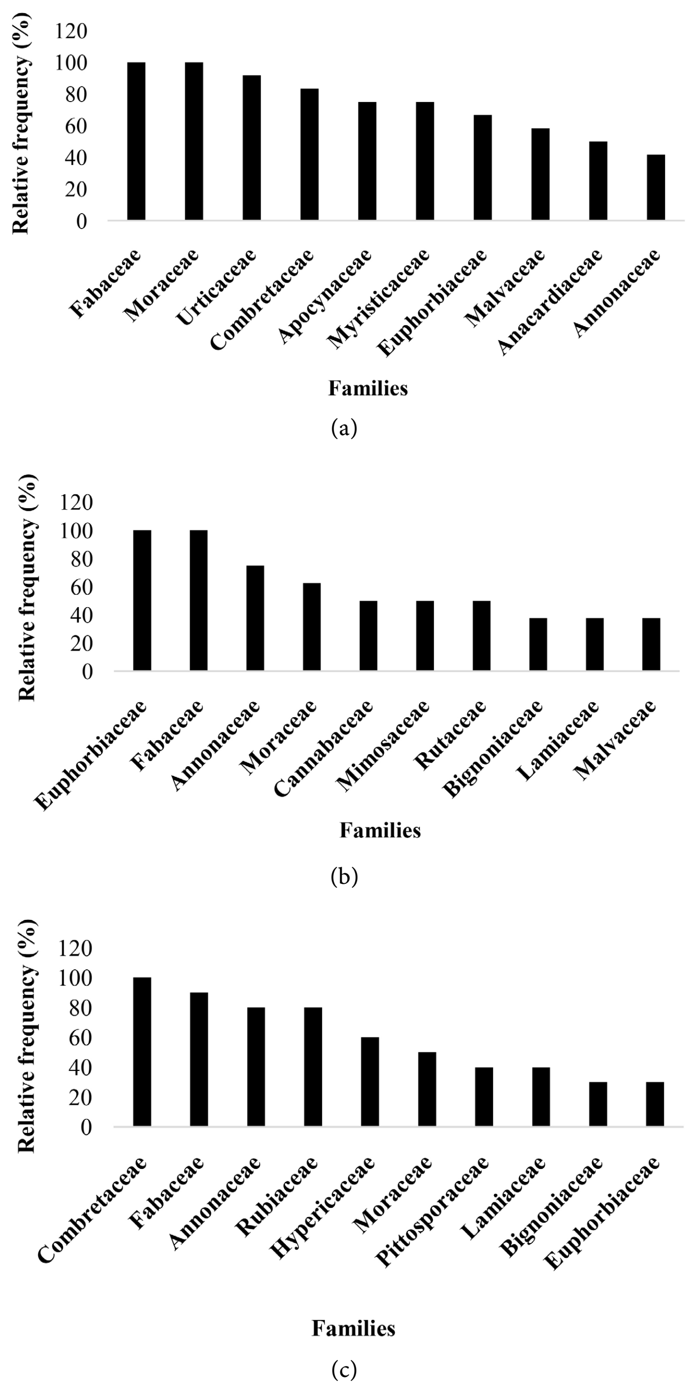

Figure 2. The ten most frequent families in the different ecosystems of the Ndjole locality: (a) Forest, (b) Contact zone and (c) Savanna.

100%. Five families have a frequency ≥ 50%, *i.e.* present in at least 4 plots (**Figure 2(b)**): Annonaceae, Moraceae, Cannabaceae, Mimosaceae and Rutaceae In the savanna, 11 families were recorded. Of these, the Combretaceae family was present in every plots, corresponding to a relative frequency of 100% (**Figure 2(c)**), followed by Fabaceae, Annonaceae, Rubiaceae, Hypericaceae, Moraceae, Pittosporaceae, Lamiaceae, Bignoniaceae, Euphorbiaceae and Phyllanthaceae.

3.2. Floristic Diversity of Different Plant Communities

The species richness and average diversity index values (Shannon diversity, Simpson diversity and Pielou equitability) of the different ecosystems in the study area are shown in **Table 1**. This table shows that forests are significatively richer than contact zones and savannas (p ≤ 0.05). The mean value of the Shannon index varies from 1.7 ± 0.3; 2.16 ± 0.19 to 2.37 ± 0.23 for savannas, contact zones and forests respectively. These values show that forest is more di-verse than contact zone and savanna, which is confirmed by Simpson's index (0.85 ± 0.06). As for Pielou's equitability, it tends towards 1 for all ecosystems. Values range from 0.86 in the savannas, 0.87 in the contact zone and 0.90 in the forests. These values show that the forest is more diverse than the contact zone and savanna, which is confirmed by Simpson's index. Similarly, forest species are more evenly distributed than those of other plant communities.

Floristic similarity between ecosystems

Sorensen's Index which is the most widely used one in ecological studies to know the similarity between two communities was used (**Table 2**). The results show that floristically, the forest and forest-savanna contact zone (59.32%) belong to the same plant community (K being greater than 50%). The degree of floristic similarity is 32.09% between the forest-savanna contact zone and the savanna, and 25.24% between the forest and the savanna.

Table 1. Floristic richness and diversity in the study area. N: number of individuals, ISH: Shannon diversity index, D: Simpson diversity index, EQ: Pielou equitability.

Ecosystems	N	Number of species	Number of genus	Number of families	H' (bits)	Simpson	EQ
Forest	448	68	52	30	2.37 ± 0.23^a	0.85 ± 0.06^a	0.9 ± 0.05^a
Forest-savanna contact	278	45	35	22	2.16 ± 0.19^b	0.84 ± 0.03^b	0.87 ± 0.03^b
Savanna	207	18	15	11	1.7 ± 0.3^c	0.77 ± 0.07^c	0.86 ± 0.07^c

^{a,b,c}: Means followed by the same letters, in the same column,, are not significantly different at the 5% probability threshold.

Table 2. Sorensen's coefficient (K) of similarity between different plant communities in the Ndjole locality.

