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Floristic and structural traits of tree vegetation in three sites with different level of disturbance in dense humid forest of Cameroon

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This study characterizes the floristic and structural traits of trees in three sites of rainforest of Cameroon. The sites were exposed to different intensities of disturbances: Mangombe, highly and frequently disturbed; Bidou, moderately disturbed and Campo, undisturbed. Data collection were carried in a disposive comprising 65 plots of 20 m × 20 m randomly installed in each site for inventory, identification and measurement of diameter of trees greather than 10 cm at 1.30 m height. In total, 4717 plants belonging to 130 species and 43 families were recorded in all the sites. Basal area showed a declining trend with the increase in disturbance intensity while tree density, species richness and families increase with disturbances: Campo (87 m²/ha, 569 trees/ha, 75 species and 29 families); Bidou (54, 538, 88 and 32); Mangombe (49, 708, 91 and 38). The vegetation indices showed a high diversity in all the sites. The Shannon index (5.40 to 5.52) and generic diversity (1.10 to 1.16) had greater value. According to the sample, the floristic composition of Mangombe considerably differs from those of Bidou and Campo. The undisturbed site (Campo) contained young tree population showing a vigorous regeneration while in the highly disturbed site (Mangombe), tree density was scarce, with few big size trees having high cultural importance and low economic value. Low shrub density was recorded in Mangombe and Bidou due to frequent human disturbances. Canopy gaps favor direct sunlight which enhanced the abundance of Shrub in all the sites. More protection is needed for the restoration in the long term of forest cover in Mangombe, which can be done naturally due to high density of small trees composed of species generally found in the upper strata.

Key words: Cameroon, dense humid forest, disturbance, species richness, structure of population.

INTRODUCTION

Forest ecosystem offers various ecosystemic services for humanity. Its plays an important role for the survival of

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rural communities. These anthropogenic disturbances in tropical forests are old and date from the beginning of their occupation by men (Chazdon, 2003). Therefore the dense humid forest of Cameroon presents heterogeneity in the spatial distribution of patches of disturbed and undisturbed forest. The studied sites were formerly inhabited and cultivated during a century, then gradually abandoned with old and even contemporary reoccupation; making disturbance old in this ecosystem (Letouzey, 1968). A selective cutting of wood and harvesting of non-timber forest product were made in the sites at different period, intensity and frequency. Mangombe was highly and frequently disturbed; Bidou, moderately disturbed and Campo, undisturbed. Various studies attest that anthropogenic activities constitute one of the major threats to the conservation of tropical forest. Soft logging exploitation does not exist, but reduces the diversity and richness of forest in wood species with high economic value. Logging exploitation also involves damage on the surrounding forest. These disturbances can affect the floristic and structural threat of ecosystems (Thapa et al., 2010; Naing et al., 2011). Other authors think that disturbances related to moderate human pressure cannot necessarily affect the species richness of forest because it create new environmental condition which sometimes increase the flora diversity (Budke et al., 2010). The comparison of the vegetation analysis would help in understanding the effects of disturbance on the composition and dynamics of forest community and also help in managing the Mangombe and Bidou secondary forests more exposed to anthropogenic disturbance.

MATERIALS AND METHODS

Description of study area

This study was conducted in the southwestern dense humid forest of Cameroon, in the middle of the Biafran Rain Forest. The area is an important site of the Guineo Congolian regional centre of endemism. The sites especially Campo is composed of many forest types with species of high conservation priorities (114 endemic species of which 29 are only found in the area and rich fauna). Despite his importance, the area is under human pressure which leads to the degradation of coastal forest and depletion of lowland forest. The main conservation effort was the creation of community council forest in Mangombe and a national park in Campo (Tchouto, 2004).

Sampling and data collection methods

A set of 65 plots of 20 m × 20 m were randomly installed in each site, a total cover of 2.6 ha; for inventory, and measure of tree (using a meter) with diameter greater than 10 cm at 1.30 m height. The use of plots has many advantages; it helps to highlight the different phenomena of forest dynamics, to intensify the study of the milieu and study the composition and structure of a forest ecosystem (Picard, 2007).

Data analysis

Floristic analysis

Specific Richness (SR): The specie richness is the total number of species observed. The Area - Species curve and Hurlbert curve (Abundance - Species) show evolution of the species richness in relation with the sampled area and help to describe the forest. This approach was used by several authors to estimate extinction rate of species in rain forests (Reid, 1992; Jha et al., 2005).

Diversity of families and genera: The diversity of families is the expression in percentage of appearance of each of the inventoried families.

$$E / G \qquad (1)$$

where E represents the number of species and G the number of genera which helps to appreciate the floral diversity. A low value (close to 1) of this equation indicates a strong diversity of the flora, but does not inform about the species distribution between the various genera and families. Analysis of families' spectrum is important, because rich ecosystems are characterized by few large genera and families rich in species.

