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Woody flora and dynamic of *Aucoumea klaineana* forest in the Congolese littoral

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ABSTRACT

The floristic dynamics of the woody facies of the *Aucoumea klaineana* forest of the Congolese littoral has been done according to a gradient evolving of the pioneer front towards the interior of the ecosystem. This settlement integrates a dynamics going from the youthful stages towards the most stable of this formation. The objective of this study was focused on the dynamics of the woody formation, the monodominant installation of the *Aucoumea klaineana* facies with $d^{1.30} \geq 10$ cm and highlights the evolution and the correlation between the density, the basal area and the floristic diversity. The phytoecological parameters count 1186 trees of $d^{1.30} \geq 10$ cm (an average 395 arbres.ha^{-1}) for 71 species. The trees number by subplot oscillated between 70 and 159 trees (6 to 13% of listed trees). The species number by subplot varies from 8 to 28 (11 to 39% of inventoried species). Basal area by plot oscillates of 22 and 35 m^2.ha^{-1} (27 m^2.ha^{-1} an average). It varies from 4 to 10 m^2 per subplot (7 m^2 by ¼ ha an average). The trees number by subplot and diameter classes vary from 3 to 636 trees (1 to 212 trees.ha^{-1} an average). The trees of $10 < d^{1.30} \leq 20$ cm are dominating with 54% and this prevalence is regular in all the subplots. As for the indices of diversity, the Green index (GI) decrease from 0.9 to 0.1 as the ecosystem increases in age. This observation is also true for the skewness coefficient which regresses from pioneer front towards the interior of the forest. The values are respectively 2.10^{-2} in the first plot, 7.10^{-4} in the second and 4.10^{-3} for the third. In this inventory where *Aucoumea klaineana* is dominating, its density by subplot varies from 42 to 384 trees.ha^{-1} (183 trees.ha^{-1} an average). Just like the density, basal area is decreasing to pioneer front towards the interior of the forest. The values oscillate from 87 to 32% of basal area of the subplot (19 m^2.ha^{-1} an average). The report basal area by the density of *Aucoumea klaineana* is lower than 1 for an average of 0.1. The ecological parameters analysis which allowed seizing the floral dynamics of this forest is stressed by a numerical multivariate analysis (grouping and ordination). It highlights the weak resemblance degree between the twelve plots of the inventory and clearly marks the existence of variation characterizing the Congolese coastal forest, notably during the first stages of installation.
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Keywords: Congo, *Aucoumea klaineana*, biological diversity indices, Coastal forest, floristic diversity, phytoecological parameters.

INTRODUCTION

In central Africa, the Congo Basin represents a main forest where the interests of the conservation constitute a planetary challenge. Its development being spread out over several countries with the various concerns, the level of knowledge of its flora is only partial and to different degree according to the States. The floristic situation of this forest is more crucial on the level of Congo,

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where on an estimate from 6,000 to 8,000 species, hardly 4,500 were the object of a collection (Sita and Moutsamboté, 1988; Cusset, 1989; Lachenaud, 2011). Congo Republic, not having a long tradition of the inventory of the flora, has a floristic list, serving as catalogue of the plants of Congo. It is specially found on the phanerophytes and the pteridophytes (ferns). These results which are the reflection of a very partial investigation of the various ecosystems mark the low level of floristic inventory and knowledge on the operation of the main forests.