Ecosystems	Forest	Forest-savanna contact
Forest		
Forest-savanna contact	59.32	
Savanna	25.24	32.09

Importance value of species

Table 3 shows the species with the highest importance value indices in the Ndjole locality, according to different communities. The species with the highest importance index (IVI) values in the forest overall (10.07% to 24.57%) are *Ceiba pentandra*, followed by *Musanga cecropioides*, *Pycnanthus angolensis*, *Terminalia superba*, *Myrianthus arboreus*, *Albizia adianthifolia* and *Pentacletra macrophylla*. Three species have a preponderance of less than 1%. These are *Alstonia boonei*, *Bridelia micrantha* and *Canthuim* sp. In the savanna-forest contact zone, eight species have a preponderance value of over 10%. These are *Terminalia glaucescens*, *Macaranga assas*, *Piptadeniastrum africanum*, *Xylopia aethiopica*, *Albizia ferruginea*, *Milicia excelsa*, *Albizia adianthifolia* and *Afzelia pachyloba*. The remaining species (82%) have an importance value of less than 10%. In the savanna, *Terminalia glaucescens* is the species with the highest importance index value, followed by *Nauclea diderrichii*, *Annona senegalensis*, *Piliostigma thonningii*, *Pittosporum* sp. and *Ficus* sp2. Six species have a preponderance value of less than 10%: *Cassia* sp., *Markhamia lutea*, *Bridelia* sp., *Alchornea cordifolia*, *Ficus* sp. and *Macaranga assas*.

Vegetation structure in Ndjole locality

- **Density**

A total of 933 individuals with DBH ≥ 10 cm are distributed across the different plant communities. Density is the highest in the forest (235.78 stems/ha), followed by the forest-savanna contact zone (217.18 stems/ha) and the savanna (150.62 stems/ha) (Figure 3).

- **Basal area of species in different plant communities**

Figure 4 illustrates the variation in basal area in the different ecosystems of the Ndjole locality. Basal area is higher in the forest (30.1 m^2/ha) than in the contact zone (13.08 m^2/ha), and lower in the savanna (3.75 m^2/ha). The forest is home to larger-diameter trees in the study area, followed by the contact zone and finally the savanna.

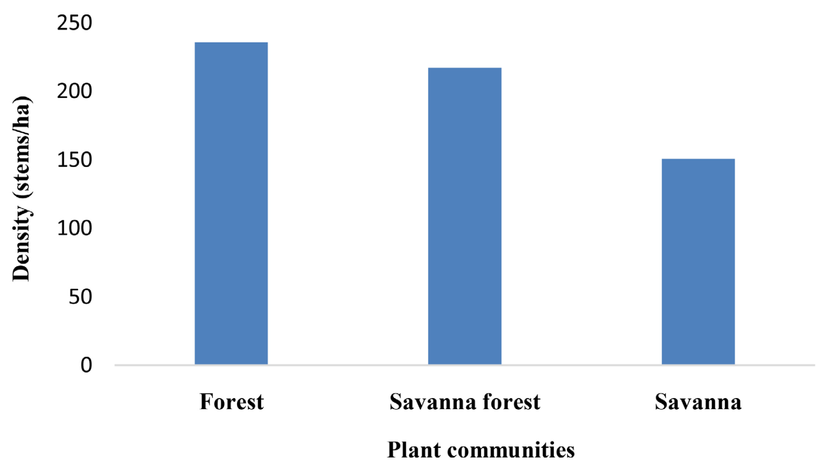

Figure 3. Average density (number of individuals per hectare) in different plant communities.

Table 3. Preponderance values of species in the study area (DBH ≥ 10 cm) with higher IVI. With Fr: Relative frequency; Dor: Relative dominance; Dr: Relative abundance; IVI: Importance Value Index.

Communities	Species	Fr %	DR %	Dor %	IVI
Forest	*Ceiba pentandra*	2.11	2.00	20.44	24.57
	Musanga cecropioides	4.76	14.06	1.57	20.39
	Pycnanthus angolensis	4.76	5.80	4.41	14.97
	Terminalia superba	5.29	6.69	2.90	14.89
	Myrianthus arboreus	0.52	10.26	0.85	11.65
	Albizia adianthifolia	3.17	2.90	4.23	10.31
	Pentacletra macrophylla	4.76	2.90	2.41	10.07
	Piptadeniastrum africanum	2.64	1.78	5.07	9.50
	Milicia excelsa	0.52	2.67	5.01	8.22
	Albizia zygia	3.17	2.67	1.95	7.81
Forest-savanna contact zone	*Terminalia glaucescens*	2.83	18.70	2.02	23.65
	Macaranga assas	6.63	8.63	0.67	15.90
	Piptadeniastrum africanum	3.77	3.59	8.31	15.58
	Xylopia aethiopica	5.66	5.39	3.34	14.40
	Albizia ferruginea	3.77	4.31	4.29	12.38
	Milicia excelsa	3.77	2.15	5.35	11.28
	Albizia adianthifolia	4.71	2.51	3.88	11.12
	Afzelia pachyloba	2.83	0.35	7.91	11.10
	Albizia zygia	2.83	2.51	4.54	9.89
	Pentacletra macrophylla	2.83	0.1	6.13	9.68
Savanna	*Terminalia glaucescens*	34.57	24.89	9.83	69.30
	Nauclea diderrichii	14.40	10.37	11.96	36.74
	Annona senegalensis	17.28	12.44	3.21	32?95
	Pittosporum sp.	12.67	9.12	3.71	25.52
	Piliostigma thonningii	11.52	8.29	4.09	23.91
	Ficus sp2.	8.06	5.80	6.51	20.39
	Vitex doniana	7.49	5.39	5.88	18.77
	Albizia zygia	5.76	4.14	7.21	17.13
	Milicia excelsa	2.88	2.07	11.96	16.92

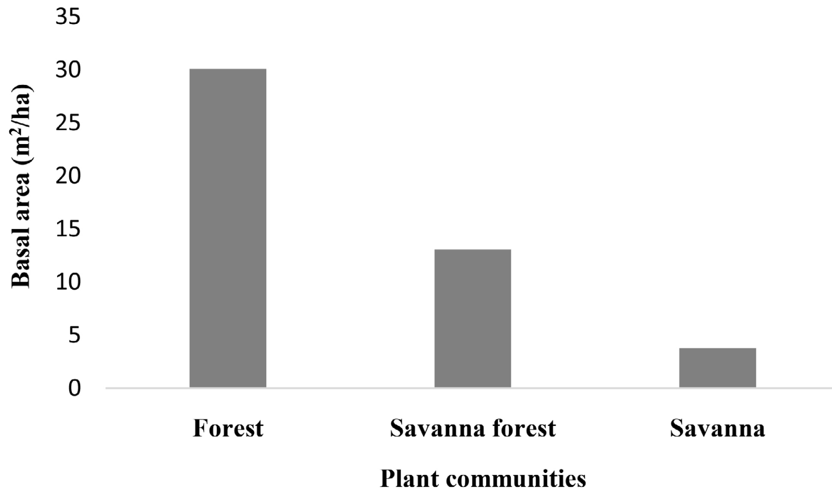

Figure 4. Average basal area in different plant communities.

