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Research article

VEGETAL DIVERSITY AND STRUCTURE OF ONE STRATUM IN THREE SITES OF YINGUI´S FOREST MANAGEMENT UNIT (CAMEROON-CENTRAL AFRICA): A COMPARATIVE STUDY

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ABSTRACT: The aim of this study was to investigate and compare the floristic composition of three sites belonging to the stratum "evergreen wet dense forest with partial logging and low density" of Yingui´s Forest Management Unit (FMU), located between the Centre and the Littoral Regions in Cameroon), with an emphasis on their structural parameters and diversity indices. A total of 18365 individuals with diameter at breast high (DBH) ≥ 20 cm belonging to 305 species, 203 genera and 55 families was recorded during the surveys. Diameter structures showed that the three population of the FMU had a regressing exponential structure. The Shannon - Weaver diversity index (H') varied from 6.53 (site 3) to 6.73(site 2) with an evenness from 0.818 (site 1) to 0.884 (site3).Those high indices can be explained by the large number of species met (265 in site 1, 233 in site 2 and 167 in site 3) and of individual met (13 238 in site 1, 4 114 in site 2 and 1 013 in site 3). Concerning exploitable species, the Student t-test showed a significant difference between site 3 and the two other sites ($p < 0.05$). Site 3 had specific composition different to those found in site 1 and site 2. Taken together, our results can contribute to increase the data bank on Yingui´s FMU and at national level, can ameliorate the management of forests production.
Keywords: Biological diversity, forest management unit, management inventory, sustainable management, Yingui-Cameroon.

INTRODUCTION

Cameroon is one of the six countries forming the Congo Basin which is the second largest area of contiguous tropical rainforest after the Amazon [1, 2]. The north of Cameroon is cover by Sudano-sahelian savanna, the centre by high altitude moist savanna and the south mostly by ever green rain forests and semi-deciduous rain forests. In Cameroon, forest ecosystem services provide goods for almost 80% of the predominantly rural communities, thereby, reducing poverty and contributing to national development. In addition, forests provide medicines for the most majority of urban and rural people, and these medicines are one of the most-valued forest products by local people [3, 4]. Furthermore, forests at the global scale, contribute to climate regulation, whereas at the regional scale, they contribute to water storage capacity. Intense anthropogenic activities and climate change have long been considered as significant drivers of dynamics and diversity through loss of biodiversity and consequently species extinction [5, 6, 7]. Cameroonian forest ecosystems face serious threats, mainly due to unprecedented rates of human population growth and other factors including timber harvest, cropland cultivation and infrastructure construction. The loss and degradation of tropical forest biodiversity have become issues of popular concern and political debate across the world. Conserving forest biodiversity is a key element of regional, national and international forest management policies, agreements and guidelines. The World Commission on Environment and Development of the United Nation, the Brundtland Commission, used the expression "sustainable development" as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [8, 9]. In this context, sustainable management appears as a solution to forests conservation since it maintains, perpetuates, and contributes to the economy of the country [10, 11]. In line of this, Cameroon has adopted statutory texts allowing her to preserve a part of these heritage composed of about 22 523 732 ha [12] covering 48 % of national territory. A total of 6 000 000 ha, that represents 27 % of these forests is dedicated to sustainable production of timbers and is divided into Forest Management Units (FMU). However, after allocation of a Forest Management Unit, the winning company had to apply a management plan allowing the preservation of the biodiversity.

This plan is made on the basis of the data (grown, damages and mortality rate) and available scientific knowledge such as the remote detection. The remote detection allows establishing strata formed by the same type of vegetation. Every stratum groups together forest spaces which are considered as being homogeneous (the same specific composition). It is on this basis that the fragmentation is realized in order to obtain Forest Exploitation Units (with the same cutting potential), which are divided each into five Annual Cutting Plots (with the same surface) as seen in MINEF [13]. Therefore, knowing structure of stems (density, diameters or basal area) can be useful in forest management by directing rotation interventions and the volume of forest to exploit without becoming impoverishment in species. The overall objective of this study was to determine and compare the floral specific composition of a stratum in three sites of Yingui´s Forest Management Unit (FMU), with an emphasis on their structural parameters and diversity indices.