In Congo, works on the main forests were for a long time related to the development of the woody potential. So research on the floristic composition, the structure of the forest, the renewal and the operation of the forest ecosystems is recent (Makany, 1976; Fabing, 2001; Loumeto, 2002). By contrast to the Gabonese forest where *Aucoumea klaineana* only characterizes forest facies or in co-dominance with *Sacoglottis gabonensis* or even *Lophira alata* (Saint-Aubin, 1963), in the Congolese littoral forests located at the extreme south of the area distribution of this species, *Aucoumea klaineana* brand at least in the stages of its installation, of the facies where it is almost monodominant (Kimpouni et al., 2008a, 2008b). The forest with *Aucoumea klaineana*, like ecosystem and *Aucoumea klaineana* as a species, was the object of very thorough studies in Gabon, as it is showed by the works of Leroy-Deval (1973), Fuhr et al. (1998a, 1998b, 2001), Brunck et al. (1990), Fuhr (1999), Muloko-Ntoutoume et al. (2000), Muloko (2001). They are typical Atlantic element of the Nigero-Cameroono-Gabonese area (Saint-Aubin, 1963; UICN, 1996) and remain associated to the anthropic effects (Leroy-Deval, 1973; Fuhr et al., 1998; Brunck et al., 1990; Fuhr, 1999). This biology pioneer species which is in extreme cases southern of its distribution area in Congo, is in fact the object of several studies in the Gabonese forest (Muloko-Ntoutoume et al., 2000; Muloko, 2001). The *Aucoumea klaineana*, exploited in all its distribution area, is introduced in forest plantations in Gabon (Leroy-Deval, 1973; Brunck et al., 1990), and is a dioecious species (Grison, 1977, 1978). Currently, this species rises the questioning on the balance of the populations, (i) during the Holocene and (ii) on the dynamics and the organization of the genetic structure of the current populations (Koumba-Zaou et al., 1988; White et al., 2000; Muloko, 2001).

Aucoumea klaineana is distributed in Congo on the littoral (Kouilou) and in two main forests namely Mayombe and Chaillu (Loumeto, 2002). These entities correspond to three phytogeographical districts which in the absence of geographical barriers, are in continuity on the Gabonese territory (Kimpouni et al., 1992). The studies referring to the facies with *Aucoumea klaineana* are numerous and interest more Chaillu, via the station of Ngoua 2. However, data on the forest of the Congolese littoral, with them the facies with *Aucoumea klaineana*, are compartmental and meet various problems and aims (Makany, 1976; Cusset, 1989; Dowsett-Lemaire, 1991; Hecketsweiler and Mokoko-Ikonga, 1991; Doumenge, 1992; Fabing, 2001; Loumeto, 2002; Kimpouni et al., 2008a, 2008b). If all these studies treat floristic composition, very little of them approach the related aspects with the structure and the regeneration of the forests with *Aucoumea klaineana* (Hecketsweiler and Mokoko-Ikonga, 1991; Doumenge, 1992). As for the operation of these ecosystems, we underline work of Fabing (2001) and Loumeto (2002). Let us raise that most this work interest the old forest in *Aucoumea klaineana* and not youthful stages of its installation. This study is focused on the dynamics of the floristic change of the woody formation, of the installation at the mature stage. This work which is undertaken in a relatively young piece, integrates the floristic inventory of the individuals having a diameter at breast height ($d^{1.30}$) ≥ 10 cm to 1.30 m above ground level, the density and basal area. These various ecological parameters made it possible to show that this ecosystem pioneer, who is dominated at the beginning by *Aucoumea klaineana,* transforms into a unit where it is not any more the absolute reference.

This study had two main objectives: *(i)* to investigate the improvement of knowledge of the Congolese flora, in particular of the natural main forests containing *Aucoumea klaineana*; *(ii)* to better appreciate the importance of *Aucoumea klaineana* in the littoral forest dynamics.

Research hypotheses were *(i)* the forest facies dominated by *Aucoumea klaineana* over the Congolese littoral, is a transitional stage of the installation of the typical littoral forest as described by Cusset (1989); *(ii)* the Congolese littoral forest is not a typical facies of the "biafréenne" forest marked by a co-dominance of *Aucoumea klaineana* and *Saccoglottis gabonensis*; *(iii)* the density of *Aucoumea klaineana* decreases face pioneer towards the interior of the forest and it is compensated within the system by an important contribution in woody elements with growth slow and more adapted to the new ecological conditions of the station.

MATERIALS AND METHODS

Presentation of the study site

Youbi is localized (4°04'- 4°30' at the southern latitude and 11°30'- 12°00' of longitude East) is located at approximately 90 km north of Pointe-Noire town of (04°49' S, 11°47' E) shelters the studied forest (Figure 1). This ecosystem evolves under a climate type of equatorial of transition or subequatorial qualified by Aubréville (1949) from climate low-Congolese. It is marked by an annual average temperature of about 25 °C, with a low thermal amplitude (4-6 °C); a bimodal pluviometry of approximately 1200 mm/year on average, whose peaks are observed in March and November; one hot and wet season from October to May, with a deceleration of rainfall from January to February; one dry and fresh season from June to September (Vennetier, 1977; Samba-Kimbata, 1978).