Important Value Index (IVI): Important Value Index (IVI) helps to determine the place occupied by each tree species within the community according to Curtis's and Macintosh (1950) formula.

$$\mathrm{IVI} = \left(\sum_{i=1}^{n} \frac{\mathrm{Ni}}{\mathrm{N}} + \sum_{i=1}^{n} \frac{\mathrm{Gi}}{\mathrm{G}}\right) \mathrm{x}\ 100 \qquad (2)$$

In this Equation 2, Ni/N is the relative frequency of the individuals of specie "i"; Ni is the population of specie and N is the total number of the counted individuals. The report Gi/G is the relative dominance of the individuals of a specie "i"; Gi is the basal area of the individuals of the specie "i" and G is the total basal area.

Shannon diversity Index (H'): The Shannon (1949) diversity index in Legendre and Legendre (1984) is an indicator of the specie richness ponderated by the number of individuals per species. It compares the floral richness of different forest sites, in particular when the number of individuals censured in the different sites presents a large gap (Magurran, 2004).

$$H' = -\sum_{i=1}^{n} \frac{\mathrm{Ni}}{\mathrm{N}} \log_2 \frac{\mathrm{Ni}}{\mathrm{N}} \qquad (3)$$

The Shannon-Wiener index varies from 0 to $\log_2 S$. The value 4.5 corresponds to a rich community, composed by an important number of species with almost equal frequency per species (Senterre, 2005).

Structural parameter

Mean Diameter (D_m): The mean diameter of trees (Equation 4) is:

$$Dm = \sum_{i=1}^{n} \frac{\mathrm{Di}}{\mathrm{N}} \qquad (4)$$

Basal area (B): The basal area gives a good visualization of a

Table 1. Abundance and diversity index of tree species censured in Mangombe, Bidou and Campo forest sites

Parameter	Mangombe	Bidou	Campo	All the sites
Number trees	1840	1398	1479	4717
Density (trees/ha)	708	538	569	605
Number of species	91	88	75	130
Number of genus	77	81	68	110
Number of families	38	32	29	43
Generic diversity (E/G)	1.16	1.10	1.10	1.19
Shannon index (H')	5.52	5.41	5.40	6.12
Mean diameter (cm)	23.45 ± 18.28[c]	28.21 ± 22.02[a]	33.91 ± 28.27[b]	28.14 ± 23.31
Basal area (m²/ha)	49.13[c]	54.08[a]	87.06[b]	63.42
Level of disturbance	High	Mean	Low	

forest ecosystem and highlights the species and the families which occupy most place. It is a descriptor directly connected to the diameter usually used to study the structure of forest and was calculated using the following formula.

$$B = \frac{\pi}{4}\sum_{i=1}^{n} D_i^2 = \frac{1}{4\pi}\sum_{i=1}^{n} C_i^2 \quad (5)$$

where B: Basal area (m²/ha), d: diameter (m), C: circumference (m), N: number of trees.

Data were compiled and analyzed with Excel, while R was used to test the significance of differences between parameters of the three forest site, and also for cluster analysis.

RESULTS

Floristic richness, basal area and important value index (IVI) of taxas

A total of 4717 trees were counted in the 195 plots which cover 7.8 ha. The average density of trees is estimated to 605 individuals/ha. This density presents a highly significant difference between the three sites ($F_{2,\ 192}$ = 20.95, P < 0.001). The density was high in Mangombe (708 individuals/ha), average in Campo (569) and low in Bidou (538). The inventoried trees can be grouped into 43 families, 110 genera and 130 species. Shannon index is high in all the sites. The specific diversity decreases with the level of disturbance. The floristic diversity value is high in Mangombe the most disturbed site (38 families, 77 genera and 91 species), comparing to Bidou (32, 81 and 88) and Campo (29, 68 and 75). The basal area is significantly low at Mangombe (49.13 m²/ha) with regard to Bidou (54.08 m²/ha) and Campo (87.06 m²/ha) (F2, 4714 = 93.21, P <0.001) (Table 1).

The Areas - Species curve and the Abundance - Species Richness curve of Mangombe and Bidou are very close. They belong to the same reliable intervals and both present a regular growth more important than that of Campo, characterized by the recruitment of a high number of species when the number of trees and the inventoried area increase. The site of Campo is the least disturbed and less diversified comparing to others, with reliable intervals which do not recover those of Mangombe (Figure 1). In terms of their IVI, the five most important families and species are respectively estimated at 57 and 31% in Mangombe, Bidou (54 and 34%) and Campo (61 and 30%) (Table 2).

Floristic composition

Abundant species are generally more frequent and more distributed. This group is composed in Mangombe by: *Tabernaemontana crassa* Benth (8%), *Strombosia scheffleri* Engl. (8%), *Oncoba glauca* (p. Beauv) Planch (6%) and *Lophira alata* Banks ex C.F. Gaertn (5%). In Bidou, this group includes *Dialium guineense* Willd (8%), *Diospyros crassiflora* H. Perrier (8%), *Uapaca guineensis* Müll Arg. (6%) and *Keayodendron bridelioïdes* (Gilg and Mildbr. Ex Hutch. and Dalziel) Leandri (6%), whereas in the site of Campo, we have *K. bridelioïdes* (11%), *Anthonotha macrophylla* P. Beauv. (6%), *D. crassiflora* (6%) and *Polyalthia suaveolens* (Engl. and Diels) Verdc (5%).

