Original Research Article

Mid and submontane altitude forests communities on the West hillside of mount Bambouto (Cameroon): Floristic originality and comparisons

ASTRACT

Background and aims - Situated on the oceanic part of the Cameroon mountainous chain, the Western flank of Bambouto Mountains include the Atlantic biafran forests rich in endemic species but not well known. The objective of this work is to compare specific diversity, floristic composition and structure of two forests on this hillside.

Methods - The inventories have been carried out in 18 plots of 20 m x 250 m plot established to cover all corners and centers of each forest in order to collect as many species as possible; also depending on the size of the forest block, vegetation physiognomy and altitude. Therefore, on a total area of nine hectares, all individuals with diameter at breast height ≥10 cm (dbh =1.30 m above ground) were counted. Phytodiversity has been assessed based on the usual diversity indices; these are the Shannon, Equitability and Simpson indices. The chi-square and Anova test were used to compare the data obtained.

Keys results - With 168 species recorded in four hectares, the submontane forest noticeably appears richer than that of low and mid altitude (161 species in 5 hectares). Among these species, 46 are common to the two forests. The mean stands density with diameter at breast height (dbh) ≥ 10 cm recorded per hectare is 855 ± 32,7 at low and mid altitude forest and 1182 ± 38,4 at submontane forest. The diversity index, specific richness and the endemism rate values are comparable to those registered in other Central African sites. Shannon's diversity means are 3 ± 0.25 in Fossimondi forest and 3.17 ± 0.22 in Bangang forest. While species evenness means are 0.80 ± 0.03 and 0.83 ± 0.03 respectively in Fossimondi and Bangang. The Simpson means index are 0.91 ± 0.02 and 0.92 ± 0.02 in Fossimondi and Bangang respectively. This result shows a great species diversity in the area as well as a good stability of these forests. Mean basal areas (respectively 60 m^2/ha and 52 m^2/ha in Fossimondi and in Bangang) are similar to those regularly observed in tropical rainforests. A total of 14 endemic species in Cameroon and 7 vulnerable were recorded in this study area.

Conclusions- The most meaningful differences in these two forests reside in their floristic composition and in the importance of some species in term of individual's number and basal area. Since the area is not yet profoundly explored, this work highlights its floristic importance for basis of

Keywords: Forest of altitude, diversity, floristic structure, Bambouto Mountains, West Cameroon

1. INTRODUCTION

Tropical forests are the richest in flora and fauna, but also the most endangered **[1].** The annual loss of tropical forest cover was estimated at 13 million hectares between 2000 - 2010 **[2]**. In the year 2001, that of all Africa was estimated at 5.3 million hectares, that is 0.78% of the total forest area **[3]**. The Central African regions (Cameroon, Gabon) and Madagascar are among the most varied areas of woody species **[4]** but also the most threatened.

Cameroon forest ecosystems cover about 21 million hectares **[5]**. They are diversified, with more than 8,000 species of plants including more than 300 species of exploitable wood **[6]**. Part of these forests is located in the Cameroon mountainous chain, which is one of the biogeographic zones with a high degree of endemism. With extreme deforestation at over 415,000 hectares per year [7], no primary forests will remain in the coming years. Indeed, the population explosion, slash-and-burn agriculture and the commercial exploitation of forests for the external market are among the main causes of deforestation in Cameroon. This deforestation leads to the loss of biodiversity, soil leaching and the increase in the greenhouse effect due to the overproduction of carbon dioxide [**8**].The study of the relationships between environmental characteristics and plant community structure can not only reveal the mechanisms that control community structure but also predict the response of plant communities to changes in their environment; hence the importance of a good understanding of these transformations for effective environmental management **[9].** The high-altitude areas, notably those of West Cameroon, are not exempt from the impact of these various anthropogenic factors, which is exacerbated by the high density of human populations and a generally very rugged terrain. The west hillside of the Bambouto Mountains is not only a refuge for a large number of endemic species (both plants and animals such as mammals and birds) but also for endangered species**[10,11].** It is also a critical site for understanding the distribution of species along the Cameroon mountainous chain **[12].**

Research has shown that the composition and diversity of plant communities change with altitude, multiple disturbances, and other abiotic factors [**13,14,15**]. Very few botanical studies have been conducted on the western side of the Bambouto Mountains. Very few botanical studies have been carried out on the western slope of the Bambouto Mountains. It includes work on plant diversity in Lewoh-Lebang village [**16**], the publication of a conservation checklist based on collections along Fossimondi and Betchati villages **[12]** and the study of medicinal plants used in traditional medicine in Aguambou-Bamumbu village **[17]**. These works are still fragmentary and do not provide a complete view of the flora on this slope. Since plant species and community conservation strategies are based on specific richness and endemism rates **[18,19,20]**, detailed information on vegetation on the western slope of the Bambouto Mountains is an important tool for establishing a forest ecosystem management plan in this area. Thus, to better understand and manage the submontane plant communities of Fossimondi and Bangang, it is therefore necessary to have a good knowledge of the ecology of these forest ecosystems, which constitute an important genetic reservoir for plant species. Some of these plants represent an important potential for medical and commercial applications. They are also essential habitats for wildlife.

The aims of this work are to carry out a comparative study of the floristic composition, diversity, vegetation structure and phytogeographic analysis of the Fossimondi submontane forest and the Bangang mid altitude forest species.