- **Stand diameter class distribution**

Figure 5 shows the distribution of individuals by diameter class in the various plant communities. The histograms show an inverted "J" shape in all plant communities since the number of stems decreases steadily from small to large diameter classes. The number of young individuals is relatively higher in the forest than in the savanna and contact zone. In the forest, the [10 - 20 cm[diameter class accounted for 206 individuals (46.81%), followed by the [20 - 30 cm[diameter class with 90 individuals (20.45%). In the forest-savanna contact zone, 126 individuals are present in the [10 - 20 cm[diameter class, *i.e.* 45.32%, and 74 individuals in the [20 - 30 cm[diameter class, *i.e.* 26.97%. In the savanna, individuals included in the [10 - 20 cm[class accounted for 170 individuals, or 82.12%, followed by the [20 - 30 cm[class with 20 individuals recorded, or 9.66%. The number of individuals in other classes decreased progressively in the different plant communities, reaching the lowest values.

Life form and phytogeographic distribution

The flora is largely dominated by Guineo-Congolese species in the forest (39.69%) and in the contact zone (40.9%) (**Table 4**). This is followed by liaison species in the forest (38.23%), in the contact zone (36.36%) and widely distributed species in the forest (13.23%) and in the contact zone (15.89%). The savanna is also well represented by Guineo-Congolese species (44.43%) and liaison species (44.43%). Wide-ranging species are not represented in the savanna. Analysis of the biological types of woody individuals with DBH ≥ 10 cm reveals a clear predominance of mesophanerophytes both in the forest and in the contact zone, with (44.11%) and (44.51%) respectively. Microphanerophytes are more dominant in the savanna (45.43%). Megaphanerophytes are better represented in the forest (35.29%), followed by the savanna (26.77%) and the contact zone (25%). With regard to the types of diaspores of the species inventoried, sarcochores are more important in the forest, contact zone and the savanna, with 60.29%, 57.27% and 38.88% respectively, followed by barochores.

Table 4. Phytogeographical distributions, biological types, diaspore types and modes of dissemination of species in the different plant communities of the Ndjole forest-savanna ecotone.

Ecological parameters		Ecosystems % Forest	Ecosystems % Savanna-forest	Ecosystems % Savanna
Phytogeographical distributions	Guinean-Congolese endemic species	39.69	40.9	44.43
	Lower-Guinean-Congolian	5.88	13.66	16.66
	Centro-Guinean-Congolian	13.23	9.09	5.55
	Omniguinean-congolese	20.58	18.18	22.22
	Linking species	38.23	36.36	44.43
	Afrotropical	38.23	34.09	38.88
	Guinean-Sudanese-Zambézian	0	2.27	5.55
	Wide-ranging species	13.23	15.89	0
	Afro-American	1.47	2.27	0
	Pantropical	8.82	6.81	0
	Paleotropical	2.94	6.81	0
Biological types	Mesophanerophytes	44.11	44.51	27.8
	Megaphanerophytes	35.29	25	26.77
	Microphanerophytes	20.58	27.27	45.43
Types of diaspore	Ballochores	4.1	9.09	11.11
	Barochores	10.29	9.09	16.66
	Pogonochores	4.41	4.54	5.55
	Sarcochores	60.29	57.27	38.88
	Sclerochores	5.88	9.09	5.55
	Pterochores	10.29	6.81	5.55
Dissemination methods	Endozoochory	60.29	54.54	55.55
	Anemochory	16.17	15.9	0
	Autochory	8.82	13.63	16.66
	Barochory	5.88	6.81	5.55

Pogonochores are least abundant in the forest and contact zone, at 4.41% and 4.54% respectively. Throughout the study area, endozoochory is dominant in forest (60.29%), contact zone (54.54%) and the savanna (55.55%). Barochory is weakly represented in the various biotopes, at 5.88%, 6.81% and 5.55% respectively.

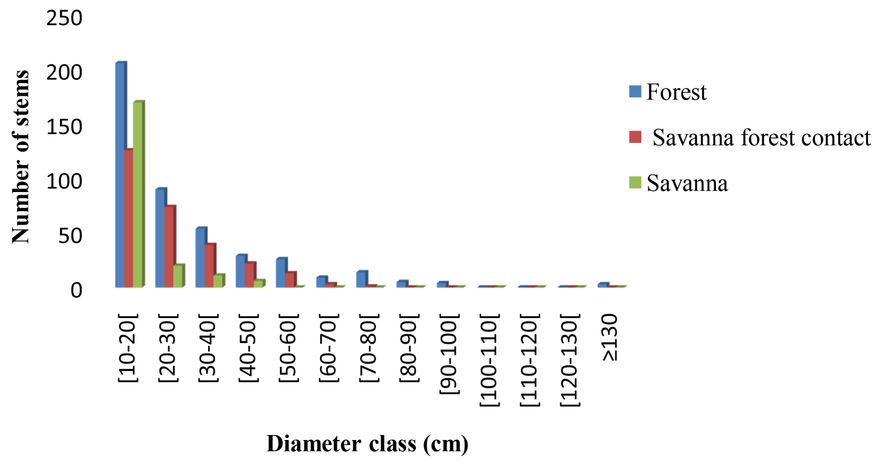

Figure 5. Diameter structure of woody species in different plant communities.