Table 3 presents the specific composition of genera; it shows that Kola is the most diversified with 5 species. The forests of Mangombe and Bidou are more varied in genus. The number of genus represented by single specie is estimated at 67 genera at Mangombe, 74 at Bidou and 61 in Campo. In all the sites, more than 88% of the genera were composed of single specie. The numbers of genera composed of several species decreases considerably while the number of species per genus increases.

In Mangombe, the more diversified genus are *Dacryodes* and *Strombosia* (with three species each), and *Kola* (with 4 species). In Bidou they are: *Afzelia*, *Anthonotha*, *Kola*, *Hallea*, *Markhamia*,

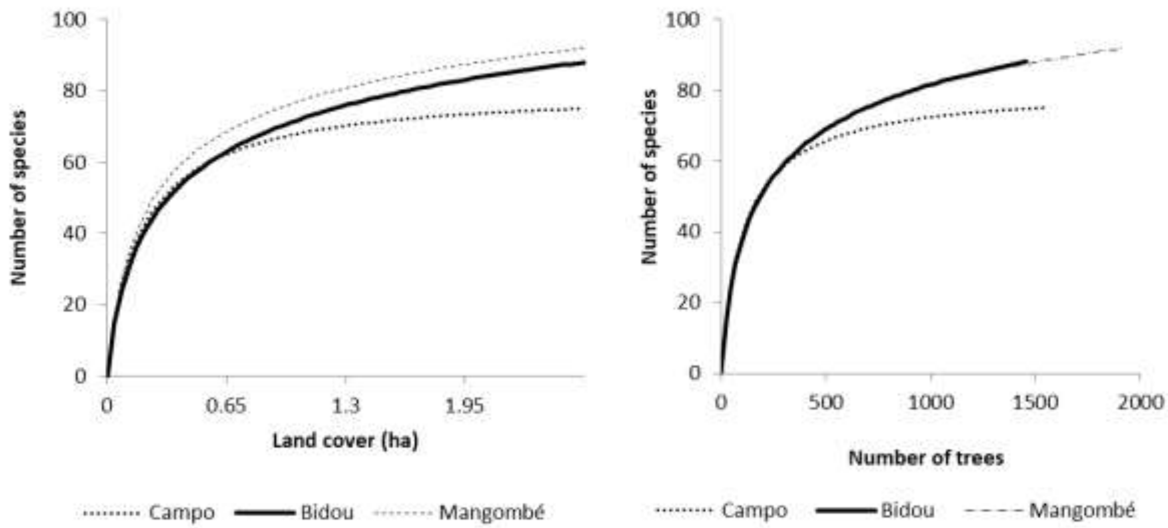

Figure 1. Area-species curve (left) and Abundance-species curve of Hurlbert (right) of censured species in Mangombe, Bidou and Campo forest station.

Table 2. Biological parameters of the 5 most important families and species in Mangombe, Bidou and Campo forest station.

Site	Families	G (m²/ha)	N (ind/ha)	IVI (%)	Species	G (m²/ha)	N (ind/ha)	IVI (%)
	Olacaceae	13.32	125	22	*Strombosia scheffleri*	5.82	54	10
	Fabaceae	6.13	93	13	*Coula edulis*	5.30	19	7
Mangombe	Annonaceae	3.63	74	9	*Tabernaemontana crassa*	1.53	55	5
	Apocynaceae	2.64	72	8	*Oncoba glauca*	2.11	41	5
	Euphorbiaceae	1.84	45	5	*Lophira alata*	1.55	34	4
	Fabaceae	15.60	102	24	*Dialium guineense*	7.01	43	11
	Humiriaceae	8.12	18	9	*Sacoglottis gabonensis*	8.12	18	9
Bidou	Euphorbiaceae	2.47	72	9	*Diospyros crassiflora*	1.32	42	5
	Annonaceae	2.55	47	7	*Anthonotha macrophylla*	2.75	21	5
	Ebenaceae	1.32	42	5	*Uapaca guineensis*	1.20	32	4
	Fabaceae	26.30	112	25	*Keayodendron bridelioïdes*	3.18	60	7
	Annonaceae	7.17	73	11	*Lovoa trichilioïdes*	6.93	24	6
Campo	Meliaceae	9.67	49	10	*Anthonotha macrophylla*	4.41	37	6
	Euphorbiaceae	4.48	77	9	*Sacoglottis gabonensis*	7.89	11	6
	Humiriaceae	7.89	11	6	*Erythrophleum suaveolens*	8.03	4	5

IVI: Important value index, N: density; B: basal area.

Table 3. Synthesis of number of species per gender in Mangombe, Bidou and Campo forest station.

Number of species	Number of genera in the different forest station		
	Mangombe	Bidou	Campo
1	67	74	61
2	7	7	7
3	2	/	/
4	1	/	/
Total	77	81	68

Tabernaemontana, *Xylopia* and *Zanthoxylum* (with 2 species each) and at Campo the diversified genera are *Afzelia*, *Anthonotha*, *Kola*, *Entandrophragma*, *Tabernaemontana*, *Xylopia* and *Zanthoxylum* (2 species).