2. METHODOLOGY

2.1. STUDYSITE

Located about 150 km from the Atlantic Ocean, the western slope of the Bambouto Mountains where the study was conducted is found in the oceanic part of the Cameroon Ridge **[21].** The plant communities in this area (Fig. 1) are Biafran Atlantic forests **[22]**. Administratively, the studied zone is found in the southwest region of Cameroon, in Lebialem Highlands. Bangang Forest is located at an altitude between 200 m - 600 m. The mean geographical coordinates are 5 ° 36'10.5 '' North latitude and 9 ° 54'24.5 '' East longitude while the Fossimondiforest is between 1000 m - 1900 m altitude with geographical coordinates averaging 5 ° 37'54.5 '' North latitude and 9 ° 57'57.6 '' East longitude. The relief is marked by plateaus, mountains and lowland plains. The soils of the Bamboutos Mountains vary according to altitude. Andosols, dry ferralitic soils and armoured ferralitic soils can be found there **[23]**

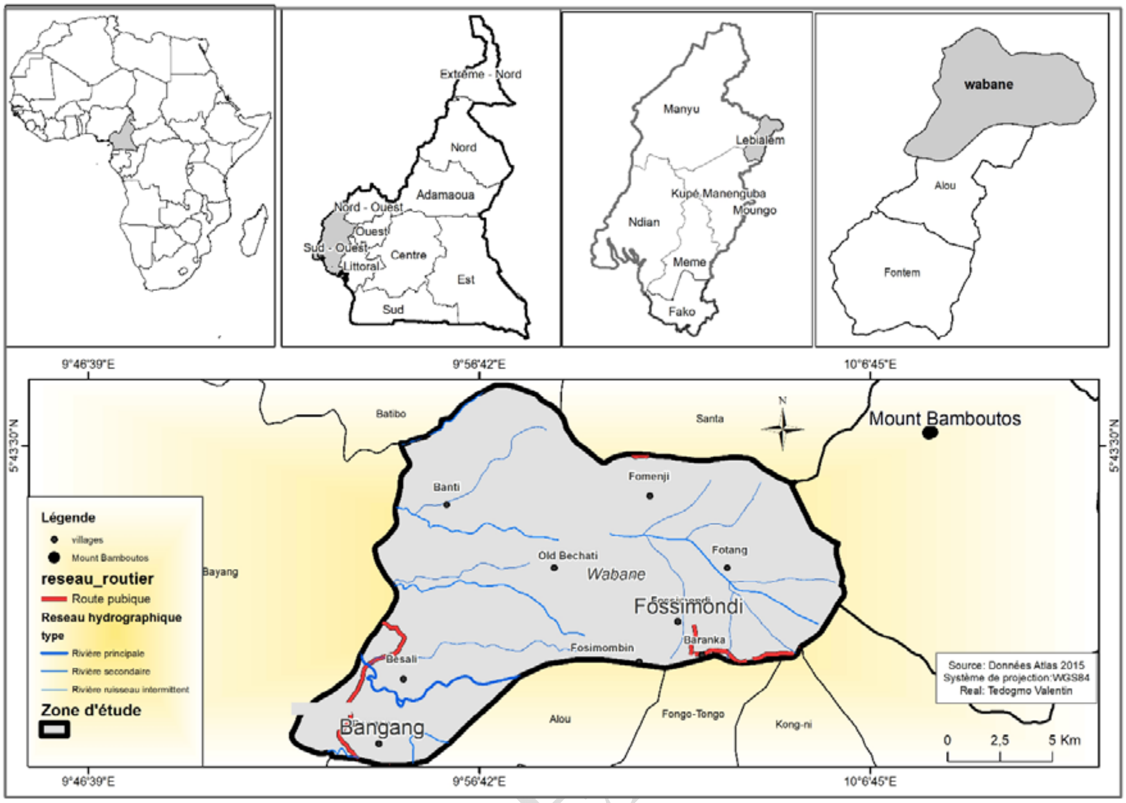

Figure 1: Location of Bangang and Fossimondi villages in the Southwest Cameroon region

Lebialem highlands has an equatorial climate characterized by two seasons; a long rainy season (from March to November) and a short dry season (from December to February). Temperatures range from 15.2°C to 18.2°C and 25°C to 27.7°C respectively in Fossimondi and Bangang with annual averages of 16.8°C and 26.34°C/year. Average rainfall is 2112 mm /year in Fossimondi and 2530 mm/year for Bangang (http://fr.climate-data.org/location/780244/, accessed on 01-02-2016). It is an area formed by the Biafran Atlantic forests [**24**]

