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Research article

COMPARISON OF THE DISTRIBUTION AND STRUCTURAL PARAMETERS OF FIVE CHARACTERISTIC SPECIES FROM CAMEROON COASTAL ECOSYSTEMS : DOUALA AND KRIBI

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ABSTRACT : This study aimed at determining the diversity of 5 non-timber forest products (NTFPs) and their structural parameters in the Douala and Kribi forests ecosytems. All individuals of Diameter at breast height (dbh) ≥ 5 cm were censured and their diameters measured. The coefficients of abundance-dominance were also determined. In Kribi, specie diversity H'_1 was 3.34 with H'_1max = 3.89, evenness R_1= 0.85. For herbaceous and woody species, H'_2 = 3.73 with H'_2max = 4.07; the evenness R_2 = 0.91. In Douala, H'_1 = 2.33 with H'_1max = 3.89, evenness R1= 0.59. For woody and herbaceous, H'_2 = 2.90 with H'_2max = 3.25; the evenness R2 = 0.89. For the diversity of both cities, there was no significant difference (P = 0.59, df = 2). In Kribi, the number of individuals of *Baillonella toxisperma* was 2; *Coula edulis*, 32; *Irvingia gabonensis*, 10; *Ricinodendron heudelotii* , 8 and *Scorodophleus zenkeri*, 14 while in Douala, number of individuals of: *B. toxisperma* was 1*; C. edulis*, 12; *I. gabonensis*, 7; *R. heudelotii* , 7 and *S. zenkeri*, 0. There was no significant difference in the distribution of species in the study areas (Kribi: df = 8, P = 0.59 > 0.05; Douala: df = 6, P = 0.127 > 0, 05). The diversity of the study areas was fairly high despite the low number of species. The determination of structural parameters showed a vegetation with virtual absence of individuals of very small diameter.

Keywords: Cameroon, density, diversity, forest, NTFPs.

INTRODUCTION

Intense anthropogenic activities and climate change have long been considered as significant drivers of dynamics and diversity [1, 2, 3, 4, 5] through loss of biodiversity and consequently species extinction. In fact, tropical rainforests support the majority of global biodiversity and contain large numbers of endemic species, and so understanding the impacts of forest fragmentation in these areas is crucial to the conservation of biodiversity. It has been suggested that approximately 2.300 km^2 that represent 0.5 to 0.6 % of tropical forests from Central Africa disappears in an annual rhythm [5]. As well as being renowned for their biodiversity, tropical forests provide multiple local, regional and global ecosystem services [6,7,8]. For instance, at the global scale, they contribute to climate regulation, whereas at the regional scale, they provide water storage capacity and at the local scale they can support pest regulation, pollination, seed dispersal and soil fertility.

The towns of Cameroon in general and those of Douala and Kribi in particular are cities of concern by the national leaders in the management of their ecosystems because of important exchanges that they shelter. This is mainly attributed to the presence of seaports in those towns that increase the influx of people to urban zones. The overpopulation of Douala and Kribi involves important pressures on the availability of certain forest products and thus the reduction in the quantity available in forest. Indeed, for survival needs, non-timber forest products (NTFP) such as medicinal plants, spices, cosmetics etc are permanently used for different purposes and also for traditional healing [6]. The forests of these towns contains some characteristic species such as *Lophira alata* Banks, *Baillonella toxisperma* Pierre, *Ricinodendron heudelotii* (Bail) Pierre ex Pax, Coula edulis Baill, *Irvingia gabonensis* (Aubry-Lecompte ex O' Rorke) Baill, *Scorodophleus zenkeri* Harms**.**

These species have high economic values and constitute a source of income for the local population since they are commercially available on local, national and international markets [7, 8, 9, 10]. Considering that loss of biodiversity as a result of human activities can have negative impact on the functioning and stability of ecosystems and that it can lead to the extinction of some characteristics species, the objective of this study was to determine the diversity of *B. toxisperma*, *C. edulis*, *I. gabonensis*, *R. heudelotii*, *S. zenkeri* and their structural parameters in Douala and Kribi ecosystem´s for a better conservation of their biodiversity.