In Mangombe, the five abundant families are: Olacaceae (18%), Fabaceae (13% dominated by the Caesalpinioïdeae 10%), Annonaceae (11%), Apocynaceae (10%), and Euphorbiaceae (6%), while in Bidou the group is composed of Fabaceae (19% dominated by the Caesalpinioïdeae 16%), Euphorbiaceae (13%), Annonaceae (9%), Ebenaceae (8%) and Meliaceae (7%), whereas in Campo we have Fabaceae (20% dominated by the Caesalpinioïdeae 16%), Euphorbiaceae (14%), Annonaceae (13%), Meliaceae (9%) and Ebenaceae (6%).

The diversified families are among the more abundant. Fabaceae is the more diversified floral group in all the sites and are dominated by the sub family of Caesalpinioïdeae. Other richness families are Euphorbiaceae, Apocynaceae and Annonaceae.

Comparison of the floristic composition of Mangombe, Bidou and Campo

Comparison of Bidou and Campo: The sites of Bidou and Campo have 63 common species. These common species represent 91% (1275 trees) of the counted trees in Bidou and 94% (1397 trees) of the effective of Campo. With regard to the sampling, this information suggests that there is very little difference between the floral compositions of these two sites. Bidou, still have impact of logging exploitation. The timber species like *L. trichilioïdes* are little represented with regard to the site of Campo. *P. suaveolens* used as firewood is less frequent at Bidou than Campo. The population of *P. nitida* presents gaps between Bidou and Campo, due to exploitation. *P. nitida* is a medicinal plant, with the bark and the roots used to cure malaria, stomach pains and pneumonia. *K. bridelioides* is a mesophanerophyte generally abundant in semi deciduous forests, and can be found scattered in dense humid forests. *D. guineense* is more abundant in Bidou; it is a riparian species found in the undergrown of dense humid forest, and the seeds of this species are consumed by local communities. In the site of Campo, we found emergent trees with bigger diameters.

Comparison of Mangombe with Bidou-Campo: The vegetation of Mangombe (91 species, 1840 individuals) is very different from those of Bidou (88, 1398) and Campo (75, 1479), in particular as regards the density, structure of population and floral composition. The Mangombe vegetation has 30 species (574 individuals) different from those of Bidou and Campo, and 44 common species (814 individuals) representing 44% of the species present in Mangombe. The common species are dominated by those familiar to less disturbed forest; they are mostly commercial wood such as: *Afzelia pachyloba (Doussié), Canarium schweinfurthii (Aïlé), Coula edulis, Didelotia africana, D. crassiflora, Duboscia macrocarpa, Irvingia gabonensis, Khaya ivorensis, Pachyelasma tessmanii, Pseudospondias longifolia, Saccoglottis gabonensis, Triplochiton scleroxylon,* and *U. guineensis.* The species of secondary forests in this group are: *Cleistopholis patens, Dacryodes macrophylla, L. alata, Markhamia tomentosa, Musanga cecropioïdes, Pycnanthus angolensis, Spathodea campanulata, Zanthoxylum gilletii, Zanthoxylum heitzii,* and *Xylopia aethiopica*.

Structural analysis of tree population in the different sites

Figure 2 represents the ACP based on the projection of the structural parameters for all the 4717 trees listed and distributed in class (Cl) of individuals with amplitude of 10 cm diameter. Cl_1 represents the class of the individuals 10 cm ≤ dbh ≤ 20 cm; Cl_2: 20 cm < dbh ≤ 30 cm; Cl_3: 30 cm < dbh ≤ 40 cm etc. These analyses show on axis 1 an opposition between diversified diameter classes, composed of abundant tree with small diameters, on one hand, and on the other hand classes of individuals with low density and big trees. This confirms the presence of forest patches at different growing stage.

In Mangombe, the vegetation is characterized by height trees with small diameters; this can be due to disturbance and canopy gap which favor the growth in height among trees which are in competition for light in the undergrowth. In all the sites, the first class of individuals Cl_1 is distinguished from others by the presence of various small sizes trees, while the upper classes are composed of few big trees.

In Mangombe, the classes of big diameters (Cl_{11}) distinguish themselves from others by their very low density (5 individuals and 3 species) and the presence of emergent species like *Sacoglottis gabonensis* (dbh = 135.35 cm), *C. edulis* (dbh = 318.18 cm). There is a big difference in the abundance of trees between the small size diameter classes Cl_1 (1025 trees), Cl_2 (429 trees) and Cl_3 (202 trees).

In Bidou, the class of big trees Cl_{13} counts only 6 individuals composed of 6 species, such as *Staudtia kamerunensis* (156.13 cm), *D. africana* (162.69 cm) and *Baillonella toxisperma* (238.73 cm), which dominate the landscape by their sizes. The difference in terms of trees abundance and species richness explains the gap between Cl_1 (702 ind), Cl_2 (276 individuals) and Cl_3 (143 individuals).

In Campo, the class of the superior diameters is composed of 3 species (3 individuals); they are emergent species like *S. gabonensis* (207.16 cm), *Erythrophleum suaveolens* (382.23 cm).