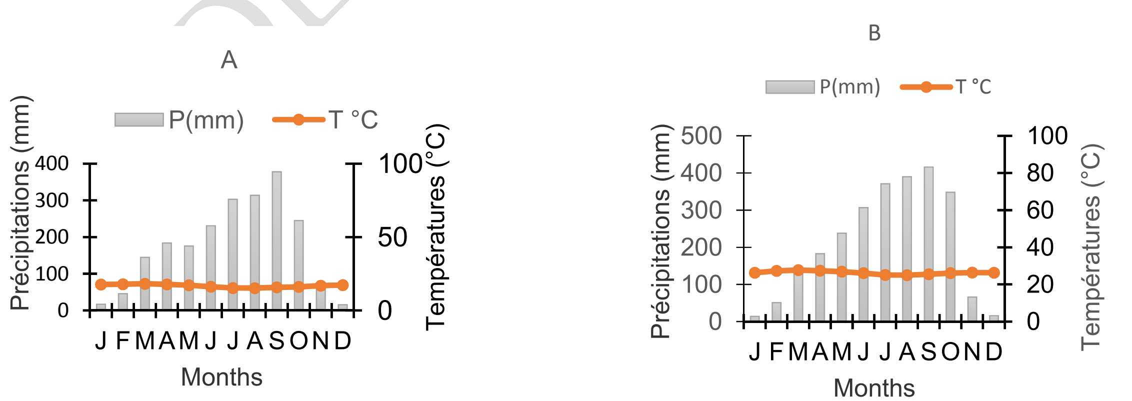

Figure 2: Ombrothermal diagram of Fossimondi (A) and Bangang (B) villages (source: http://fr.climate-data.org/location/780244/, accessed 01-02-2016)

2.2. Sampling and collection method

Sampling plots were chosen based on work that has been carried out in tropical forests, particularly in Cameroon **[25]** and Burundi **[26]**. These phytodiversity plots are 250 m x 20 m (0.5 ha) (Fig.3). The census was done on all woody trees with a diameter greater or equal to 10 cm (at 1.30 m). Depending on the size of the forest block, vegetation physiognomy and altitude, 10 and 8 plots were established respectively in the Bangang mid-altitude forest and the Fossimondi submontane forest (fig. 1). Some species were identified directly in the field using common identification criteria such as trunk and morphology, leaf type and arrangement, rhytidome nature and bark **[27]** and with the help of a botanist who had experience in identifying plant species in this area.

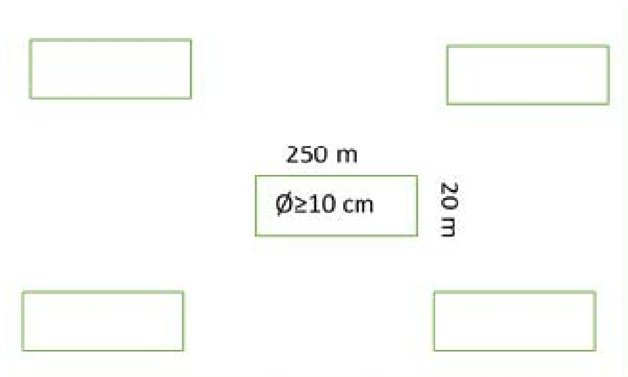

Figure 3: Sampling design

Samples of unidentified species were collected; then brought back to the Cameroon Herbarium for identification by comparison with the herbarium samples or using the documents dealing with flora in the tropical zone. The nomenclature of the species encountered was confirmed using the online African Plant Database (Conservatoire du Jardin Botanique de Genève http://www.villege.ch/musinfo/bd/cjb/africa/recherche.php?langue=en). The taxonomic nomenclature adopted is the phylogenetic botanical classification of angiosperms **[28]**.

Phytogeographic analysis were evaluated using White's method **[29-30]** and others publications on Cameroon flora **[31,32,12,33]**. The following categories have been assigned to species: Widespread species (Ld) such as pan-tropical and paleotropical species, Guineo-Congolese species (Gc), Upper and Lower Guinean species (Gs), Lower Guinean species (Gi), Cameroonian species (Cam) and Southwest Cameroon species (So-Cam)

2.3. Data analysis

In order to estimate absolute specific richness through the species-individual relationship, regardless of sample size [**34**], the Margalef index (Rm) was used.

The degree of stability of the flora of the two forests was estimated base on the specific quotient (Q) [**35**].

Basal area (G), relative dominance (D %) and relative frequency (F %) of species were also calculated to get an idea of the degree of filling and forest structure.

Different diversity indices such as Shannon's diversity index(H), Simpson index(D') and evenness index(Eq) were used to determine the diversity. **[36,37]**.

These three diversity indices were chosen to provide a more complete view of the structure of the different plant communities. They were calculated using PAST 2.09 software. Shannon's diversity index considers the rarest species; Simpson's diversity index is rather sensitive to the most abundant species. On the other hand, the Equitability Index, ranging from 0 to 1, indicates the degree of diversity achieved in relation to the maximum possible and better expresses intra-community variation. When regularity is low (tends towards 0), it indicates a dominance phenomenon; however, when it is high (tends towards 1), there is a regular distribution of individuals among species, resulting in a lack of dominance **[38].** The significance between the results was determined by the chi2 and ANOVA test (Bonferroni post-hoc test) using XLSTAT 2014.5.03 software.

3. RESULTS

3.1. Species richness, abundance and dominance

In the Fossimondisubmontane forest, 4,837 individuals have been recorded belonging to 168 species, 131 genera and 61 families. The number of species per plot varies between 33 and 51 (41.25 ±7.74). The absolute specific richness according to the Margalef Index (Rm) is 15.20. In contrast, in the Bangang mid-altitude forest, the 4285 individuals recorded include 161 species, 127 genera and 48 families, with a Margalef (Rm) value equal to 14.17. The number of species varies between 35 and 62 per plot (with mean of 44.3 ± 7.24). The average number of individuals is 855 ± 32.7 and 1182 ± 38.4 per hectare in Bangang and Fossimondi forest, respectively (Table 1).