The vegetation of the site is integrated in the forest sector of mosaic forest-savannas as defined by Hecketsweiler and Mokoko-Ikonga (1991). This formation corresponds to a unit of landscape pertaining to the coastal forest to Clusiaceae and Sapotaceae described by Cusset (1989). According to the data collected by Hecketsweiler (1990) and Doumenge (1992) on the littoral forest formations; the facies of Youbi refers to the relic forests. Its floristic characteristics are marked by the abundance of *Symphonia globulifera, Manilkara obovata, Piptadeniastrum africanum, Newtonia leucocarpa, Maranthes glabra, Chrysobalanus ellipticus, Syzygium guineense, Trichilia heudelotii* and *Trichoscypha acuminata*. According to the conclusions of the above mentioned studies, they would be secondary forests.

Materials

The irregular dispersion of certain species is, in general, insufficient to describe a perfectly standard forester. Thus, several floristic plots are carried out in the study area, in order to characterize this natural woody formation, in particular, the upper floor. During this inventory, the species identification was done *in situ* for most current and *ex situ* for the others. The confirmation of the identifications is made by comparison with the specimens of the IEC and the diagnoses of flora of Gabon, the Cameroon and the flora of the spermaphytes of Belgian Congo – Rwanda – Urundi. The taxonomic nomenclature used is in agreement with the APG III (Angiosperm Phylogeny

Group (2009) and Lebrun and Stork (1991-1997).

Experimental device

The experimental device describes in this present study has been developed by Kimpouni et al. (2008a, 2008b). With minor modification, it was constituted by 3 plots. Each plot had been subdivided into 4 subplots (Figure 2). The area of the subplot being of 0.25 ha, each plot covers an area average of 1 ha. The unit of inventory being the plot, four repetitions were made to cover subplots (4 x 0.25 ha = 1 ha). In total, the floristic inventory covers 12 subplot units. In adequacy with the aims of the study, the positioning of the plots of floristic inventory directed face pioneer (forest edge) towards the interior of the forest. Thus, the 1st plot which is made up of the subplots 1.1 and 1.4 is brought closer to edge; the 3rd plot, made up from the subplots 3.1 and 3.4, is further away from the edge; whereas 2nd plot (subplots 2.1 to 2.4) occupies an intermediate position between the two first plots. To avoid the edge effect likely to skew the data, the basic tailboard of the experimental device was placed nearly 12 meters inside the forest.

Inventory and measurement of $d^{1.30}$ of the trees

The floristic inventory of the woody was carried out in the plots of 25 X 100 m (either 0.25 ha). It interests all the individuals having a diameter ($d^{1.30}$) minimal of 10 cm at 1.30 m with the top of the ground (Dallmeier, 1992). The trees inventoried were arranged in 7 classes being declined diameter of ten centimetres. The other parameters appreciated within the forest type were the density, basal area and the report basal area by the density.

Statistical analysis

The data were analysed according to:

- the Jaccard coefficient of similarity gives same quotation to the presence and the absence. The formula of the Jaccard coefficient of similarity arises as follows: J (%) = 100 x (nc/(na+ nb - nc)) where na = the number of species of the plot has, nb = the number of species of the plot B and nc = the number of species common to both plots;
- multivariate analysis (grouping and ordination) carried out with the software "Statistical social package for the sciences (SPSS) version 13.0 for Windows". Ascending hierarchical classification and analysis in principal components. The grouping bases on the methods "even Average linkage or Unweighted group method with arithmetic mean (UPGMA) and nearest neighbour";
- the Green index (GI) is used to appreciate the distribution of taxa in *Aucoumea klaineana* forest (Jayaraman, 1999; Gouwakinnou et al., 2009). This index, varying from 0 to 1, authenticates an irregular distribution (randomly) or gregarious with taxa. $GI = [(\sigma^2/X) - 1] – 1/(N – 1)$; with σ^2 la variance of the density, X average density and N sample size;
- the skewness coefficient (Feeley et al., 2007) is used to evaluate trends intra-community within the structure of the trees system. This coefficient describes the regularity of the distribution of taxa (Condit et al., 1998; Feeley et al., 2007) and are defined as follows: $g = [N \sum (xi – X)^3]/[(N – 1) (N – 2) \sigma^3]$; with n the stems number of the species, xi and x are the diameter at breast height of the stems i and the mean of the $d^{1.30}$ of the sample, and σ the variation type. When G > 0, the distribution in class of diameter relatively shows a small proportion of small trees and much of large stems; on the contrary, when g < 0 distribution relatively indicates a small proportion of the trees of large diameter and much of trees of small diameter.