The structures of trees population of Bidou and Campo

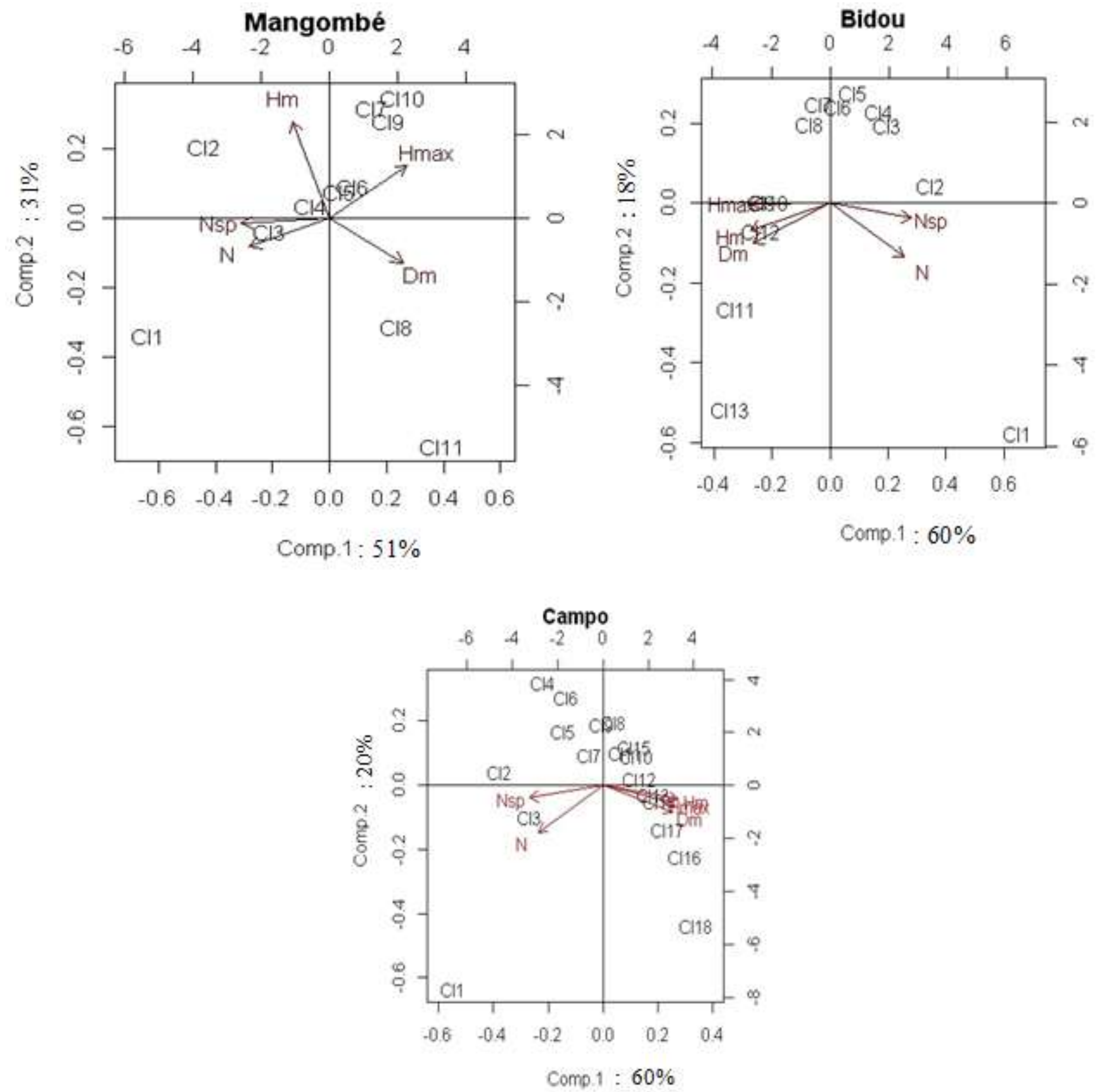

Figure 2. ACP presenting the correlation between two axis and structural parameters of trees in Mangombe, Bidou and Campo forest station. (Hm: mean heigh of trees, Hmax: maximum heigh, N: density, Dm: mean diameter, Number of trees per diameter class: Cl_1, Cl_2……Cl_n).

are similar to an opposition between groups of plots composed of small trees, dense and diversified which doubtless find themselves in disturbed area; while on the other side there is a group of plots composed of big trees. Also, a group of intermediate plots was observed; and in Mangombe, the appearance of new altitudinal strata was observed.

Individualization of group of trees

Figure 3 is the HAC obtained from the presence/absence of tree species censored in 195 plots. It shows five groups of trees. The composition of groups indicates that: Group 1 is a mixture at equal proportion of plots of Bidou and Campo; the Group 2 represents the site of Bidou, the Group 3 can be linkened to the site of Campo and the Groups 4 and 5 belong to Mangombe.

According to their floral and structural composition, the groups can be classified in various types of forests.