Table 1: Total area studied, number of individuals and specific richness in the Fossimondisubmontane forest and the Bangang medium altitude forest. (*R: plot, Ni. ha-1: number of individuals per hectare, S: area per hectare, S. ha-1: average specific richness per hectare and RM: Margalef absolute richness, FDI: Fossimondi ; BG : Bangang*)

Sites	R	$S.ha^{-1}$	$Ni.ha^{-1}$	$\bar{x}$ $S.\ ha^{-1}$	RM
Submontaneforest (FDI)	8	4	1182±38.4	83 ± 15.48	15.20
Mid altitude forest (BG)	10	5	855±32.7	89 ± 14.48	14.17

Of a total of 329 woody species inventoried, 47 are common to both forests, 121 are found exclusively in the Fossimondi submontane forest and 114 occur only in the Bangang mid altitude forest.

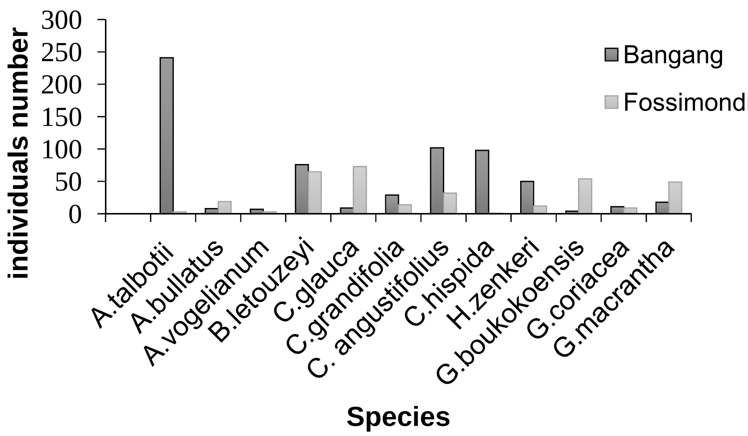

Figure 4: Comparison of the numbers of the most abundant species common to both forests (*A. taboltii: Anglylocalyx_talbotii, A. bullatus: Allophylus_bullatus, A. vogelianum: Antidesma_vogelianum, B. letouzei : Beilschmiedia_letouzeyi, C.glauca : Caloncoba glauca, C. grandifolia : Carapa_grandifolia, C. angustifolius : Chytranthus angustifolius, C. hispida : Cola hispida, H. zenkeri : Hypodaphnis_zenkeri, G. boukokoensis : Gambeya_boukokoensis, G. coriacea : Grewia_coriacea, G. macrantha : Grossera_macrantha*)

However, these species observed in both forests have different absolute abundances; Figure 4 shows the numbers of the 12 most abundant common species in the two forests. Species showing high absolute abundances in Bangang compared to Fossimondi are represented by: *Anglylocalyx_talbotii* Bak (241 individuals, Photo1), *Beilschmiedia_letouzeyi* Robyns & Wilczek (76 individuals), *Chytranthus_angustifolius* Exell (102 individuals), *Cola hispida* Brenan & Keay (98 individuals) and *Hypodaphnis_zenkeri* (Engl.) Stapf (50 individuals). In Fossimondi, on the other hand, the species with high absolute abundances compared to Bangang are: *Allophylus_bullatus* Radlk (19 individuals), *Caloncoba glauca* (P. Beauv.) Gilg (73 individuals), *Gambeya boukokoensis* Aubrév. & Pellegr (54 individuals) and *Grossera macrantha* Pax (49 individuals). The ratio of number of species/number of genera or specific quotient (Q) is 1.19 and 1.18 for the Fossimondi and Bangang forests, respectively.

Among the exclusive species of the submontane forest, there are several abundant species: *Heckeldora ledermannii* (Harms) J.J. de Wilde (478 individuals), *Santiria trimera* (Oliv.) Aubrév. (456 individuals) *Tabernaemontana* sp. (274 individuals), *Leptaulus daphnoïdes* Benth. (232 individuals). In the middle altitude forest, *Napoleonaea egertonii* Baker f. (297 individuals), *Cola chlamydantha* Hutch. & Dalziel (230 individuals), *Allexis cauliflora* (Oliv.) Pierre (144 individuals) and *Diogoa zenkeri* (Engl.) Exell & Mendonça (263 individuals) are highly representative among the species that are exclusive to it.

3.2. Specific diversity

Examination of the diversity indices (Table 2) reveals that they vary little, not only within the same stand but also between the two forest communities. Shannon diversity index ranges from 2.63 to 3.43 (3 ± 0.25 on average) in the Fossimondi forest. It is between 2.78 and 3.73 (3.17 ± 0.22 on average) in Bangang Forest. Pielou's Equitablity varies between 0.74 and 0.95 (0.80 ± 0.03 on average); between 0.76 and 0.89 (0.83 ± 0.03 on average) respectively in Fossimondi and Bangang. The Simpson index is between 0.86 and 0.95 (or 0.91 ± 0.02 on average); between 0.89 and 0.96 (or 0.92 ± 0.02 on average) in Fossimondi and Bangang respectively. The comparison of the values of each index between the two forest communities using ANOVA test shows that there is no significant difference between the averages of these different indices obtained in the two forests (Table 2).