MATERIALS AND METHODS

Study area

The study area was composed of three sites located in Yingui Forest´s Management Unit (FMU) which is situated in the Centre and Littoral regions (Cameroon-Central Africa). The FMU with a surface of 94917 ha is divided into two topographic zones: a relatively hilly area (less than 500 m) on the West side of river Makombe and a very hilly (up to 1300 m) in the East. The climate in the study region is characterized by a dry season ranging from December to February and a rainy season from March to November. Annual rainfall varies from 1500 to 2800 mm. The annual average temperature is 22.4°C and the thermal amplitude is 2.9°C.

According to the Classification of Denamur [14], the FMU can be classified as an evergreen wet dense forest characterized by species with leaves always green, the absence of total defoliation and a flora rich in *Lophira alata*. The forest stratification permitted to show three strata divided into eleven under strata (annex 1).

Annex 1. Strata and affectations used in management plan in Cameroon

Stratum	Affectation	Surface (ha)	% total surface
DHS b	FOR	8 782.81	9.26
DHS CHP b	FOR	4 527.41	4.77
DHS CHP d	FOR	4 379.71	4.62
DHS CP b	FOR	14 025.90	14.78
DHS CP d	FOR	24 944.79	26.29
DHS d	FOR	1 382.20	1.46
DHS In b	PEN	9 796.19	10.33
DHS In d	PEN	5 175.20	5.46
SA CP d	FOR	89.50	0.09
MIT	FOR	21 186.40	22.33
EA	EAU	578.62	0.61
Total		94 868,73	100.00

DHS: evergreen wet dense forest; SA: secondary forest; MIT: swampy flooded temporarily; EA: water; CHP: partial Chablis; CP: partial Cut; b: high density; d: low density; IN: inaccessible; EAU: lakes and stream; FOR: production of timber; PEN: protection of strong slopes (Denamur, 1990)

The site 1 was characterized by a total rainfall of more than 2000 mm with less than three dry months a year, a rich flora and an evergreen canopy, with the presence of *Lophira alata*. Consequently, the site 1, based on the classification of Denamur [14] could be classified in the evergreen wet dense forests. As for the site 1, the Site 2 was classified in the evergreen wet dense forests. Whereas, the site 3 near to the zone of Bafia (where the total rainfall is lower than 1 800 mm a year) with characteristics similar to those of site 1, was classified as wet dense semi-deciduous forests. This type of forests is observed in transitional zones.

Data collection

Types of stratum were defined for the entire Forest Management Unit. The FMU was divided into 3 sites following the heights, the rainfall of the nearby cities and the natural barriers such as streams. In every study site, plots of 5000 m^2 (250m x 20m) each being on stratum «DHS CP d» DHS: evergreen wet dense forest with partial Cut (evergreen wet dense forest with partial cut and of low density) were aligned along equidistant transect as indicated in Figure 1. 74 plots were taken into account as follow: 50, 18 and 6 in site 1, site 2 and site 3 respectively. Woody species of diameter at breast height (DBH) ≥ 20 cm were identified and measured using a diameter tape [15].