MATERIAL AND METHODS

Study sites

The sites were located in PK21, Ngompè (PK25) and Tondè (PK31) in the North-eastern part of Douala town, on the old heavy center line of Douala-Yaounde highway and extend respectively on 04°10' NR; 04°11' NR and 04°12' NR of latitude and 09°50' E; 09°51' E and 09°53' E of longitude. The climate is of equatorial type, Cameroonian wet coastal maritime field with a long rainy season (March-November) and a short dry season (December-February). Annual rainfall is abundant and can reach approximately 3615 mm. Monthly relative moisture constantly remains high and is around 80%.

In the region of Kribi, the selected sites were Pama, Fifinda1 and Bipaga1 located at 45 km, 35 km and 25 km of the town of Kribi respectively. The respective geographical coordinates of the sites were 10°04' NR, 10°03' NR and 10°01' NR of latitude and 03°16' E, 03°13' E and 03°08' E of longitude. The climate is hot and wet, of Cameroonian equatorial type with two seasons; a rainy season (from March to November) and a dry season (from December to February), with an average temperature of 25°C. Annual rainfall is approximately 2970 mm and the relative humidity is almost with saturation (superior with 90%) throughout the year.

Data collection

4 plots of 2500 m^2 (250m x 10m) each were taken in each of the regions to give a total of 12 plots per study area (Douala and Kribi). Woody species of diameter at breast height (DBH) ≥ 5 cm were counted and measured using a diameter tape. In addition, Braun-Blanquet coefficients of abundance-dominance were established for each species (woody and/or herbaceous) in each plot.

A scale with six indices was carried out for the distribution of the individuals of a species in the following ways

+: simple presence, individuals very scarce, mean cover (M.C.) =0.5%;

1: individuals scarce covering less than 1/20 of the surface, M.C. = 3%;
2: individuals abundant and covering 1/20 to 1/4 of the surface area, M.C. = 15%;
3: individuals recovering 1/4 to 1/2 of the surface, M.C. = 37.5%;
4: individuals recovering 1/2 to 3/4 of the surface, M.C. = 62.5%;
5: individuals recovering more than 3/4 of the surface, M.C. = 87.5%.

Woody or erect plants were counted and a presence index was attributed (P_i). While taking into account tree and herbs, for each species i, we have M.C.i (mean cover) and for all species we have T.M.C. (total mean cover), therefore P_i, the presence index for species i will be equal to

$M.C._i$ /T.M.C.

Shannon-Weaver ($H' = - \sum P_i \times \ln P_i$),

Simpson ($D = \sum Ni (Ni-1) / N (N-1)$ or $D = \sum P_i^2$),

Ni represent the number of species i and N the total number of all the species.

Pielou and Sheldon indexes were then calculated to appreciate vegetation status.

Pielou index ($E_1=H'/H'_{max}$; $H_{max} = \ln S$) close to 1 means that all species have the same recovery.

Sheldon index was calculated as follow

$E_2 = \exp(H')/S$ where S is the total number of species.

To appreciate the diversity, we considered H'_1 which used the coefficients of abundance-dominance (herbaceous and the ligneous species) and H'_2 which consider only woody erected individuals. On the other hand, to evaluate the richness and specific dominance, the index of dominance "d" of Berger and Parker was calculated using this formula:

d = Nmax/N where Nmax is the maximum abundance and N total abundance-dominance.

When d tended towards 0, there was a great diversity and a null dominance. On the other hand, when it tended towards 1, there was dominant species and a low diversity. The number of dominant species was calculated using the index of Hill ($N_1 = \exp H'$).

The absolute frequency of a species is the number of plots in which a given species is observed. The relative frequency can also be used, which corresponds to the ratio of the absolute frequency to the full number x 100.