4. Discussion

The floristic richness of the Ndjole locality was estimated at 85 species belonging to 67 genera in 33 families, of which 68 species were found in semi-caducifolia forest, 45 in the savanna forest contact zone and 18 species in the savanna. This floristic richness is lower than that obtained by Koulibaly [38] who have225 species in the forest-savanna mosaics of the Lamto Reserve and Comoé National Park in Côte d'Ivoire. This result is also lower than those found by Soro *et al.* [39] in the forest-savanna ecotone of the Lamto reserve in Côte d'Ivoire (223 species) and this high species richness could be explained by the fact that the reserve enjoys protected area status and by Tiebre *et al.* [40] (349 species) in the forest-savanna transition zone of Foungbesso. This difference is due to the fact that these authors inventoried trees, shrubs, lianas, grasses and epiphytes. This difference in results could also be explained by sample size, sampling methods and other parameters such as climatic and edaphic conditions. The low number of species in savannas (18 species) is due to the fact that savanna environments are generally not very diverse [41] [42]. The loss of savanna diversity is also linked to the use of these biotopes for the establishment of certain perennial crops [43]. The specific diversity of families varies according to ecosystem. In the forest, we have the Urticaceae, Malvaceae, Fabaceae, Euphorbiaceae and Moraceae families. In contact zones, on the other hand, the Annonaceae families, followed by Fabaceae, Euphorbiaceae and Combretaceae were more diversified, and in savannas, the Combretaceae, Fabaceae, Annonaceae, Rubiaceae, Hypericaceae and Moraceae families. All these families, with the exception of Cannabaceae, are recognized for their high diversity in lowland Cameroonian dense forest [44] or in highland forest [35] [45] [46]. Indeed, according to Xiao-Tao and Jian-Wei [47], Fabaceae, Euphorbiaceae, Annonaceae and Rubiaceae are common tropical forest families. Other studies on floristic diversity carried out in the Dja reserve (Cameroon) have shown that Fabaceae, Rubiaceae, Malvaceae, Euphorbiaceae, Sapotaceae, Annonaceae and Meliaceae are the most diverse families [48]. N'Dja *et al.* [49] in the Besso classified forest (Ivory Coast), Soro *et al.* [39] in the forest -savanna ecotone of the Lamto reserve in Ivory Coast and Tiebre *et al.* [40] in the forest-savanna transition zone at Foungbesso in Ivory Coast found virtually the same family procession. Indeed, several Ivorian forests are dominated by the same family procession [50]. The Fabaceae family is also considered to characterize old-growth forests, alongside the Burseraceae and Olacaceae [51]. According to Gonmadje *et al.* [52], the high diversity of this family in an environment is indicative of environments belonging to the Guineo-Congolese domain.

The highest Shannon index value (H') is obtained in the forest (2.37 bits), showing that it is more diverse than other ecosystems. The Shannon diversity index increases as specific diversity increases [29]. However, according to Kent and Coker [53], forest communities are considered rich according to the Shannon index with a value of 3.5 bits. The value for the forest is below the norm and therefore reflects the low specific richness of this plant formation. This low species richness may be due to human activities, the main ones being agriculture, NTFP harvesting, energy/timber exploitation and road infrastructure, as well as environmental factors. This value is lower than that found by Kamga *et al.* [44] in *Garcinia kola* formations in the Central and Eastern Regions of Cameroon (2.98 bits and 2.13 bits respectively) and that obtained by Sunderland *et al.* [54] (3.92 bits) in the forests of the Monts de Cristal in Gabon. These authors concluded that this high value reflects high diversity and a good reconstitution of understory floristic diversity, no doubt due to favorable environmental conditions. These low values of the shannon diversity index (of which 2.37 bits is maximum and 1.7 bits is minimum) characterize the dominance of a species or group of species over the stand [30]-[55]. Indeed, these formations have recently undergone a great deal of anthropogenic disturbance, which is thought to be responsible for the reduction in their biodiversity. However, the Shannon index in these formations remains high compared with that of the gallery forests of Koupa Matapit (West Cameroon), which averages 1.28 bits [14]. The Pielou Equitability values (0.86 to 0.9) found in the present work tend towards 1, indicating that the species in these sites have the same abundance. These values fall within the range of values considered optimal (0.6 to 0.8) by Odum [56]. They reflect a good distribution of individuals within species. These values are comparable to those of Tiebre *et al.* [40] in the forest-savanna transition zone of Foungbesso (western Côte d'Ivoire) (0.60 and 0.95), these authors asserting that the high value of Pielou Equitability testifies to a good distribution of individuals within the stand. Simpson's index, which is highly sensitive to the distribution of individuals between species, varies from (0.77 to 0.85). These high values of Simpson's index in all plant formations express a weak organization of the ecological system and correspond to environmental conditions favorable to the installation of numerous species represented by a small number of individuals [30] and are higher than that obtained by Ngueguim [57] in the Mangombe forests (0.5); to that found in the Dja reserve in Cameroon, *i.e.* 0.50 [58] and to that of Wouokoue [59], 0.12 at Mount Bambouto (Cameroon). According to these authors, the high value of Simpson's index shows that the probability of two individuals taken at random belonging to the same species is high.

The species importance value index for individuals with DBH ≥ 10 cm varies according to plant communities. Important species in the Ndjole forest-savanna ecotones are (in order of importance): *Terminalia superba*, *Myrianthus arboreus*, *Pycnanthus angolensis*, *Pentacletra macrophylla*, *Milicia excelsa* and *Musanga cecropioides* (73.97% to 92.93%). In the contact zone, we have Xylopia aethiopica, Terminalia glaucescens, *Piptadeniastrum africanum*, *Albizia ferruginea*, *Albizia adianthifolia* and *Nesogordonia papaverifera.* Indeed, some of these species (including *Musanga cecropioides*, *Pycnanthus angolensis*, *Myrianthus arboreus* and *Terminalia superba*) are recognized by N'guessan and Kassi [60] as the most important species in the forests of the Agbo ecotone in Ivory Coast. According to Kamga *et al.* [44], the latter include *Musanga cecropioides* and *Myrianthus arboreus*, which are pioneer species. This is confirmed by the high proportion of pioneer species in all the different ecosystems and exotics such as *Mangifera indica*, which shows that the environment has been disturbed by anthropogenic activities. In the savanna, we have *Terminalia glaucescens*, *Nauclea diderrichii*, *Annona senegalensis*, *Piliostigma thonningii*, *Pittosporum* sp. and *Albizia zygia* as the most important species, of which only *Annona senegalensis* has been in the periphery of the Mbam and Djerem National Park [61]. It should also be noted that the presence of certain savanna species found at Ndjole was reported by the same author and recognized as important by Youta *et al.* [15] in the valley of the confluence of the Mbam and Kim rivers in Central Cameroon; these are *Hymenocardia acida*, *Lophira lanceolata*, *Combretum micranthum*, *Olax subscorpioidea*, *Vitex doniana*, *Crossopterix febrifuga* and *Albizia zygia*. From the above, it is clear that the *Albizia* genus is represented in forest, contact zone and savanna. Youta [62] confirms that *Albizia adianthifoli*a and *Albizia zygia* are part of the floristic procession with a wide distribution linked to their important ecological plasticity due to their important dispersal capacity. Kassi [63] asserts that the presence of *Albizia adianthifolia* in a stand is proof of its secondary origin.