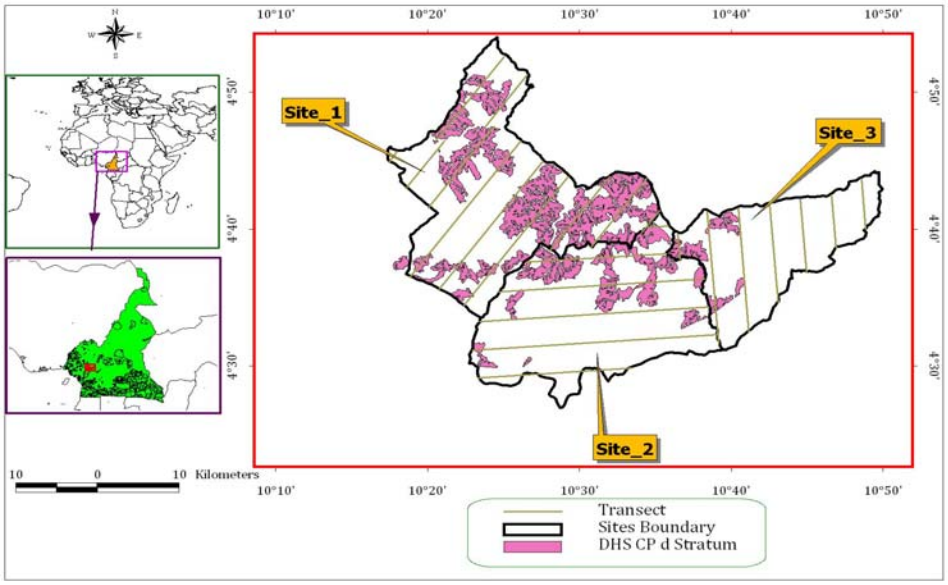

Fig. 1. Transect, sites and DHS CP d Stratum in Forest Management Unit 00-004
DHS: evergreen wet dense forest; CP: partial Cut; d: low density

Structural parameters

The abundance (number of individuals) was established for each specie and in each site. The five most abundant species were determined by taking into account all the species seen and the commercial or exploitable species (individuals having a DHB more than allowed diameter for cut and being a part of the commercial company list).The density species and their total basal area (E) which is the sum of the surface occupied by the base of the same species were calculated. E was calculated as follow:

where: π= 3.14

Ni: number of individuals of the species "i", dmi: is the arithmetic diameter mean of all the individuals of the species "i".

Diversity of trees

The diversity index in the three studied sites was determined by the Shannon-Weaver index, which is based on the frequency or the presence index [16, 17].The presence index (Pi) is given by the formula:

where: N: Total number of individuals, Ni: Number of individuals of the species i. Thus, the Shannon-Weaver index (H') was calculated as follow:

To appreciate the diversity, we considered H'_1 the diversity index of the site taking into account all the individuals with DBH $\geq$ 20 cm and H'_2 which consider only commercial individuals species. In addition, the evenness (R) which is the ratio between the observed diversity and the maximal diversity was calculated using the formula:

$H'_{max} = \log_2 S$,

where S is the total number of species. We used R_1 the evenness of all the individuals and R_2 the evenness of commercial individuals species.

Statistical analysis

A t-Student test was used to compare the specific composition of sites. A Detrente Correspondence Analysis (DCA) was made with the software Canoco to determine if the sites were nearby [18]. For this comparison, the nominal values (presence = 1 and absence = 0) were used. To verify the variation between the studied sites, the Sorensen similarity coefficient was used. It was given for two sites (A and B) by the following formula:

$$K = \frac{2a}{(2a + b + c)}$$

Where:

a = Number of species being in both sites compared (A and B);

b= Number of species found in site A and but not in site B;

c= Number of species found in site B and but not in site A.

This coefficient can be expressed in percentage and varies from 0% to 100% depending on the level of resemblance of the sites. Increasing coefficient indicates an increase in the similarity of the sites [19, 20].
A graph was made with software Canoco 4.5 for relation determination within sites notably resemblances and distances. The results were considered significantly different at $p<0.05$.

RESULTS

The inventory realized in three sites of stratum DHS CP d in Yingui's forest management unit enable us to sample 18 365 individuals belonging to 305 species, 203 genera and 55 families (Table 1). As it can be seen, the number of species, genera and families increased with the size of the sample (Table 2).

Vegetal diversity and structural parameters in site 1

The five most abundant species were: *Sterculia rhinopetala* K. Schum (lotofa/nkanang); *Desbordesia glaucescens* (Engl) Van Tiegh. (Alep); *Pycnanthus angolensis* (Welw). Warburg (ilomba); *Funtumia elastica* (Preuss) Stapf (mutondo) and *Plagiostyles africana* (Muell. Arg.) Prain (alomba/essoula). Their densities were 7.45; 6.77; 6.35; 5.15 and 4.81 individuals per hectare respectively.
A total of 13 238 individuals was counted, for a total basal area of 26 m^2 /ha. The highest presence index was 0.050 (*Sterculia rhinopetala*). The diameter of population in this site showed a decreasing exponential structure (Fig. 2).