Structural parameters

Structural parameters such as density, relative dominance and basal area were evaluated. The density of a species is the number of individuals per hectare. Total Basal area was determined as follow:

TBA= $\pi\ dm^2/4 \times N$ (N being the number of individuals per hectare of the species i or its density and dm is the arithmetic diameter mean of all the individuals of the species i). Relative dominance was the ratio of surface occupied by a tree over the entire surface of the settlement, expressed as a percentage. It was defined as being the sum of surfaces of the sections of all the measured calculated according to the formula: $S = \sum \pi\ Di^2/4$; where Di was the diameter of the DBH tree measured at 1.30 m of the ground. The variance of each index of diversity was given according to the procedure described by Zar [11]. The indices of diversity were compared using a 2 x 2 student t-test and the software used was Statxact - 3 versions 3.1. To compare the indices of the sites of each city, nonparametric tests were used like Kruskall-Wallis and the exact test of Fisher-Freedman-Haltm. The test of Fisher-Freedman-Haltm was used to see whether there was a significant difference in the distribution of the important NTFP in various sites and also to compare the distribution in their diameters.

RESULTS

In the region of Douala, 84 individuals belonging to 14 families, 17 genera and 17 species were sampled. The most represented family was *Euphorbiaceae*. The greatest number of individuals found were *M. cecropioides* (22), *C. edulis* (12) and *F. heitzii* (11). The number of individuals per study site varied from 18 to 36 and the distribution of the species from 7 to 14.

The Shannon-weaver diversity index varied from 1.74 to 2.45 per site. While considering all the species, in the region of Douala H'_1(only woody or erected species) = 2.33 with H'_1 max = 3.89. The equitability R_1 = 0.59 and the Sheldon index = 0.21. The absolute density in the various sites varies between 18 and 36 individuals per hectare. The average density observed in the three sites is of 28.00 ± 9.16 (Table 1).

Table I. Diversity and parameter of stucture at PK21, Ngompe and Tonde in the region of Douala.

	S	N	H'_1	H'_1 max	R_1	E1	RM	H'_2	H'_2 max	R_2	E2	Density	TBA
PK21	9	18	1.87	2.19	0.85	0.72	2.5	2.48	2.63	0.94	0.005	18	9.95
Ngompe	7	30	1.74	1.94	0.89	0.81	3	2.28	2.39	0.95	0.009	30	9.54
Tonde	14	36	2.45	2.63	0.93	0.83	3.87	2.84	2.39	0.96	0.003	36	11.75
Douala1	17	84	2.33	2.83	0.60	0.21						28.00 ± 9.16	10.59
Douala2	26						3.17	2.90	3.26	0.89	0.002		

S: number of species; N: number of individuals; H': Shannon-weaver diversity index. Density: number of individuals /ha; R: equitability; E: Sheldon index; TBA: Total basal area; RM: main recovery; NI: number of' individuals.

[1]: Woody or erected species

[2]: Woody or erected species and herbaceous species

The diameter of the studied species varied from 38 cm (*Anthocleista vogelii* Planch.) to 108 cm (*B. toxisperma*). Total basal area calculated for Douala region was 10.51 m^2/ha. The basal area obtained per species was 2.21 m^2/ha (*M. cecropioides*) 2.11 m^2/ha (C. edulis) and 1.75 m^2/ha (*F. heitzii* Aubrev. & Pellegr.).

For herbaceous and woody plants, the greatest main covering of the species was found with *C. edulis* (0.333), *Elaeis guineensis* Jacq. (0.333), *I. gabonensis* (0.208), *L. alata* (0.208), *Maranthochloa purpurea* (0.250) and *M. cecropioides* (0.458); and the diversity index was H'_2 = 2.90 with H' max = 3.25; R_2 = 0.89 and E_2 = 0.002 (Table 2).

With regard to the five NTFP chosen, it appears that they were unequally distributed in the three sites. Results showed that *S. zenkeri* was absent in all the plots and *B. toxisperma* was also absent in Ngompe and Tonde. The relative frequencies of *R. heudelotii*, *C.edulis*, *I.gabonensis*, *S. zenkeri* and *B. toxisperma* were 8.43%, 14.45%, 8.43%, 0% and 1.19% and their dominance 8.46%, 21.04%, 6.23%, 0% and 7.29% respectively.

Table II. Diversity and parameter of stucture at Pama, Fifinda 1and Bipaga 1 in the region of Kribi.