Frequently disturbed patches of forest

Group 2 is vegetation in a dynamic state. The most abundant families are Fabaceae (20%), followed by

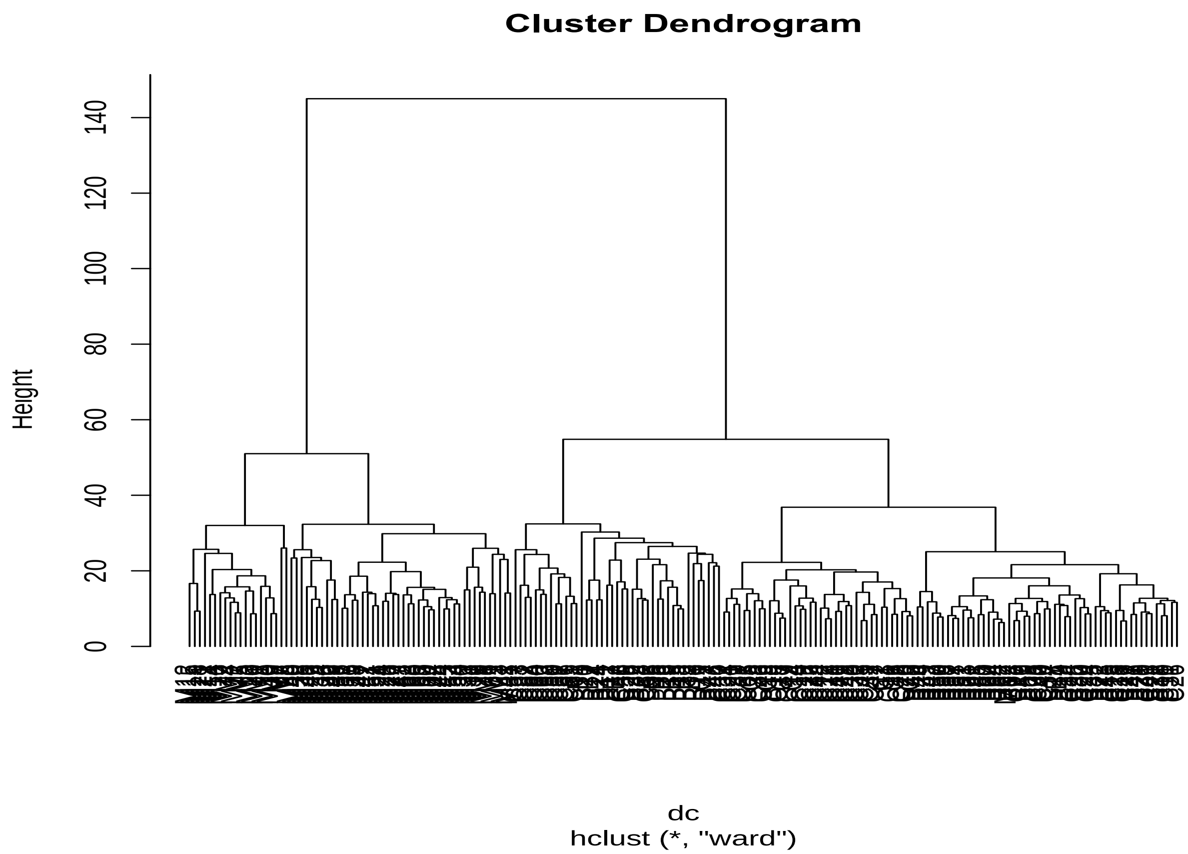

Figure 3. Representation of group of plots by the Hierarchical AscendantClassification (HAC) 195 plots × 130 species.

Euphorbiaceae (17%), Meliaceae (8%) and Annonaceae (8%), whereas the abundant species are in decreasing order: *K. bridelioides* (9%), *D. crassiflora* (8%) and *D. guineense* (7%).

Group 4 counts various shade-intolerant species like *A. macrophylla, T. pachysiphon, P. suaveolens, D. macrophylla* and earlier growing species such as *C. patens*. These species mark signs of past and present disturbances. The abundant families are: Olacaceae (24%), Fabaceae (15%), Annonaceae (9%), Ebenaceae (9%) and the abundant species are: *S. scheffleri* (10%), *Diospyros kamerunensis* (9%), and *O. glauca* (6%).

Moderately disturbed patches of forest

The plant grouping 5 is the densest. The abundant families are: Olacaceae (15%), Apocynaceae (12%), and Annonaceae (11%). While the abundant species comprise: *T. crassa* (11%), *L. alata* (7%), *S. scheffleri* (6%), and *O. glauca* (6%). The higher number of pioneers and shade-intolerant species is an indicator of disturbed forest.

Table 4 presents the average biological parameters of the groups; we can note that Groups 4 and 5 are diversified, with a strong density and an ascendancy of shrubby stratum (23 cm ≤ dbh ≤ 24 cm), these characteristics shows vigorous forest regeneration. Group 2 is composed of trees with average diameter (29 cm) whereas Group 3 and 1 have big trees.

Undisturbed patches of forest

In Group 1, the abundant ligneous families are: Fabaceae (18%), Annonaceae (10%), Euphorbiaceae (10%) and the frequent species are: *D. guineense* (6%), *D. crassiflora* (5%), and *U. guineensis* (5%).

Group 3 possesses the most important families, Fabaceae (20%), Annonaceae (15%), Euphorbiaceae (14%); whereas the frequent species are: *K. bridelioides* (13%), *D. crassiflora* (8%), and *A. macrophylla* (7%).