Table 1. Number of Families, genera and species counted in DHS CP d stratum.

	Site 1	Site 2	Site 3	All FMU
Surface (ha)	88	27	8	123
Individual	13 238	4 114	1 013	18 365
Species	265	233	167	305
Genera	180	171	132	203
Families	51	50	46	55

Table 2. Classes of diameter in Yingui's forest.

Classes	01	02	03	04	05	06	07	08	09	10	11	12	13
Diameter (cm)	[20-30]	]30-40[	]40-50[	]50-60[	]60-70[	]70-80[	]80-90[	]90-100[	]100-110[	]110-120[	]120-130[	]130-140[	]140-150[

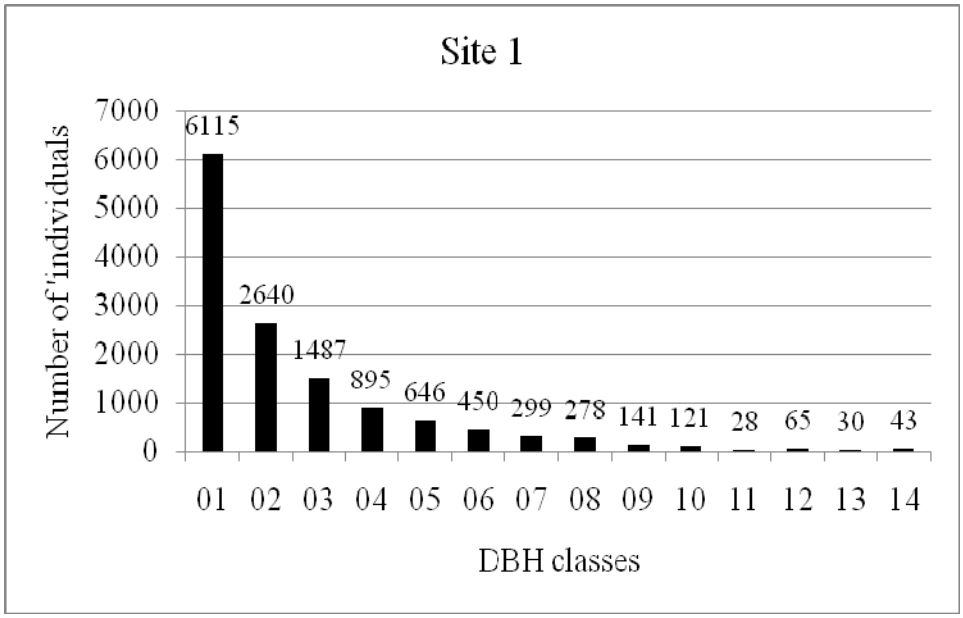

Fig. 2. Diameter of the population in site 1.

When considered only the commercial species, the five most abundant were: *Pycnanthus angolensis* (Welw.) Warburg (ilomba); *Desbordesia glaucescens*(Engl.) Van Tiegh (alep); *Terminalia superba* Engl. and Diels (fraké / limba); *Ceiba pentandra* (Linn) Gaertn. (fromager / ceiba) and *Pterocarpus soyauxii* Taub. (red padouk). Their densities were 20; 1.89; 1.85; 1.69 and 1.16 individuals per hectare respectively. For these species, 1 457 individuals were counted and the total basal area was 10.27m^2 /ha. Here, the highest presence index was 0.194 (*P. angolensis*). The Shannon-Weaver index gave $H'_2 = 4.129$ with $H'_{2\ max} = 5.615$. The evenness gives $R_2 = 0.735$.