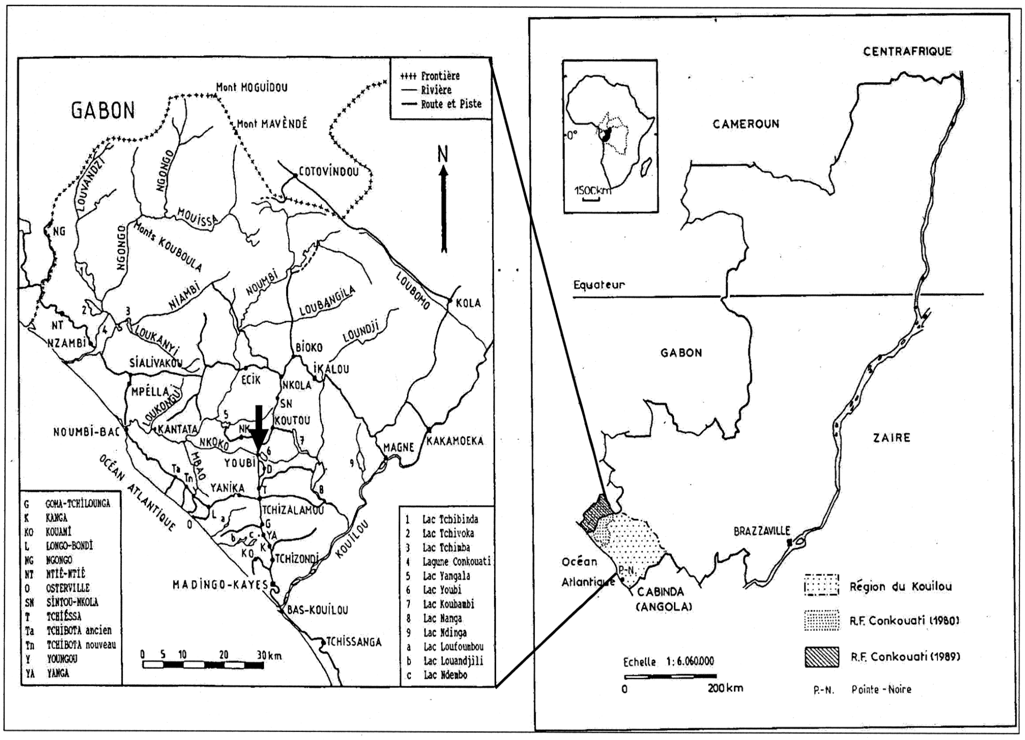

Figure 1: Localization of the study zone (according to Hecketsweiler et Mokoko Ikonga, 1991; Doumenge, 1992).

RESULTS

Composition and variation of floristic diversity

The taxonomic composition of the flora is consigned in Kimpouni et al. (2008a). Data were obtained from 1186 individuals of $d^{1.30} \geq 10$ cm (or 395.3 trees.ha^{-1}), and a specific diversity of 71 species. The trees number in plots is in an interval ranging between 70 and 159, is a variable rate from 5.9 to 13.4% of listed trees (Table 1). However, the number of species by subplot oscillates from 8 to 28, which accounts for 11.3 to 39.4% of inventoried species. The Green index of diversity (GI) decreases from the 1st plot, the most brought closer to the edge, towards the 3rd plot, most distant. The computed values are: 0.85 in the 1st plot; from 0.08 in the 2nd; and finally of 0.07 in the 3rd.