In these plant groupings, the abundance of Meliaceae in the understory indicates the importance of shade-intolerant species which are gradually replaced by tolerant species; this marks signs of past disturbances and the presence of Ebenaceae reminds one of an advanced maturity of the forest.

Table 4. Biological parameters of the vegetation groups issued from the 195 plots censured in Mangombe, Bidouand Campo forest stations.

Group	Number of trees	Number of species	Density (ind/ha)	B (m^2/ha)	Dm (cm)	Hm (m)
GR1	945	94	591	70	31	18
GR2	1004	72	502	55	29	17
GR3	942	61	628	97	33	18
GR4	580	60	580	55	24	16
GR5	1246	76	692	39	23	18

B: Basal area; Dm: mean diameter; Hm: mean height.

DISCUSSION

Floristic traits

The studied sites are rich and diversified as indicated by their species diversity (75 - 91), Shannon's index (5.40 - 5.52), low value of the generic coefficient (1.10 ≤ E/G ≤ 1.16) and the ascendancy of families and mono specific genera. This wealth characterize rainforests recognized by their favorable environment necessary for their evolution (Stebbins, 1974), for the preservation of biodiversity (Leigh, 2008) and marked by the presence of a high number of genera represented by low number of species.

The number of species is high in Mangombe, a situation that results from logging exploitation and other human pressures which increased canopy gaps and favored pioneers and shade-intolerant species, which are added to the species existing in the forest before exploitation. Gaps in the canopy engendered by the death of trees modify the ecological conditions of the forest and constitute the driver of sylvigenesis. Other processes such as the substitution of emergent trees dead from foot and by the dominated trees also contribute to the mechanisms of renewal of the forest.

Generally, when environmental conditions are favorable, the natural regeneration which settles down after deforestations, can contain, a few years later, the seedling of all the forest species of the environment with however an important frequency and vitality of pioneers species able to mask the presence of other species (Chazdon, 2008). According to Sahu et al. (2008) and Chazdon et al. (2009), natural disturbances (tree blow downs) or anthropogenous pressures can contribute to biodiversity in the canopy gaps, or constitute a threat (Hanster Steege, 2010; Loreau, 2010). In disturbed area, certain species can easily settle down favoring a fast increase of the biodiversity; however, some of these species cannot sustainably stay in these environments. Therefore, the maturity of the forest can lead to the reduction of specific richness (Chave et al., 2003). Disturbances are not always negative to an ecosystem as it depends on their frequency and intensity. It can contribute to the diversity richness, renewal of the ecosystem and release of nutrients.

The higher value of observed Shannon diversity index corresponds to the conditions where environment is favorable to installation of several species represented by few numbers of individuals. This tendency to a high specific diversity associated with a low density of species is a remarkable phenomenon in rain forest.

Specific richness and diversity

The Area - Species curve for all the sites shows a regular growth. It presents a classic structure of the recruitment of species when the number of trees increases. These curves are not stabilized; it indicates that additional inventories may increase the number of species. The comparison of the Area - Species curves shows a good correlation between the curve of Mangombe and Bidou where the number of species increase more quickly with the sample area comparing to the site of Campo. These tendencies find themselves in the Abundance - Species curve. The sites of Mangombe and Bidou seem richer and diversified than that of Campo, resulting from the importance and frequency of disturbances.

Important value index (IVI) and floral composition of the sites

This index shows a general representation of the composition of the vegetation in term of dominant species. Few numbers of species has an important contribution in IVI. Several wooden species are listed among the ten important species by their IVI in Bidou and Campo, viz; *U. guineensis, Lovoa trichilioïdes, E. suaveolens, K. ivorensis, D. africana, Eribroma oblonga*. At Mangombe, non wood species belong to those with important IVI such as *C. edulis* Baill., *S. scheffleri* Engl., *O. glauca* (P. Beauv.) Planch, *T. crassa* and *L. alata* Banks ex C.F. Gaertn which is a secondary forest wooden species.

At Mangombe, one can assume that wood exploitation which is selective because it takes only few big trees on a reduced number of species, affects the specific composition of the forest and the process of reconstitution of the natural environment by increasing or strengthening the abundance of certain less appreciated species.

Family richness

Fabaceae, particularly the sub families of Caesalpinioïdeae and Mimosoïdeae is well represented in the whole forest sites. One of the fundamental characters of the African dense forests is their higher richness in Fabaceae who is closer to those of America and different from those of Asia (White, 1986). Small size trees are abundantly represented by Anacardiaceae, Annonaceae, Apocynaceae, Ebenaceae, Euphorbiaceae, Guttifères, Icacinaceae, Ochnaceaea, Olacaceae, Rubiaceae, Tiliaceae, Sapindaceae and Violaceae.

The floristic composition of lower and superior strata in Campo and Bidou differs from that of Mangombe. At Mangombe, we can observe in the undergrowth the presence of some species generally found in superiors strata like *Alstonia congensis* Engl, *Ceiba pentandra* (L.) Gaertn*, C. edulis* Baill.*, D. africana* Baill.*, L. alata* Banks ex C.F. Gaertn*, Milicia excelsa* (Welw) CC Berg*,* and *Piptadeniastrum africanum* (Hook f) Brenan.