Table 2: Variation of diversity indices in the Fossimondi (FD) and Bangang (BG) forest *plots H: Shannon index;Eq : Equitability of Pielou ; D' : Simpson diversity, $\bar{x}$: mean*

Mid-altitude forest			
Plots	H	Eq	D’
BG1	3,63	0,88	0,96
BG2	3,15	0,84	0,93
BG3	3,1	0,82	0,91
BG4	3	0,79	0,91
BG5	3,09	0,89	0,96
BG6	3,17	0,86	0,95
BG7	3,37	0,82	0,96
BG8	3,28	0,84	0,94
BG9	3,14	0,83	0,93
BG10	2,78	0,76	0,89
$\bar{x}$Indices	3,17 ± 0,22**a**	0,83 ± 0,03**a**	0,92 ± 0,02**a**

Submontaneforest			
Plots	H	Eq	D’
FD1	2,89	0,78	0,9
FD2	2,83	0,79	0,9
FD3	2,63	0,74	0,86
FD4	3,19	0,82	0,94
FD5	3,43	0,87	0,95
FD6	2,86	0,81	0,92
FD7	2,99	0,83	0,92
FD8	3,17	0,80	0,93
$\bar{x}$indices	3 ± 0,25**a**	0,80 ± 0,03**a**	0,91 ± 0,02**a**

The values of each mean per column followed by the same letter are not significantly different (p = 0.05).

3.4. Frequency, dominance and basal area

Table 3 summarizes some parameters (relative dominance (Do), relative frequency (Fr) and basal area (ST) that highlight the horizontal structure of each forest formation studied. It includes the ten most dominant species in the two forests. In the Fossimondi forest the most dominant species

(13.10%), the most frequent (2.43%) and showing the highest basal area (31.54 m^2/ha) is *Santiria trimeria* (Oliv.)Aubr.; other species with a high dominance are: *Cola acuminata* (P. Beauv.) Schott & Endl. (6.35%), *Leptaulus daphnoides* Benth (4.40%), *Cola digitata* W. Mast. (4.39%), *Tabernaemontana* sp. (3.41%), *Drypetes molunduana* Pax & K. Hoffm. (3.02), *Placodiscus angustifolius* Radlk. (2.22%), *Zenkerella citrina* Taub (1.53%), *Rinorea oblongifolia* (C.H.Wright)Marquand ex Chipp (1.48%) and *Ritchiea macrantha* Gilg & Gilg-Ben. (1.45%). In contrast, in the Bangang forest, *Piptadeniastrum africanum* Hook.f. Brenan is the most dominant species (9.85%) while *Napoleonaea egertonii* Baker f. has the largest basal area and is also the most frequent (2.26%) and most dominant (5.46%). The other most dominant species are: *Pycnanthus angolensis* (Welw.) Warb (5.25%), *Hymenostegia afzelii* (Oliv.) Harms (4.35%), *Lophira alata* Banks Ex Gaerth (4.08%), *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill. (3.94%), *Diogoa zenkeri* (Engl.) Exell & Mendonça (3.03%), *Cordia platythyrsa* Bak (3.00%), *Pentadesma grandifolia* Baker f. (2.92%) and *Beilschmiedia letouzeyi* Robyns & R. Wilczek (1.61%). These dominant species differ completely from one forest to another. The average overall basal area is 60.9 ± 15.38 m^2/ha for Fossimondi Forest and 52.63 ± 16.19 m^2/ha for Bangang Forest respectively.

Table 3: Some of the most important species in terms of relative dominance *(Do), basal area (ST) and relative frequency (Fr) in the Fossimondi (FDI) and Bangang (BG) forests*

	D (%)		Fr (%)		ST(m^2/ha)	
Species	FDI	BG	FDI	BG	FDI	BG
Piptadeniastrum africanum Hook.f. Brenan	0.00	9.85	0.00	0.90	0.00	1.70
Napoleonaea egertonii Baker f.	0.00	5.46	0.00	2.26	0.00	5.84
Pycnanthus angolensis (Welw.) Warb	0.00	5.25	0.00	2.03	0.00	5.45
Hymenostegia afzelii (Oliv.) Harms	0.00	4.35	0.00	0.90	0.00	0.97
Lophira alata Banks Ex Gaerth	0.00	4.08	0.00	0.45	0.00	3.60
Irvingia gabonensis Aubry - Lec	0.00	3.94	0.00	1.13	0.00	4.08
Diogoa zinkeri (Engl.)Exell&Mend	0.00	3.03	0.00	0.90	0.00	2.04
Cordia platythyrsa Bak.	0.00	3.00	0.00	0.22	0.00	3.06
Pentadesma grandifolia Baker f.	0.00	2.92	0.00	0.90	0.00	3.06
Beilschmiedia letouzeyi Robyns & R. Wilczek	0.00	1.61	0.00	1.58	0.00	1.84
Santiria trimeria (Oliv.) Aubr.	13.10	0.00	2.43	0.00	31.54	0.00
Cola acuminata (P. Beauv.) Schott & Endl.	6.35	0.00	0.91	0.00	15.23	0.00
Leptaulus daphnoides Benth.	4.40	0.00	0.60	0.00	10.57	0.00
Cola digitata W. Mast.	4.39	0.00	0.34	0.00	10.55	0.00
Tabernaemontana sp.	3.41	0.00	2.13	0.00	8.18	0.00
Drypetes molunduana Pax & K. Hoffm.	3.02	0.00	1.52	0.00	7.26	0.00
Placodiscus angustifolius Radlk.	2.22	0.00	0.91	0.00	5.34	0.00
Zenkerella citrina Taub	1.53	0.00	0.69	0.00	3.68	0.00
Rinorea oblongifolia (C.H. Wright)Marquand ex Chipp	1.48	0.00	1.21	0.00	3.57	0.00
Ritchiea macrantha Gilg & Gilg-Ben.	1.45	0.00	0.91	0.00	3.49	0.00