This study highlights the dominance of mesophanerophytes followed by megaphanerophytes in forests and forest-savanna contact zones, and the dominance of microphanerophytes in savannas. This result is in partial agreement with the findings of Soro *et al.* [42] in forest relics in the Poro region of Côte d'Ivoire, who obtained a predominance of microphanerophytes (70%). The high representation of microphanerophytes in savanna shows a preponderance of shrub or low forest formations in the study environment [64]. Koffi *et al.* [65], notes that in tropical forests, phanerophytes make up almost the entire plant community, while other biological types are poorly represented. Sarcochores are the most important type of diaspora in the study area. This dominance of sarcochores is in line with the work of Sonké (1998) [58] in Central Africa, with proportions in excess of 50%. The predominance of sarcochores over other types of diaspore is also highlighted in work by Yangakola *et al.* [66] and Nshimba [31] in intertropical Africa. The proportion of sarcochore species that correspond to zoochore species shows the importance of the role of animals in diaspora dissemination. Indeed, the main mode of spread in our surveys is zoochory (endozoochory). The importance of zoochory is noted in most studies of forests in Côte d'Ivoire [67], as is the dominance of zoochorous species in the Congo Basin, with proportions generally exceeding 50% [58] [68] [69]. This dissemination mainly concerns birds, mammals (elephants) and frugivorous vertebrates (monkeys, rats, tiger cats, antelopes and squirrels). With regard to the distribution of phytogeographical types, it shows the overall dominance of Guineo-Congolese species in all plant formations. This result is similar to that of [38], who also obtained the dominance of Guineo-Congolese species in the forest-savanna mosaics of the Lamto Reserve and Comoé National Park in Côte d'Ivoire. According to Sonké [58], a high proportion of Guinean species in the floristic background of an area is proof that the area belongs to the Guinean-Congolian region. The high proportion of Guinean-Congolese species reflects the great maturity of these plant formations, which appear to be little or undisturbed by human activity [45].

Vegetation structure

The distribution of individuals by diameter class in the various plant formations found in the different ecosystems is characterized by more individuals in the [10 - 20 cm[diameter class. But from class [10 - 20 cm[upwards, the number of individuals decreases from lower to higher classes. This is characteristic of tropical forests, where stand structure is generally inverted J-shaped and small trees (DBH < 10 cm) account for around 80% of species diversity [70] [71] [72]. In other words, they demonstrate that the number of individuals per diameter class decreases in much the same way as one moves successively from small-diameter classes to larger classes. This exponential downward trend confirms that the stand studied has a high regeneration potential. The density of individuals with DBH ≥ 10 cm for all plant communities studied is higher in the forest (235.78 stems/ha), than in the contact zone (217.18 stems/ha) and savanna (150.62 stems/ha). These values are lower than those found by Djuikouo *et al.* [73] in the Dja reserve (350 - 460.4 stems/ha). The low density observed in the Ndjole locality can be explained mainly by the strong anthropic pressure exerted on the trees.

5. Conclusion

In the present study, floristic diversity and plant composition types were analyzed for the vascular plants in Ndjole Forest-savanna ecotones and provided baseline information for further studies. The study has resulted in the documentation of 85 species belonging to 67 genera and 33 families. There were 68 species in semi-caducifolia forest, 45 in contact zone and 18 in savanna. In the forest, the Urticaceae, Combretaceae, Apocynaceae, Myristicaceae, Euphorbiaceae and Malvaceae families were the most diverse. In the contact zone, the Euphorbiaceae, Fabaceae, Annonaceae and Moraceae families were the most diverse, and in the savanna, we have the Combretaceae, Fabaceae and Annonaceae families. Diversity index values (Shannon's index ranging from 1.7 to 2.37; Pielou's equitability, 0.86 to 0.9; Simpson's varies from 0.77 to 0.85) are generally low, however, forest is more diverse compared to contact zone and savanna. The degree of floristic similarity shows that the forest and contact zone (60.17%) belongs to the same plant community. The IVI values show variation in ecologically dominant species and have helped in understanding the ecological significance of the species in the forest-savanna mosaic. The diametric distribution of the different plant communities has a descending exponential trend, with a high regeneration potential. The flora is dominated by mesophanerophytes and megaphanerophytes in the forest and in the forest-savanna contact zone, and by microphanerophytes in the savanna. Sarcochores are the most important diaspores types, and the main mode of dissemination is zoochory (endozoochory). As for the distribution of phytogeographical types, it shows the overall dominance of Guineo-Congolese species in all plant communities. Plant diversity can often be increased at the local scale by changing or diversifying the management of a site. Local populations need to be made aware of the importance of biodiversity and the measures to be taken, such as protecting natural habitats, reducing logging, planting native species and promoting sustainable agricultural practices.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Gemerden, B.S. (2004) Disturbance, Diversity and Distributions in Central African Rain Forest. Ph.D. Thesis. Department of Environmental Sciences. Wageningen University, Netherlands.

[2] Dalimer, J., Achard, F., Delhez, B., Desclée, B., Bourgoin, C. and Hugh, E. (2022) Répartition des types de forêts et évolution selon leur affectation. In: Atyi, R.E., Hiol, H.F., Lescuyer, G., *et al.*, Eds., *Les forêts du bassin du Congo*: *État des Forêts* 2021. https://www.cifor.org/publications/pdf_files/Books/Etat-des-forets-2021.pdf

[3] Tchatchou, B., Sonwa, D.J. and Tiani, A.M. (2015) Déforestation et dégradation des forêts dans le Bassin du Congo: État des lieux, causes actuelles et perspectives. Cen-

tre de recherche forestière internationale (CIFOR), 43.