	S	N	H'_1	H'_1 max	R_1	E_1	RM	H'_2	H'_2 max	R_2	E2	Density	TBA
Pama	21	83	2.40	3.04	0.79	0.52	11.5	3.08	3.38	0.91	0.74	83	23.10
Fifinda 1	26	57	3.07	3.25	0.94	0.83	13.0	3.46	3.68	0.93	0.79	57	22.68
Bipaga 1	32	69	3.35	3.46	0.96	0.88	12.4	3.6	3.76	0.95	0.85	69	28.82
Kribi1	49	20	3.34	3.89	0.86	0.57						69.66 ± 13.01	23.42
Kribi2	59						12.5	3.74	4.07	0.91	0.71		

S: number of species; N: number of individuals; H': Shannon-weaver diversity index. Density : number of individuals /ha ; R : equitability; E : Sheldon index; TBA : Total basal area; RM: main recovery; NI: number of' individuals.

[1]: Woody or erected species

[2]: Woody or erected species and herbaceous species

On the other hand, the vegetation in the region of Kribi showed some herbaceous species such as *Marantochloa purpurea* (Ride) Milne-Redh., *Costus afer* Ker Gawl, *Aframomum* sp., *Megaphrynium macrostachyum* (K. Schum.) Milne-Redh. A total of 209 individuals found in 39 families, 42 genera and 45 species were recorded in the 3 study sites. The most represented families were *Annonaceae*, *Mimosaceae* and *Euphorbiaceae*. The greatest number of individuals were found in *C. edulis* (33), *F. heitzii* (18), *S. zenkeri* (14) and *I. gabonensis* (10).

The Shannon-weaver diversity index H'_1 was $H'_1 = 3.34$ with $H'_1max = 3.89$. It varied from 2.20 (Pama) to 3.35 (Bipaga 1). The equitability for the Kribi area was $R_1 = 0.86$ and the Sheldon index was 0.57. The absolute density of the woody species (dbh ≥ 5 cm) per site varied between 57 and 83 individuals per hectare (Table II).

The largest diameters were found in *Canarium schweinfurthii* Engl. (122 cm), *L alata* (110 cm), *Erythrophleum suaveolens* (Guil. &Perr.) Brenan (106 cm), *M. cecropioides* R. Br.exTedlie (104 cm) and *Sacoglottis gabonensis* (Baill.) Urban (77 cm). The diameters within the sites varied from 28 cm to 122 cm.

Total basal area in kribi was 23.42 m^2/ha. However, the highest basal area was found in *Enantia chlorantha* Oliv. (1.13 m^2/ha) and *F. heitzii* (2.84 m^2/ha).

Taking into account the herbaceous and woody species, the greatest main covering based on the abundance-dominance of the species was found in *C. edulis* (0.75), *F. heitzii* (1.00) and *Marantochloa purpurea* (0.833). In the region of Kribi, the Shannon-Weaver diversity index was $H'_2 = 3.74$, H'_2 max = 4.07 while equitability was $R_2 = 0.91$.

S. zenkeri was absent at Bipaga 1 and *B. toxisperma* at Fifinda 1 and Bipaga 1. In Kribi, *R. heudelotii*, *C.edulis*, *I. gabonensis*, *S. zenkeri* and *B. toxisperma* presented a frequency of 3.82%, 15.31%, 4.78%, 6.69%, 0.01% and a dominance of 2.71%, 16.96%, 3.39%, 2%, and 1.19% respectively.

The distribution in classes of diameter of all the species of the site showed that the class of diameter V (41 - 50) was the most represented in Kribi with 45 individuals per hectare. Whereas, in Douala, the classes IV (31-40) and IX (91-100) were the most represented with 14 individuals per hectare (Fig. 1, 2 and 3).