3.5. Family Dominance

In terms of relative family dominance, Figure 5 shows the predominance of Fabaceae (12.19%), *Malvaceae* (6.61%) and *Myristicaceae* (6.53%) in the Bangang Mid Altitude Forest. In the submontane forest of Fossimondi, there is a significant overlap of Burseraceae (31.43%), *Sterculiaceae* (29.74%) and *Euphorbiaceae* (18.84%). According to the specific richness of the families, the Bangang forest is dominated by *Euphorbiaceae* (15 species), *Fabaceae* (*Leguminoseae*) forest with 15 species including six *Caesalpiniaceae*, five *Papillionaceae* and four *Mimosaceae* and *Malvaceae* (14 species) while in the Fossimondi forest we notice *Rubiaceae* (19 species) and *Euphorbiaceae* (13 species).

Table 4: Relative dominance (Do) of the 10 most represented families in Bangang and Fossimondi

Families	Bangang Dof (%)	Fossimondi Dof (%)
Annonaceae	2.64	13.05
Apocynaceae	1.11	18.55
Autres	37.00	87.54
Burseraceae	3.83	31.43
Euphorbiaceae	3.05	18.84
Fabaceae	12.19	1.84
Guttifereae	2.98	5.60
Icacinaceae	0.70	10.73
Lecythydaceae	2.73	0.00
Meliaceae	2.47	10.71
Myristicaceae	6.53	0.09
Olacaceae	3.16	1.15
Sapindaceae	1.32	7.92
Sterculiaceae	6.61	29.74

3.6. Diameter classes

Large shrubs [10-20] are strongly represented (Fig. 5) both in Bangang Forest (802 individuals/ha) and Fossimondi Forest (978 individuals/ha). The small trees (20 to 50 cm in diameter) show the mean absolute abundance of 97 individuals / ha and 127 individuals / ha for Bangang and Fossimondi forests respectively. Individuals with diameters greater than 50 cm are very poorly represented and decrease sharply as the diameter increases. They now show only 5 and 7 individuals / ha respectively in the Bangang and Fossimondi forests. This abundance decreases even more rapidly when tending towards large trees. The Chi-square test applied to compare the number of individuals between the diameter classes of the two zones show that there is no significant difference in the number of individuals in these classes compared (X^2=19.67, α = 0.05).

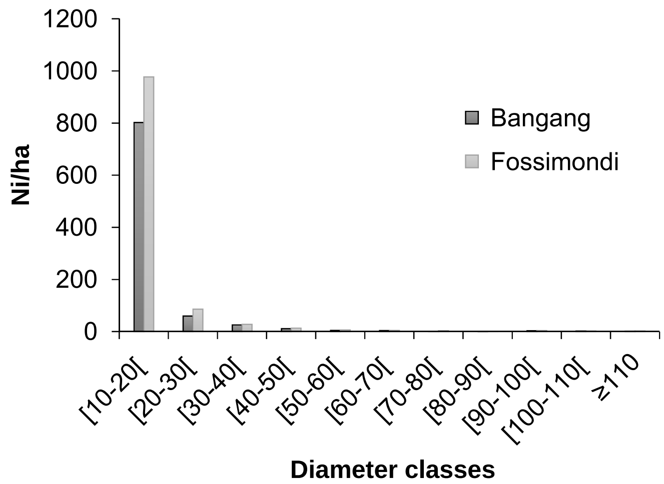

Figure 5: Distribution of individuals per hectare by diameter classes in Bangang and Fossimondi mid-altitude and submontane forests (Ni: number of individuals per hectare)

3.7. Phytogeographic distribution of taxa

In the Fossimondi forest, the phytogeographical status could be attributed to 131 species out of the 168 inventoried. In the Bangang forest, the phytogeographic status was determined for 139 out of 160 species recorded. The basic element in both forests is formed by species with a lower Guinean-dominant phytogeographic area (Figure 6). The proportions of this element are higher in Bangang Forest (56%) than in Fossimondi Forest (34.24%). Next come the Guinea-Congolese domain species with proportions of 31% and 20%, respectively, in the Bangang and Fossimondi forests. The other phytogeographical elements consisting of widely distributed species from southwest Cameroon, the Upper Guinea and Cameroon are much more abundant in Fossimondi and thus reflect the floristic particularity of this submontane forest formation. A total of 17 endemic species in Cameroon have been recorded. In general, both forests are of the same phytogeographic origin. The chi-square test used to compare the proportions of phytogeographic elements recorded in the two forests does not show significant differences in these proportions between the two phytogeographic distributions (X^2=11.07, α = 0.05).