[4] FAO (2010) Evaluation des ressources forestières mondiales 2010. FAO, Rome, 378.

[5] Ngomin, A. and Mvongo, N.M.N. (2015) Sylviculture de 2ème génération au Cameroun: Bases conceptuelles, leviers et schéma d'opérationnalisation. Cameroun, Yaoundé, 86.

[6] Fongnzossie, F.E., Biwolé, A.B., Nguenang, G.M., Ngo, S.S., Fono, L.A., Dibong, S.D., Flore, N. and Ngoufo, R. (2019) Analyse floristique, structurale et phytogéographique de la végétation du massif forestier de Ngog-Mapubi-Dibang (Cameroun) *Le Journal de Botanique de la Société de botanique de France*, **86**, 75-92. https://doi.org/10.3406/jobot.2019.1899

[7] Kark, S. (2013) Effects of Ecotones on Biodiversity. In: Levin S., Ed., *Encyclopedia of Biodiversity*, Academic Press, Waltham, 142-148. https://doi.org/10.1016/B978-0-12-384719-5.00234-3

[8] Yarrow, M.M. and Marín, V.H. (2007) Toward Conceptual Cohesiveness: A Historical Analysis of the Theory and Utility of Ecological Boundaries and Transition Zones. *Ecosystems*, **10**, 462-476. https://doi.org/10.1007/s10021-007-9036-9

[9] Araujo, M.B. (2002) Biodiversity Hotspots and Zones of Ecological Transition. *Conservation Biology*, **16**, 1662-1663. https://doi.org/10.1046/j.1523-1739.2002.02068.x

[10] Dexter, K.G., Pennington, R.T., Oliveira-Filho, A.T., Bueno, M.L., Miranda, P.L.S. and Neves, D.N. (2018) Inserting Tropical Dry Forests into the Discussion on Biome Transitions in the Tropics. *Frontiers in Ecology and Evolution*, **6**, Article 00104. https://doi.org/10.3389/fevo.2018.00104

[11] Hoffmann, W.A., Geiger, E.L. and Gotsch, S.G. (2012) Ecological Thresholds at the Savanna-Forest Boundary: How Plant Traits, Resources and Fire Govern the Distribution of Tropical Biomes. *Ecology Letters*, **15**, 759-768. https://doi.org/10.1111/j.1461-0248.2012.01789.x

[12] Felfili, J.M. and Silva, J.M.C. (1992) Floristic Composition, Phytosociology and Comparison of Cerrado and Gallery Forests at Fazenda Água Limpa, Federal District, Brazil. In: Furley, P.A., Procter, J. and Ratter, J.A., Eds., *Nature and Dynamics of ForestSavanna Boundaries*, Chapman and Hall, London, 393-415.

[13] Bellefontaine, R., Gaston, A. and Petrucci, Y. (1997) Aménagement des forêts naturelles des zones tropicales sèches. FAO, Rome, 316.

[14] Momo, S.M.C., Temgoua, L.F., Fedoung, E. and Zangmene, D.R. (2018) Végétation et spectres fonctionnels de la galerie forestière de Koupa Matapit. *Geographie-Ecologie-Tropicale*, **42**, 147-158.

[15] Youta, J.H., Bonvallot, J., Hotyat, M., Achoundong, J.G., Dessay, N., Guillet, B., Peltre, P., Schwartz, D., Servant, M. and Simonneaux, V. (2003) Bilan de la dynamique du contact forêt-savane en quarante ans (1950-1990) dans la région du confluent du Mbam et du Kim, Centre-Cameroun. In: Froment, A. and Guffroy, J., Eds., *Peuplements anciens et actuels des forêts tropicales: actes du séminaire-atelier*, 211-218.

[16] Souza, L.A.S. and Eisenlohr, P.V. (2020) Drivers of Floristic Variation in Biogeographic Transitions: Insights from the Ecotone between the Largest Biogeographic Domains of South America. *Acta Botanica Brasilica*, **34**, 155-166. https://doi.org/10.1590/0102-33062019abb0057

[17] Lugo, E. (2008) Ecosystem Services, the Millennium Ecosystem Assessment, and the Conceptual Difference between Benefits Provided by Ecosystems and Benefits Provided by People. *Journal Land Use Environ Law*, **23**, 243-261.

[18] Sinsin, B., Kampmann, D., Thiombiano, A. and Konaté, S. (2010) Atlas de la

Biodiversité de l'Afrique de l'Ouest. Tome I.

[19] Atsri, H.K., Konko, Y., Cuni-Sanchez, A., Abotsi, K.E. and Kokou, K. (2018) Changes in the West African Forest-Savanna Mosaic, Insights from Central Togo. *PLOS ONE*, **13**, e0203999. https://doi.org/10.1371/journal.pone.0203999

[20] Tchuikoua, L.B. and Banaga, H. (2016) Contribution des organisations paysannes dans la production des cultures vivrières dans l'arrondissement de Ntui. *Revue Canadienne de Géographie Tropicale*, **3**, 53-65.

[21] République du Cameroun (2012) Stratégies et Plan d'Action National pour la Biodiversité, Version II (SPANII), Minepded, Yaoundé, 189.

[22] Plan communal de développement (2011) Action Commune pour la Préservation de l'Environnement et le Développement, 177.

[23] Kémeuzé, V.A., Solefack, M.C.M., Nkongmeneck, B., Decocq, G., Jiofack, T. and Johnson, M. (2009) Variation altudinale de la distribution des plantes à activité insecticide dans la forêt communautaire de Kilium-Ijium: cas de *Clausena anisata*. *Bois et Forêt des Tropiques*, **299**, 75-76. https://doi.org/10.19182/bft2009.299.a20425

[24] Meunier, Q., Moumbogou, C. and Doucet, J.-L. (2015) Les arbres utiles du Gabon. Presses Agronomiques de Gembloux, Gembloux, 340.