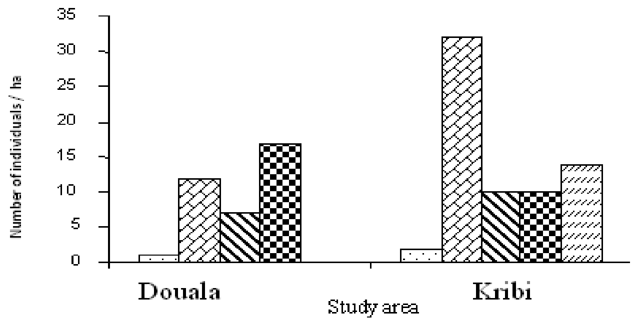

Fig.1. Distribution of the NTFP in the two zones

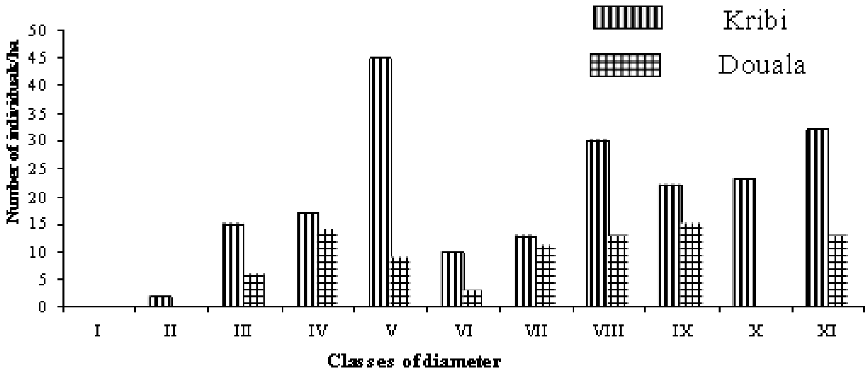

Fig. 2.Distribution of all the species by classes of diameter.

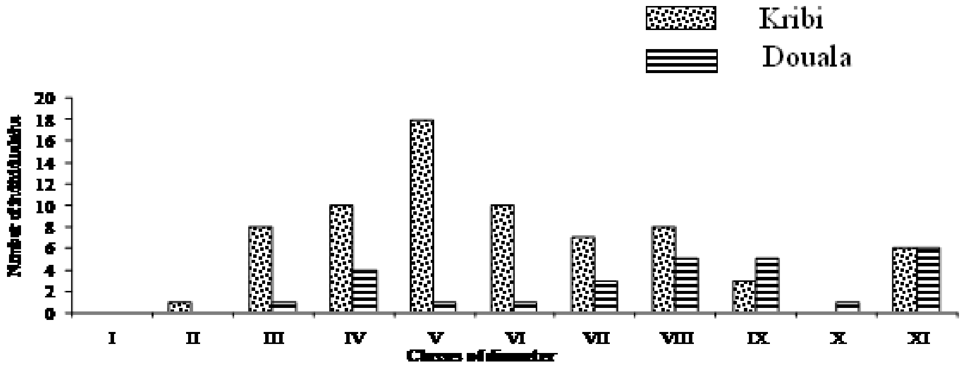

Fig. 3. Distribution of the NTFP chosen by classes of diameter.

Based on the five studied NTFPs species, class V (41 -50 cm) was prevalent in Kribi with 18 individuals per hectare, whereas class VIII (71-80 cm) was dominant in Douala with 8 individuals per hectare. Concerning the classes of diameter of the various sites of study, in Kribi, VIII (71 - 80) was the most represented, particularly in Bipaga 1 and Fifinda 1. However, this class was absent in Pama. But, class X (91-100) was represented in all the three sites (Fig.4). On the other hand, all the sites of Douala have class VIII (71 -80) and the highest class (> 100) was noted in PK21 (Fig.5).

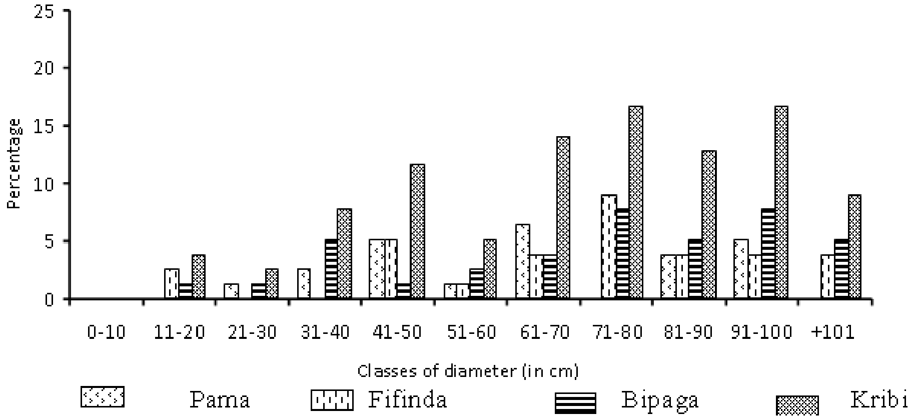

Fig. 4. Distribution of all the species by classes of diameter in the region of Kribi