Concerning *L. alata* (the most valued specie for the manager) population, in site 1, classes of diameter 01: [20-30cm], 2:] 30-40cm] and 3:] 40-50cm] were the most abundant with 21, 16 and 11 individuals respectively (Table 2). In this site, *L. alata* presented density of 0.13 individuals per hectare with a presence index of 0.007. It has an irregular diameter structure.

Vegetal diversity and structural parameters in site 2

The five most abundant species were *P. angolensis* (Ilomba); *S rhinopetala* (lotofa / nkanang); *D. glaucescens* (alep); *B. welwitschii* (Hiern) Radlk. (Awonog/akee apple); *P. africana* (alomba / essoula). Their densities were 8.56; 7.85; 5.70; 5.44 and 3.89 individuals per hectare respectively. A total of 4 114 individuals was counted, with a total basal area of 25.89 m^2/ha. The highest presence index seen was 0.056 (*P. angolensis*). The Shannon-Weaver index was $H'_1 = 6.728$ with $H'_{1\ max} = 7.864$ and the evenness was $R_1 = 0.855$. Similar to that observed in site 1, the diameter of population showed an exponential decrease in the distribution of their classes of diameters (Fig. 3).

However, when taking into account only the commercial species, the five most abundant were: *P. angolensis* (ilomba); *D. glaucescens* (alep); *Terminalia superba* (fraké / limba); *Ceiba pentandra* (fromager / ceiba); *Petersianthus macrocarpus* (P. Beauv) Liben (abalé). Their densities were: 3.59; 2.07; 1.96; 1.00 and 0.96 individuals per hectare respectively. For these species, 438 individuals were counted for a total basal area of 9.47 m^2/ha. The highest presence index was 0.221 (*P. angolens*is). The Shannon-Weaver index was $H'_2 = 4.094$ with $H'_{2max} = 5.285$ and the evenness was $R_2 = 0.775$. The density of *L. alata* was 0.22 individuals per hectare and his presence index was 0.013. Classes of diameter 01: [20-30 cm], 03:] 40-50cm] and 10:] 110-120cm] were abundant with 4, 5 and 3 individuals respectively.

Vegetal diversity and structural parameters in site 3

The five most abundant species were *M. cecropioides* R. Br. (Parasolier). *B. welwitschii* (awonog/akee apple); *Rauvolfia macrophylla* Stapf (essombi); *Polyalthia suaveolens* Engl. and Diels (otungui) and *Vitex ciliata* (Pierre Pellegr.) (Evoula/evino). Their densities were 38; 5.88; 5.13; 3.88 and 3.88 individuals per hectare respectively. A total of 1013 individuals were counted, with a total basal area of 17 m^2/ha. The highest presence index was 0.050 (*M. cecropioides*). The Shannon-Weaver index was $H'_1 = 6.527$ with $H'_{1max} = 7.384$ and the evenness was $R_1 = 0.884$. The diameter of population in site 3 showed a decreasing exponential structure (Fig. 4).