[25] Willis, K.J., Gillson, L. and Brncic, T.M. (2000) How "Virgin" Is Virgin Rainforest? *Science*, **304**, 402-403. https://doi.org/10.1126/science.1093991

[26] Onana, J.M. (2019) The Vascular Plants of Cameroon. A Taxonomic Checklist with IUCN Assessments. Flore du Cameroun, IRAD-National Herbarium of Cameroon. Yaoundé. 195.

[27] Cottam, G. and Curtis J.T. (1956) The Use of Distance Measures in Phytosociological Sampling. *Ecology*, **37**, 451-460. https://doi.org/10.2307/1930167

[28] Frontiers, S. (1983) Choix et Contraintes de l'échantillonnage écologique. Presses de L'Université de Laval, Québec, 3-62.

[29] Tagne, G.A. (2007) Etude floristique et structurale des ligneux de la forêt submontagnarde de la colline de Messa (Yaoundé) Mémoire de DEA. Université de Yaoundé, Yaoundé.

[30] Dajoz, R. (1982) Précis d'écologie. 48th Edition, Division des ressources forestières, Département des forêts, Bordas, 503.

[31] Nshimba, S.W.M. (2008) Etude floristique, écologique et phytosociologique des forêts de l'île Mbiye à Kisangani. Thèse de Doctorat, Université de Kisangani, Kisangani.

[32] Raunkier, C. (1934) The Life Forms of Plants and Statistical Plant Geography. Oxford University Press, Oxford, 632.

[33] Lebrun, J. (1960) Sur une méthode de délimitation des horizons et étages de végétation des montagnes du Congo oriental. *Bulletin du Jardin botanique de l'État a Bruxelles*, **30**, 75-94. https://doi.org/10.2307/3667120

[34] Schnell, R. (1971) Introduction à la phytogéographie des pays tropicaux: Les problèmes généraux. Les milieux et les groupements végétaux. Gauthier-Villard, Paris, 951.

[35] Momo, S.M.C. (2009) Influence des activités Anthropiques sur la végétation du Mont Oku (Cameroun). Thèse de Doctorat, Université de Yaoundé I, Yaoundé.

[36] Senterre, B. (2005) Recherches méthodologiques pour la typologie de la végétation et la Phytogéographie des forêts denses d'Afrique Tropicale. Thèse de doctorat, Université Libre de Bruxelles, Bruxelles.

[37] Lejoly, J., Ndjele, M.B. and Geering, D. (2010) Catalogue des plantes vasculaires des districts de Kisangani et de la Tshopo. Ulb et Unikis, 343.

[38] Koulibaly, A. (2008) Caractéristiques de la végétation et dynamique de la régénération sous l'influence de l'utilisation des terres, dans des mosaïques forets-savanes des régions de la Reserve de Lamto et du Parc National de la Comoé en Cote d'Ivoire. Université de Cocody-Abidjan, Abidjan.

[39] Soro, G., Koffi, N.M., Kone, B., Kouakou, Y.E., M'Bra, K.R., Soro, P.D. and Soro, N. (2019) Utilisation de produits phytosanitaires dans le maraîchage autour du barrage d'alimentation en eau potable de la ville de Korhogo (nord de la Côte d'Ivoire): Risques pour la santé publique. *Environnement. Risque Santé*, **17**, 155-163.

[40] Tiebre, M.S., Ouattara, B., Kpangui, K.B., Kouassi, D.F. and N'Guessan, K.E. (2016) Diversité floristique de la région de Founbesso en zone de transition forêt-savane à l'Ouest de la Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **10**, 1007-1016. https://doi.org/10.4314/ijbcs.v10i3.8

[41] Bolia, N.E., Bosanza, J.B.Z., Mongeke, M.M. and Ngbolua, K.N. (2019) Études dendrométrique et floristique des forêts mixte et mono-dominante à *Gilbertiodendron dewevrei* d'une concession forestière en République Démocratique du Congo. *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, **7**, 110-117.

[42] Soro, D., Dro, B., Seguena, F., Bakayoko, A. and Koné, M.W. (2021) Évaluation du potentiel floristique ligneux des reliques forestières de la région du Poro. *Journal of Animal & Plan Sciences*, **47**, 8506-8517. http://www.m.elewa.org/JAPS

[43] Abdoulaye, C., Ouattara, M., N'Guessan, E.A. and N'Gouan, A.J.E. (2020) Diversité végétale et usages des plantes dans une zone de savane soudanienne: Cas de la localité de Ferkessédougou (Nord, Côte d'Ivoire). *International Journal Biology Chemestry Science*, **14**, 2807-2825. https://doi.org/10.4314/ijbcs.v14i8.13

[44] Kamga, Y.B., Nguetsop, V.F., Momo, S.M.C. and Riera, B. (2018) Diversité Floristique Des Ligneux Et Structure Des Formations À Garcinia Kola Heckel Dans Les Régions Du Centre Et De l'Est, Cameroun. *European Scientific Journal*, **14**, Article 451. https://doi.org/10.19044/esj.2018.v14n21p451

[45] Tiokeng, B., Mapongmetsem, P.M., Nguetsop, V.F. and Tacham, W.N. (2015) Biodiversité floristique et régénération naturelle sur les Hautes Terre de Lebialem (Ouest Cameroun). *International Journal of Biologycal and Chemical Sciences*, **9**, 56-68. https://doi.org/10.4314/ijbcs.v9i1.6

[46] Ngnignindiwou, M.J. (2018) Diversité floristique et services ecosystématique de la forêt de Mawoun, Localité de Foumbot, dans les hautes terres de l'Ouest Cameroun. Thèse de Master, Université de Dschang, Dschang.

[47] Lu, X.-T. and Tang, J.-W. (2010) Structure and Composition of the Understory Treelets in a Non-Dipterocarp Forest of Tropical Asia. *Forest Ecology and Management*, **260**, 565-572. https://doi.org/10.1016/j.foreco.2010.05.013

[48] Sonke, B. and Couvreur, T.L.P. (2014) Tree Diversity of the Dja Faunal Reserve, Southeastern Cameroon. *Biodiversity Data Journal*, **2**, e1049. https://doi.org/10.3897/BDJ.2.e1049

[49] N'Dja, K.J., Tuo, Y. and Zo-Bi, I.C. (2017) Diversité floristique et infiltration humaine de la forêt classée de la Besso (Côte d'Ivoire). *Journal of Applied Biosciences*, **114**, 1997-5902. https://doi.org/10.4314/jab.v114i1.3

[50] Bakayoko, A. (1999) Comparaison de la composition floristique et de la structure forestière de parcelles de la Forêt Classée de Bossématié dans l'Est de la Côte d'Ivoire. Mémoire de DEA, Université de Cocody-Abidjan, Abidjan.