Structural trait of the vegetation

Trees density

The density of trees in the studied forest is situated in the order of the average density of trees observed in dense humid forest estimated at 400 to 650 individuals with dbh ≥ 10 cm per hectare (Riéra, 2011). We can however note a higher density of trees in Mangombe compared with that of many tropical sites; this is due to the reconstitution of the forest after exploitation and the regrowth who settle down and develop after anthropogenic and natural disturbances. The disturbances have a direct influence on trees density, diversity and their specific composition (Hitimana et al., 2004; Kessler et al., 2005).

Basal area

Trees population in Mangombe is dense and the basal area low (708 trees/ha; 49.13 m²/ha) compared to Bidou (538 trees/ha; 54.08 m²/ha) and Campo (569 trees/ha; 87.06 m²/ha). This situation can be explained by the abundance of big trees particularly in the site of Campo. The low gap between the basal area of Mangombe and that of Bidou can be explained by the effect of the exploitation of trees which is more frequent in Mangombe than Bidou. The basal area in Mangombe is however biased by the presence of two emergent trees *B. toxisperma* and *C. edulis* which have exceptional diameters (dhp = 373 and 318 cm) and contribute to 15% of the basal area.

In Mangombe, shrubs are abundant like in the floristic groups GR5 and GR4; in Bidou, trees have a litle big diameter (GR2); whereas in Campo we have many trees with big diameters (GR3). Basal area in Bidou and Campo are higher than the average value (30 - 50 m²/ha) frequently observed in rain forests (Riéra, 2011). Table 5 presents the distribution of basal area in some African forests. We can note that the basal area in Campo is exceptional and probably due to the type of ecosystem which is a forest rich in Fabaceae (Tchouto, 2004).

Tree and diameter class distribution

The structures of population reveal a strong presence of trees with small diameters and little number of big trees, the characteristic of vegetation with constant regeneration and in equilibrium. This forest structure is close to that of Rollet (1974), which showed that the distribution of trees in the diameter classes follows an exponential model. Mangombe forest presents a deficit of big trees due to anthropogenic cutting.

Conclusion

The studied forest sites are rich and diversified; they distinguish themselves by a mosaic of forest patches with different development stages, structure and floristic composition. The study of flora and the vegetation group highlights the role played by anthropogenic pressures in the spatial distribution of numerous taxa's and plant associations. The similarity in the floral composition of the various forest sites decreases with the gradient of anthropogenic disturbance.

The floristic composition and structure of population in Mangombe Forest differ from those of Bidou and Campo which are similar. In Mangombe, trees density is higher and the basal area is lower compared to that of the other sites; this can be due to a high number of small trees and shrubs, which is a sign of strong forest regeneration. In this forest site, a few numbers of species without a commercial value dominate by their IVI, showing that cutting of trees affected the specific composition and the process of reconstruction of the forest by strengthening the importance of little appreciated species. The presence in this group of typical secondary forests species (*L. alata, T. crassa*) mark the sign of the past and present anthropogenic disturbances. This group is composed at Bidou and Campo of various wooden species such as *D. crassiflora, L. trichilioïdes, E. suaveolens*.

Mangombe Forest can be compared to a young

Table 5. Trees density and basal area of trees in some tropical forests.

Site	Code	Forest station	Density (trees/ha)	Basal area (m²/ha)
		Mangombe	708	49.13
		Bidou	538	54.08
		Campo	569	87.06
Cameroon	1	Takamanda	/	33.5 ± 7.6
	2	Parc National de Campo	/	57.66 - 88.73
	3	Reserve de biosphère du Dja	352 - 460.4	29.0 ± 5.6 à 37.5 ± 3.9
	4	Ngovayang - région du sud	532 ± 75	28.8 -42.1
	5	Lopé - Gabon	741.5 – 931.5	19.5 -23.5
	6	Lopé - Gabon	/	20 - 58
Africa	7	Monte Mitra. Guinée Equatorial	548 ± 108	/
	8	Waka (Gabon)	589 ± 50	/
	9	Nouabale-Ndoki (Congo)	300 ± 11	/
Asia	10	Parc de Popa. Myanmar (Asie du sudEst)	604 ± 39	17.17 - 37.80
	11	Chine. Reserve naturelle de Bawangling île de Hainan	755 ± 170	53.93 ± 23.31
Europ	12	Ukraine	270 - 590	/

1-Sunderland et al. (2003); 2-Tchouto (2004); 3-Djuikouo et al. (2010); 4-Gonmadje et al. (2011); 5-Ukizintambara et al. (2007); 6-Palla (2011); 7-Balinga et al. (2005); 8-Balinga (2006); 9-Sunderland and Balinga (2005); 10-Naing et al. (2011); 11-Scotto Di Vettimo (2010); 12-Trotsiuk et al. (2012).

secondary forest in phase of maturation. The restoration of the forest can be done naturally as shown by trees structure characterized by a high frequency of small size trees and deficit of big trees. Mangombe forest can recover its original structure and functions after a long term and in the absence of anthropogenic disturbance. These will also depend on the behavior of all the species and on the interactions between them and their environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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