Comparison of basal area

Basal area reveals a satisfactory occupation of the area by woody, within this forest ecosystem. The studied forest facies has a basal area ranging between 22.4 and 34.8 m^2.ha^{-1} by plot, which is an average 27.2 m^2.ha^{-1} (Table 1). It varies from 4.1 to 9.9 m^{2}par ¼ ha within the units of inventory, with an average of 6.8 m^{2}par ¼ ha (Figure 3).

Diametric structure study of the woody

The trees number by diameter class of plots varies from 3 to 636, that is to say an average density ranging between 1 and 212 trees.ha^{-1} (Table 2). The specimens having a diameter equal or higher than 10 cm but lower than 20 cm are most numerous. With 53.6% of taxa with the inventory, they form the dominant class in front of the diameter classes

2 and 3. This prevalence is regular in all the subplots. The values of the skewness coefficient, between plots, regress from pioneer front towards the interior of the forest. They are respectively of 2.10^{-2} in the 1st plot; 7.10^{-4} in the 2nd and 4.10^{-3} in the 3rd.

Ecological data of *Aucoumea klaineana*

In this inventory where *Aucoumea klaineana* is dominating, its density in the plots varies from 12.1 to 73.9% for a general average of 183.3 trees.ha^{-1} (Table 3). Just like the density, basal area is decreasing face pioneer towards the interior of the forest. The values oscillate from 32.3 to 86.5% of basal area of the plot. As for the average, it is of 18.9 $m^2.ha^{-1}$. The report basal area by the density of *Aucoumea klaineana* is lower than 1 for an average of 0.14.

Diametric distribution and space occupation of *Aucoumea klaineana*

The distribution in diameter class of *Aucoumea klaineana* and basal area that is associated, follow the general tendency of the flora of the forest facies (Table 3 and Figure 4). Plot 1 is that which presents a number of classes of diameter more raised, as compared to both others. As one goes from the pioneer front towards the interior of the forest, the density of the small diameter stems decrease to the profit of the large trees (Figure 4). Basal area, strongly correlated with number stems follows the same trend.

Table 1: Outline of the floristic and ecological data of the woody formation.

Plots and subplots		Trees recorded		Species		Basal area (m^2)		
		numbers	%	numbers	%	0.25 ha^{-1}	%	ha^{-1}
1	1.1	134	11.30	9	12.68	6.79	0.27	27.16
	1.2	159	13.41	8	11.27	9.91	0.40	39.64
	1.3	125	10.54	9	12.68	9.10	0.36	36.40
	1.4	106	8.94	11	15.49	8.99	0.36	35.96
Average		131	11.05	9.25	13.03	8.70	0.35	34.79
Standard error		12.8	1.1	0.7	1.0	1.9	0.03	3.1
2	2.1	70	5.90	12	16.90	6.25	0.25	25.00
	2.2	79	6.66	18	25.35	6.70	0.27	26.80
	2.3	75	6.32	17	23.94	4.05	0.16	16.20
	2.4	92	7.76	17	23.94	7.42	0.30	29.68
Average		79	6.66	16	22.53	6.11	0.25	24.42
Standard error		5.5	0.5	1.6	2.2	0.9	0.04	3.4
3	3.1	82	6.91	24	33.80	6.11	0.24	24.44
	3.2	75	6.32	28	39.44	6.81	0.27	27.24
	3.3	94	7.93	27	38.03	4.51	0.18	18.04
	3.4	95	8.01	27	38.03	5.01	0.20	20.04
Average		86.5	7.45	26.5	37.33	5.61	0.22	22.44
Standard error		5.7	0.5	1.0	1.4	0.6	0.02	2.5

Table 2: Wood distribution by subplots in the diameter classes.