[51] Leal, M.E. (2001) The African Rain Forest during the Last Glacial Maximum, an

Archipelago of Forests in a Sea of Grass. Ph.D. Thesis, Wageningen University, Wageningen.

[52] Gonmadje, C.F., Doumenge, C., Sunderland, C.H.T., Balinga, P.B.M. and Sonké, B. (2012) Analyse phytogéographique des forêts d'Afrique Centrale: le cas du massif de Ngovayang (Cameroun). *Plant Ecology and Evolution*, **145**, 152-164. https://doi.org/10.5091/plecevo.2012.573

[53] Kent, M. and Coker, P. (1992) Vegetation Description and Analysis: A Practical Approach. John Wiley and Sons, New York, 167-169.

[54] Sunderland, T.C.H., Walters, G. and Issembe, Y. (2004) A Preliminary Vegetation Assessment of the Mbé National Park. CARPE Report, Monts de Cristal, Gabon.

[55] Ngueguim, J.R., Zapfack, L., Youmbi, E., Riera, B., Onana, J., Foahom, B. and Makombu, J.G. (2010) Diversité floristique sous canopée en plantation forestière de Mangombe-Edea. *Biotechnologie*, *Agronomie*, *Société et Environnement*, **1**, 167-176.

[56] Odum, E.P. (1976) Écologie. Doin, Paris, 257 p.

[57] Ngueguim, J.R. (2013) Productivité et diversité floristique ligneuse en forêt d'Afrique tropicale humide du Cameroun: sites de Mangombe, Bidou et Campo. Thèse, Ecole doctorale Sciences de la Nature et de l'homme, Muséum national d'histoire naturelle, Paris.

[58] Sonké, B. (1998) Biodiversity Study in Dja Fauna Reserve (Cameroon): Using the Transect Method. In: Huxley, C.R., Lock, J.M. and Cutler, D.F., Eds., *Chorology*, *Taxonomy and Ecology of the Floras of Africa and Madagascar*, Royal Botanic Gardens, Kew, 171-179.

[59] Wouokoue, T.J.B. (2018) Phytosociologie des monts Bambouto et Mbapit, équations allométriques pour l'estimation de la biomasse aérienne des ligneux des savanes. Ph.D. Thèse de doctorat, Université de Dschang, Cameroun Colline de Foto.

[60] N'guessan, A.E. and Kassi, N.J. (2018) Analyse de La diversité floristique de la forêt classée d'Agbo I (Côte d'Ivoire). *European Scientific Journal*, **14**, 346-357. https://doi.org/10.19044/esj.2018.v14n9p346

[61] Maiyanpa, P. (2019) Diversité floristique et exploitation des produits forestiers non ligneux à la périphérie du Parc National du Mbam et Djerem. Thèse de Master, Université de Dschang, Cameroun Colline de Foto.

[62] Youta, H. (1998) Arbres contre graminées: la lente invasion de la savane par la forêt au centre-cameroun. Thèse de doctorat, Paris-Sorbonne, Paris.

[63] Kassi, N.J. (2006) Successions secondaires post-culturales en forêt dense semi décidue de sanaimbo (Côte d'Ivoire): Nature, structure et organisation fonctionnelle de la végétation. Thèse de doctorat, Université de Picardie Jules Verne, Amiens.

[64] Thiombiano, A. (2005) Les Combretaceae du Burkina Faso: taxonomie, écologie et régénération des espèces Thèse d'État, département de Biologie et Écologie végétale Université de Ouagadougou, Burkina Faso.

[65] Koffi, D.K., Tchaa, B. and Thiou, T.K.T. (2016) Quantification des changements de l'occupation du sol dans la préfecture de Yoto (Sud-est, Togo) à l'aide de l'imagerie satellitaire Landsat. *Sciences de L'Environnement*, **13**, 137-156.

[66] Yangakola, J.M., de Foucault, B., Yongo, O.D. and Lejoly, J. (2004) Analyse phytogéographique comparative des savanes et des forêts de Ngotto (République Centrafricaine). *Acta Botanica Gallica*, **151**, 124-227. https://doi.org/10.1080/12538078.2004.10516036

[67] Chapman (1995) Primate Seed Dispersal: Coevolution and Conservation Implication. *Evolutionary Anthropology*, **4**, 74-82.

https://doi.org/10.1002/evan.1360040303

[68] Mosango, M. (1990) Contribution à l'étude botanique et biogéochimique de l'écosystème forêt en région équatoriale. Thèse de doctorat. Université Libre de Bruxelles, Laboratoire De Botanique Systématique et Phytogéographie, Bruxelles.

[69] Kouka, L.A. (2000) Recherches sur la flore, la structure et la dynamique des forets du Pare national d'Odza/a. Thèse de doctorat, Université Libre de Bruxelles, Bruxelles.

[70] Rollet, B. (1974) Introduction à l'étude des mangroves du Mexique. Photo-interprétation, Types de forêt, Bibliographie, 156.

[71] Gentry, A.H. (1998) Changes in Plant Community Diversity and Floristic Composition on Geographic and Environmental Gradients. *Annals of the Missouri Botanical Garden*, **75**, 1-34. https://doi.org/10.2307/2399464

[72] Loris, L. (2009) Analyse de la diversité floristique dans les diverses strates des forêts denses de Masako. Mémoire de DEA, UNIKIS, 106.

[73] Djuikouo, M.N.K., Doucet, J.T., Nguembou, C.K., Lewis, S. and Sonké, B. (2010) Diversity and Aboveground Biomass in Three Tropical Forest Types in the Dja Biosphere Reserve, Cameroun. *African Journal of Ecology*, **48**, 1053-1063. https://doi.org/10.1111/j.1365-2028.2010.01212.x.