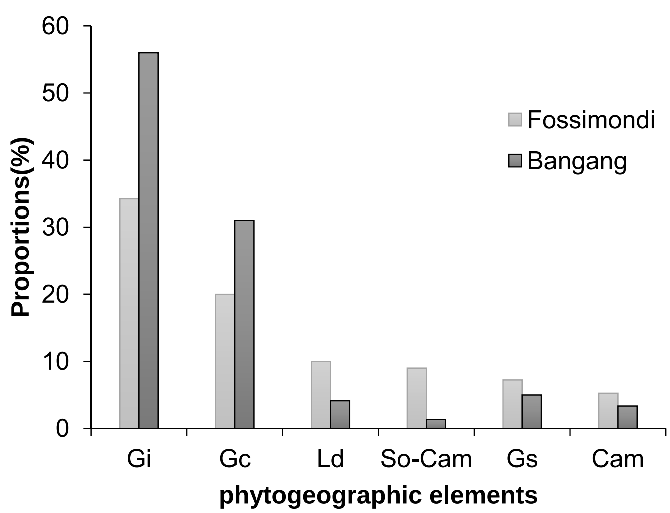

Figure6: Comparative phytogeographic spectra of species in the Fossimondi and Bangang forests *(Ld:* Broadly distributed species, Gc: Guineo-Congolese, Gs: Upper Guinean, Gi: Lower Guinean, Cam: Cameroon and So-Cam: Southwest Cameroon).

4.DISCUSSION

4.1. Composition, richness and diversity of flora

The mean absolute abundance values (855.3±32 individuals/ha and 1182.5 ±38 individuals/ha respectively in Bangang and Fossimondi forest) are close to those observed by Tiokeng **[39]** in Mekoup forest (894 ± 22 individuals/hectare) located at 2740 m on the Bambouto mountains. these differences would be related to the fact that the selected forests have not yet undergone a major disturbance. in addition, the presence of a relief consisting of mountains and hills makes access to some areas impassable. currently no logging has yet been noted in the site. However, they are higher than those observed in other dense forests in tropical Africa. This is the case of the Ngovayang forest in southern Cameroon [**32**] which shows an average of 532±75 individuals/hectare, the Monte Mitra forest in Equatorial Guinea with 548 ± 108 individuals/hectare [**40**], the Monts Cristal in Gabon which shows 562 ± 17 individuals/hectare [**41**], forest species from Takamanda in southwest Cameroon with 446 ± 40 individuals/ha [**42**], and Nouabale-Ndoki in Congo with 300 individuals/hectare [**43**]. The specific richness registered in the Lebialem Highlands (Bangang, Fossimondi) is closer to that observed by other researchers [**44,42**]. However, they are significantly lower than those observed by Balinga **[45].** The low values of the specific quotient values recorded in the two forests reflect their maturity **[46].**

The Shannon diversity index values obtained in this study indicate that these ecosystems are rich in species according to Kent & Coker **[47]**. These results confirm those of Pielou's Equitability which are ranged in Odum optimal interval **[38]**. These results indicate a more or less regular distribution of individuals within species, but also the stability of these forests. Simpson index data are comparable to those observed not only in Niger's Fauna forest galleries, which range from 0.86 to 0.96 **[48]** and in Ruvubu National Park by MASHARABU et al **[49]** in Burundi (0.94 -0.96). They are also comparable to those observed in the sacred forest of Mbing Mekoup by Tiokeng **[39]** in the Western Highlands of Cameroon (0.63 to 0.89). They are close to the value one and thus reflect a high diversity in both sites **[36].**

The particular richness of *Euphorbiaceae* noted in both forests as well as *Rubiaceae* in Fossimondi forest has been observed by other researchers, particularly in Campo-Ma'an forest in southern Cameroon **[50]**. The high values of species richness, species diversities and abundances observed in the studied sites as well as the floristic specificities can be attributed to a variability in ecological niches that accompany changes in relief and altitudinal gradient. In addition, soil texture and moisture content (proximity to rivers, hilltops) are variable and can be a factor in species variations. More generally, small-scale climate variability related to relief and altitude determines factors such as sun exposure and temperature that may explain the spatial and temporal distribution of taxa. Indeed, the mountainous terrain leads to variations in temperature and precipitation as well as certain climatic conditions in submontane areas (presence of clouds and fog) that can contribute significantly to the high diversity and structure of these ecosystems. In addition, the location of the study site in a region influenced by the Atlantic monsoon gives it moisture from the Atlantic Ocean and high amounts of precipitation (≥ 2000 mm an-1) **[53].** It has also been shown that, during arid periods, persistent stratiform clouds along the Atlantic coast of Central Africa have been a source of small precipitation and moisture in the lower hills and mountains, under a generally dry climate **[54-55]**, thus helping to maintain forest cover during the past geological times in the coastal regions of the Gulf of Guinea. According to Pascal **[56]**, higher species richness may also result from the degree of resilience of the ecosystem or its adaptability to global climate variations. For example, it can be assumed that the floristic characteristic of the vegetation on the western flank of the Bambouto Mountains is related to the fact that it has been little disturbed by climatic variations at different temporal scales observed at several sites in Central Africa **[54,57].**

The Fabaceae family is among the most dominant in the Bangang forest, the importance of this family is one of the characteristics of the Guineo-Congolese forests **[30]**; such dominance has been observed in other dense humid forests in tropical Africa **[32,50].** However, this family is totally absent in the Fossimondi forest where the Burseraceae are the most important. Burseraceae would be among the families considered as indicators of mature Atlantic forests **[58]**. The numerical importance of these families would reflect the resistance capacity of the seedlings of these families and better regeneration despite environmental constraints.