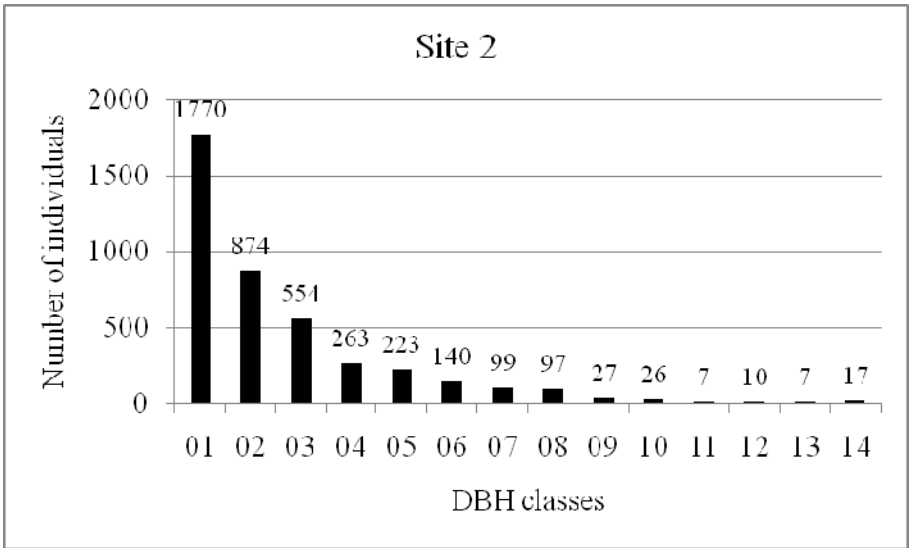

Fig. 3. Diameter of the population in site 2

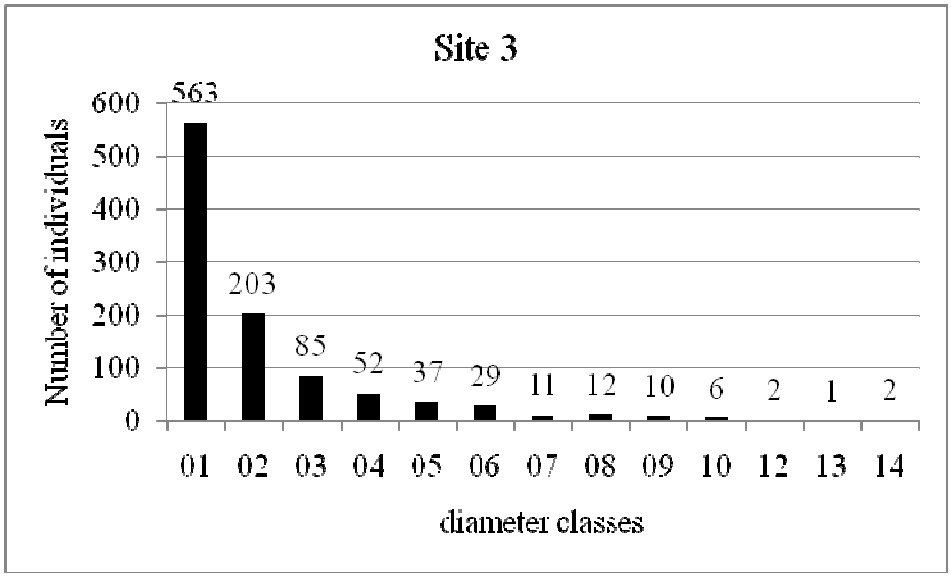

Fig. 4. Diameter of the population in site 3

Taking into account only the commercial species, the five most abundant were *P. angolensis* (ilomba); *D. glaucescens* (alep); *L. alata* (azobé); *P. macrocarpus* (abalé) and *Cylicodiscus gabonensis* Harms (okan). Their densities were 1.38; 1.12; 0.88; 0.63 and 0.63 individuals per hectare respectively. For these species, 74 individuals were counted and the total basal area was 5.64 m^2/ha. The highest presence index was 0.149 (*P. angolensis*). The Shannon-Weaver index was H'_2 = 4.24 with H'_{2max} = 4.70 and the evenness was R_2 = 0.751.Concerning *L. alata*, the density and the presence index were 1.12 individual per hectare and 0.094 respectively. The structure of population of *L. alata* was irregular with classes of diameter 01: [20-30 cm], 03:] 40-50cm], 04:] 50-60cm], 06:] 70-80cm] and 10:] 110-120cm] more abundant with respectively 5, 4, 3, 3 and 3 individuals.

Comparison of the specific floral composition, diversity and structural parameters of the studied sites

The analysis of the five most abundant species in the three studied sites revealed that four species (*D. glaucescens*, *P. Africana, P. angolensis*, *S rhinopetala*) are common on site 1 and site 2. *F. elastica* present on the site 1 was replaced by *B. welwitschii* on the site 2. This last species was the only one present both in site 2 and site 3. In contrast, none of these species was common to site 1 and site 3. The results of the diversity index and structural parameters of all the species per studied site as well as the commercial species found per site are presented in Table 3. As it can be seen, the highest H'_{max} values when we considered all the species or only commercial species were found in site 1. The lowest H'_{max} value was found in site 3 (5.615). The same observations were made for the total basal area when we considered all the species or only commercial ones.