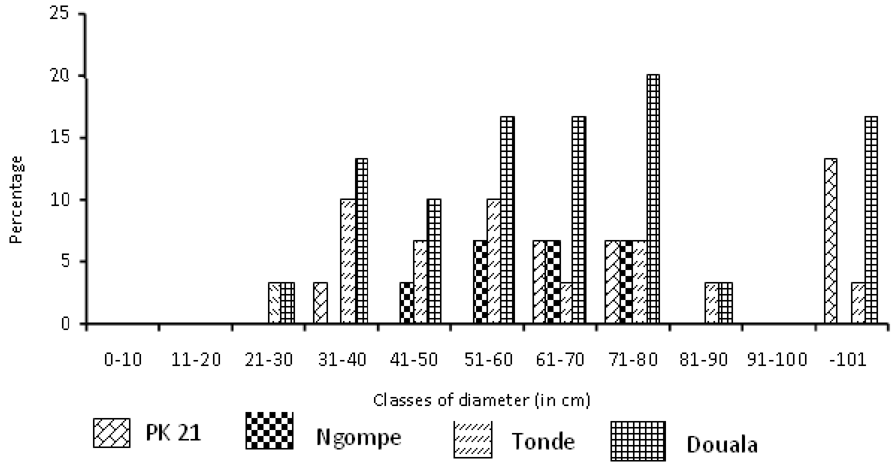

Fig. 5. Distribution of all the species by classes of diameter in the region of Douala

DISCUSSION

The present study reveals that Shannon weaver diversity indices when considering woody species and/or woody species + herbaceous was high in Kribi region (H'_1= 3.34; H'_2 = 3.74) in comparison to Douala region (H'_1= 2.33; H'_2 =2.90). However, there was no significant difference in the diversity indices when comparing Kribi (trees) and Kribi (trees + herbaceous) or Douala (trees) and Douala (trees + herbaceous). Nevertheless, the least index was found in Douala while considering only trees or erect species (H'_1= 2.33). This can be explain by anthropogenic pressure exerted on the ecosystems of this region in the form of fuel wood consumption, agricultural purposes, use of forest land [5].

Herbaceous plants influenced not only the maximum values of the diversity, but also the values of diversity indices. High indices of diversity ranging from 4.54 to 5.68 have also been found in the forests located between the plain and the southern Cameroonian plate forests [12]. Similarly, values of 4.61, 4.31, and 4.68 were seen in the reserves of Takamanda, "bois de singes", and in the forest of Bangue [5, 13] respectively.

Results from the two study sites showed that certain species were represented with (1 or 2 individuals): *Anthocleista vogelii* Planch., *Barteria fistulosa* Mast., *Canarium schweinfurthii* Engl., *Garcinia kola* Haeckel, *Ongokea gore* (Hua) Pierre, *Pentaclethra eetveldeana* Wild. & T. Durand., *Tetrapleura tetraptera* (Thonn.) Taub. The equitability was 0.86 in Kribi and 0.60 in Douala. These values are in corroboration with Odum [14] who reported that ecosystems which reached a level of maturity and that were not subjected to disturbing constraints have an optimal equitability of about 0.6 to 0.8. Moreover, the high values for the equitability shows the richness of the vegetation even if species diversity was low (Kribi: 49 and Douala: 17). Furthermore, Sheldon index also showed a low number of species and a great floristic richness.