4.2. Structural elements

An examination of the highly dominant species in the two forests shows that they are different from one forest to another. The variability of climatic factors such as precipitation, temperature, cloud cover and even variation in human influence could explain these differences. These species with significant dominance are not necessarily the most frequent. Indeed, in dense tropical humid forests, the high species richness makes a large number of species uncommon or rare; therefore, most of the forest's structure and biomass is composed of a relatively small number of species **[59,56].**

The average overall basal area of stands (60 m2/ha and 52 m2/ha respectively in Fossimondi and Bangang forests) shows higher values than those found in Ngovayang forests **[32]** with 34.6 m2/ha, Monte Mitra in Equatorial Guinea **[40]** with 31.2 m2/ha, Crystal Mountains in Gabon **[41]** with 39.5m2/ha. Nevertheless, they remain within the range ofbasal area commonly recorded in dense tropical rainforests. Indeed, Mosango & Lejoly **[60]** showed in dense tropical forests that basal areas generally vary between 25 and 50 m2/ha.

The distribution of diameter classes is that of a function close to a decreasing exponential as often found in dense tropical rainforests **[48,8].** This distribution is characterized by the high density of small diameter and young individuals in the stand unlike large individuals who have few surviving members when they approach the seed class. Some factors, such as relief, soil and altitude, could influence the diameter growth of individuals. Indeed, some authors such as Aiba & Kitayama **[61]** have shown a decrease in the average tree size with increasing altitude. Similarly, in hilly areas with steep slopes, the soils are less stable and could not support very large trees. No large-scale logging has yet been carried out in the study area; sampling remains limited to medicinal plants and firewood, so the distribution observed is probably natural.

4.3. Phytogeographic types

The floristic background is dominated by species from the lower Guinean domain (56% and 34.24% respectively in Bangang and Fossimondi). These values are comparable to those obtained in Ngovayang by Gonmadje et al **[32]** (32%), Korup by Kenfack et al **[4]** (44%) and Monte Alen by Senterre [**62**] (45%). However, they are significantly higher than those noted in the Dja reserve by Senterre **[58]** (23%), Campo-Ma'an by Tchouto et al. [**50**] (29%) and the central forests of Gabon by Doucet **[51]** where 22% of species in the lower Guinean domain are observed. The predominance of this phytogeographic element in the sites is consistent with the belonging of the flora studied in this phytogeographic sector as defined by Aubreville **[52]** and White **[29]**. We can also think of the maturity of these forests because they seem to be very little degraded. This Lower Guinea area is influenced by the Atlantic monsoon and the cooling effect of the Benguela current, which results in high atmospheric humidity even in the dry season **[53,30]**.

5.CONCLUSION

Despite the relatively high altitude of the two forests studied, the analysis of the flora of these communities shows the main features of dense humid forests. The diversity and specific richness of the Fossimondi and Bangang forests are comparable to those recorded in tropical African forests; they are very rich forests. The most significant differences in these two forests are in their floristic composition and in the importance of certain taxa in terms of number of individuals and basal area. If *Sterculiaceae* are among the most dominant families in both forests, Burseraceae and *Euphorbiaceae* have a greater importance in Fossimondi forest while this predominance is attributed to *Myristicaceae* and Fabaceae in Bangang. Environmental factors lead to a selection of the most suitable species for each site. Unlike the Fossimondi forest where *Santiria trimeria* (Oliv.) Aubr.and *Cola acuminata* are the most dominant, the Bangang forest is dominated by *Piptadeniastrum africanum Hook.f. Brenan* and *Napoleonaea egertonii*. Baker f. The global status of species according to the IUCN Red List revealed 10 vulnerable and 5 endangered species. *Rhaptopetalum geophylax cheek*&Gosline, *Medusandra mpomiana* R. Let, *Argocoffeopsis fosimondi* Tchiengué&Cheek, *Oncoba lophocarpa* Oliv., *Deinbollia oreophila cheek*, *Napoleonaea egertonii* Baker f. are among the endemic plants identified in the site. Although work on wildlife is also rare in this area, some research by non-governmental organizations such as ERuDeF (Environment and Rural Development Foundation) on birds on the western flank of the Bamboutos (Lebialem Highlands) has identified several endemic birds (*Tauraco bannermani*, *Bradypterus bangwaensis*, *Platysteira laticincta*, *Ploceus bannermani*) and some mammals (*Loxodanta africana, Gorilla gorilladeihli*, *Troglodytes vellerosus*, *Cercopithecus nictitans*, *Cercopithecus erythrotis*, *Cephalophus ogilbyi*) within the site. However, it would be interesting for further studies to focus not only on the diversity of the fauna even less explored but also on the flora of epiphytes, orchids, vines and herbaceous plants. Similarly, soil analysis of these ecosystems would provide a better understanding of their relationship to the living environment. Given the degree of endemism and the high specific richness of the area, measures should be taken for the management and conservation of these species in order to prevent their erosion and to allow future generations to benefit from them.

Ethics approval and consent to participate
Not applicable.
Consent for publication
Not applicable.
Availability of data and material
List of species

diversity indices formula

Photos
Competing of Interests
There is no competing interest.

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