Table 3. Structural parameters and diversity index of all and commercial species in sites

Parameters	All species			Commercial species		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Surface (ha)	88	27	8	88	27	8
Number of individuals	13 238	4 114	1 013	1457	438	74
Shannon - Weaver (H')	6.583	6.728	6.527	4.129	4.094	4.240
Number of species (S)	265	233	167	49	39	26
H_{1max}	8.050	7.864	7.384	5.615	5.285	4.700
evenness (R)	0,818	0,855	0,884	0.735	0,775	0,902
Total basal area(E)	26	25.89	17	10.27	9.46	5.64
Density (individuals/ha)	150.43	152.37	126.63	16.56	16.22	9.25

Variability of the specific composition between various sites

Student t-test revealed a significant difference between individuals of commercial species found in sites 1 and 3 ($p < 0.001$), sites 2 and 3 ($p < 0.05$). The plots of site 3 had specific composition which went away from those of the sites 1 and 2 (Fig. 5). Analysis made on the presence and the absence of the species showed that the site 1was closer to the site 2 with Sorensen index equal to 0.80. The Sorensen index between sites 1 and 3, sites 2 and 3 were 0.61 and 0.71 respectively.

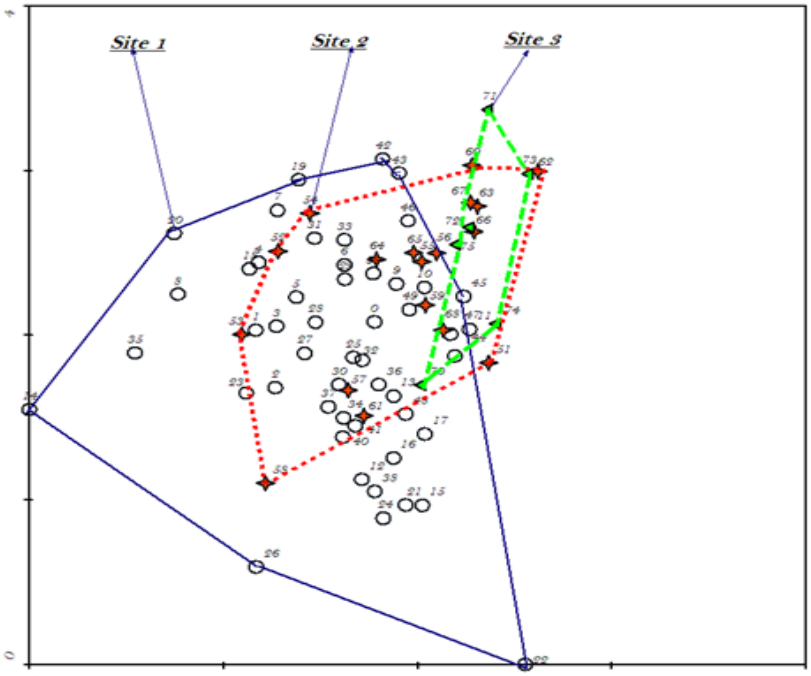

Fig. 5. Detrente Correspondence Analysis (DCA) made with Canoco on commercial species

The small diameters (Class 04, 05 and 06) were very represented on sites 1, 2 and 3. They represented 51, 54 and 56 % respectively of the total staff. Regarding diameter of commercial species, class 05 was the most representative in sites 1 and 2. In site 3, Class 06 was the most represented.

L. alata which is an important commercial species had a presence index of 0.007 in site 1. In site 1, its dominant classes were class 01, 02, 03, 5 and 10 with 21, 16, 11, 8 and 4 individuals respectively. In site 2, the presence index of *L. alata* was 0.0013. Its dominant classes were class 01, 03, 05, 07 and 10 with 4, 5, 2, 2 and 3 individuals respectively. In site 3, dominant classes of *L. alata* were class 01, 03, 04, 06 and 10 with 5, 4, 3, 3 and 3 individuals respectively. Its presence index was 0.094.