Density varied within the sites. Results for the total basal area varied in the two zones. Results obtained in Kribi were of 23.42 m^2 /ha (Pama: 23.10 m^2 /ha; Fifinda 1: 22.68 m^2 /ha; Bipaga 1: 28.82 m^2 /ha) and 10.51 m^2 /ha in Douala (PK21: 9,95 m^2 /ha; PK25: 9.54 m^2 /ha; Tonde: 11.75 m^2 /ha). This can be explained by the absence or moderated exploitation in the forests of Kribi. Total basal area values of 25.7 m^2 /ha were seen in Bangue and 67.6 m^2 /ha in the forest reserve of "Bois des Singes" [5]. Similarly, values of 18.6 to 42.1 m^2 /ha were seen in Eseka – Matomb forest [12]. Lower values for total basal area have been found in the mangroves of Cameroun [15]. The high values of total basal area in Kribi could be due to the high density of certain species such as *C. edulis*, *F. heitzii*, *I. gabonensis* and *S. zenkeri* and the presence of many individuals of classes IV, V, VI, VII, VIII and XI. Indeed, the index of Hill calculated in Kribi was approximately 18 abundant species and 8 in Douala.

The analysis of the distribution of the diameters in Kribi showed that no individual (0%) was found in class I (0-10 cm), 2 (0.95%) in class II (21-30 cm), 15 (7.17%) in class III (31-40 cm), 17 (8.13%) in class IV (41-50 cm), 45 (21.53%) in the class V (51-60 cm), 10 (4.78%) in class VI (61-70 cm), 13 (6.22%) in class VII (71-80 cm), 30 (14.35%) in class VIII (81-90 cm), 22 (10.52%) in the class IX, 23 (11%) in class X, 32 (15.31%) in class XI. The distribution of the number of individuals per class of diameter showed that the species with low values of diameter were less represented. Thus, the forest was characterized by a majority of the mature trees.

Similar to that observed in Kribi, the distribution of the diameter in Douala showed that no individual (0%) was seen in classes I (0-10 cm), II and X; 6 (7.14%) in class III (31-40 cm); 14 (16.66%) in class IV (41-50 cm); 9 (10.71%) in the class V (51-60 cm); 3 (3.57%) in class VI (61-70 cm); 11 (13.09%) in class VII (71-80 cm); 13 (15.47%) in class VIII (81-90 cm); 15 (17.85%) in class IX; 13 (15.47%) in class XI. Analysis of the distribution of the diameters in the two forests by the test of chi two showed no significant difference (P = 0.126 > 0.05).
The absence of S. *zenkeri* in Bipaga 1, *B. toxisperma* in Fifinda 1 and Bipaga 1 can be due to the fact that the orientation of the plots was done randomly. However, *B. toxisperma* seems to be a rare species because it needs much light to grow [16]. Moreover, this species is exploited by the households which consume its oil, and by the forest companies for its wood. Similarly, in the region of Douala, there was a complete absence of *S. zenkeri* in all the plots and *B. toxisperma* was absent in Ngompe and Tonde. The analysis of the distribution of the number of individuals in the plots of the two regions by the exact test of Pearson showed no significant difference (P = 0.59 > 0.05 for Kribi and P = 0.12 for Douala > 0.05).
Similarly, when analyzing the five species using a 2 x 2 Chi square test of Pearson, we observed that *R. heudelotii* and *C. edulis* were significantly different in the two regions (χ2 =10.18; dl = 2; P=0.0039) and (χ2 =14.39; dl = 2; P=0.0008) respectively . But, *I. gabonensis* was not significantly different in the two regions (χ2 =0,176; dl = 2; P = 1).
Basal area values of *B. toxisperma*, *C. edulis*, *I. gabonensis*, *R. heudelotii* and *S. zenkeri* were variable in the two regions. Values obtained were 0.29; 0.44; 0.73; 0.83 and 0.40 m^2 /ha in Kribi and 0.31; 2.11; 0.57; 0.92; 0 m^2 /ha in Douala respectively. These reduced values may be due to the fact that the density was low for some species such as *B. toxisperma*. Because of the presence of variable diameters in different plots, the distribution of the classes of diameter in each region by the test of Fisher-Freedman-Haltm was not significantly different (Kribi: P = 0.163; Douala: P = 0.352).

CONCLUSION
Based on the results obtained from the study, it can be concluded that herbaceous species did not modify significantly the value of the diversity indexes. The determination of the structural parameters showed vegetation with an absence of some species and individuals with very small diameters. It was also found that the forests of the Douala region are under risk mainly due to unsustainable exploitation of their natural resources; thus, much attention should be undertaken at National level for regeneration and conservation of these ecosystems.

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