DISCUSSION

Different indices have been used to describe species richness and their relative abundance; the number of species and the number of individuals per species, respectively [21]. In the present study, we used the Shannon-Weaver diversity index (H') which is widely used as a measure of species mixture of forests [22, 23] to determine the structural diversity of one stratum in three sites of Yingui´s forest management unit (Cameroon-Central Africa). Our results showed that the Shannon´s diversity index (H') was 6.58 for the site 1, 6.73 for the site 2 and 6.53 for the site 3 when all species were taken into account. These values were higher than those found by Dibong et *al.* [24] in forests situated between the plain and the southern-Cameroonian plateau (4.54 – 5.68); Sunderland et *al.* [25] in the reserve of Takamanda (4.61) and of Ejagham (3.69); Tchouto [18] in the forest of Campo-Ma'an (5.33); Ssegawa and Nkuutu [26] in forests of Uganda (4.67); Wu et *al.* [4] in a primary forest in Japan (5.04); Priso et *al.* [17] in bois des singes (4.31) and in Bangué (4.68); Mullet and Truong [27] in a forest logged since ten year in Vietnam (6.02). This can be explained by the fact that the number of species was high (265 on the site 1; 233 on the site 2 and 167 on the site 3) and was not subjected to strong anthropic disturbances. Furthermore, on this total of species, 85 species had less than 5 individuals on 3 sites. 47 % of the total number of individuals taken on three sites was represented by 20 species and the five most represented species were *D glaucescens*, *F. elastica*, *P. africana*, *P. angolensis* and *S. rhinopetala* accounting for 19 %.

De Fries et al. [28], Priso et al. [29] reported that forest degradation is accentuated where urbanization grew quickly and where the commerce of agricultural products per inhabitant is high. Contrary to our expectation, we did not observe such correlation in Yingui´s forest management. We suspect that it might be linked to the fact that the studied sites had species in their early stages of succession and subjected to very low anthropic disturbances. The Sorensen coefficient indicated a strong similarity between the site 1 and site 2 (0.8). However, no significant difference was detected between the two sites as analyzed by Student t-test ($p > 0.05$). The similarity between these two sites can be explained by their precipitation. The annual rainfall is more than 2000 mm in these sites with only 3 months of dry season. According to Gentry [30], high rainfall areas in the lowlands throughout the world are the areas with the highest biodiversity. In the same line, Leal [31] indicates that, the length of the dry season is an important factor in species composition and associated characteristics like diversity. The site 3 tended to go away from the others. One explanation to that could be the distribution of the rainfall which is lower towards the site 3 and by the height which is more raised. Munishi et *al.* [32] and Hua [33] suggested that the topography has more influence on the rain forest than the regional climate.
The Yingui´s forest management unit showed many trees with small diameters, as well as species in course of reconstitution, with 50% of commercial individuals ($50 \leq DBH \leq 79$ cm).
The commercial diameter of *L. alata*, one of the most exploited species in Cameroon was 60 cm.

CONCLUSION

The biodiversity showed that 85 species had each less than 5 individuals and 152 species had each less than 20 individuals in different sites. The Yingui´s forest management unit had mature trees, but species with small diameters remained abundant with permanent regeneration (trees of the future).The Shannon-Weaver diversity index on the three studied sites was similar (H'= 6.58 for site 1, H'= 6.73 for site 2, H'= 6.53 for site 3). *Diospyros crassiflora* Hiern was seen as an endangered species. Gurarni et *al*. [34] showed that 25% of all species could become extinct during the next 20-30 years. The fragmentation of FMU in many sites must depend of the topography, the nearest climate and the hydrology. As seen with Sorensen index, these sites are belonging to the same community; nevertheless, site 2 seems to be a transition zone between sites 1 and site 3. Despite the exploitation of *L. alata* and distribution of annual forest rental fee between the state (50%), communes at the vicinity of the forest (20%), other communes (20%), villagers living along the forest (10%) (Cerruti et al. [10]; Dkamela [11]), attention had to be taken for conservation of these rich species ecosystems.

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