Diameter classes (cm)	**Subplots**												**Average per plot (trees.ha^{-1})**	**Standard error**
	1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**2.4**	**3.1**	**3.2**	**3.3**	**3.4**		
I (10-19)	70	79	63	44	33	48	46	55	41	30	63	64	212	11.1
II (20-29)	33	35	23	21	11	7	14	13	19	25	19	16	78.66	9.6
III (30-39)	20	21	14	15	3	4	5	7	7	11	3	5	38.33	7.9
IV (40-49)	7	14	13	12	12	6	6	2	9	3	3	6	31.00	0.9
V (50-59)	4	7	7	8	6	7	2	4	1	2	1	1	16.66	3.1
VI (60-69)	0	2	3	6	4	4	1	6	3	4	3	3	13.00	0.6
VII (70-79)	0	1	2	0	1	2	1	5	1	0	1	0	4.66	1.1
VIII (80-89)	0	0	0	0	0	1	0	0	1	0	1	0	1.00	0.3
Total trees	134	159	125	106	70	79	75	92	82	75	94	95	1186	7.9
Density/ plot	524				316				346				395.3	64.6

Table 3: Ecological data of *Aucoumea klaineana* in the inventory plot.

Plots	**Ecological parameters of *Aucoumea klaineana***				
	Density (trees.ha^{-1})		**Basal area (m^2.ha^{-1})**		**ST/D**
	Number	**%**	**ST**	**%**	
1	384	73.28	30.1	86.52	0.08
2	124	39.24	19.5	79.85	0.16
3	42	12.14	7.24	32.26	0.17
Means	183.33	41.55	18.95	66.21	0.14
Error standard	105.0	18.0	6.7	17.4	21.0

Table 4: Variance explained by the three factors of the diagram of components.

Components	**Initial eigenvalues**		
	Total	**% of the variance**	**% cumulated**
1	3.401	28.344	28.344
2	2.043	17.027	45.371
3	1.277	10.641	56.012

Method of extraction: principal components analysis.

Table 5: Stamp floristic affinity of subplots following the Jaccard coefficient of similarity.

1.1	1.000											
1.2	.417	1.000										
1.3	.286	.545	1.000									
1.4	.429	.462	.429	1.000								
2.1	.167	.176	.235	.278	1.000							
2.2	.174	.182	.227	.208	.200	1.000						
2.3	.182	.136	.238	.273	.208	.346	1.000					
2.4	.182	.316	.182	.333	.208	.129	.172	1.000				
3.1	.138	.143	.138	.129	.200	.200	.171	.242	1.000			
3 .2	.091	.129	.125	.226	.258	.184	.294	.375	.308	1.000		
3.3	.129	.172	.129	.233	.188	.222	.303	.265	.250	.559	1.000	
3.4	.029	.030	.029	.088	.086	.128	.303	.229	.250	.359	.486	1.000
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.4	3.4

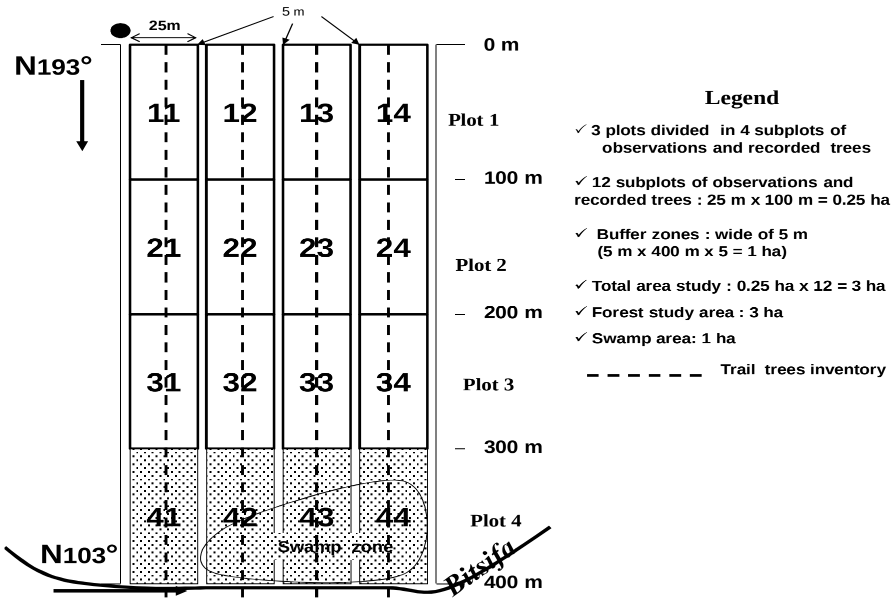

Figure 2: Experimental device of *Aucoumea klaineana* forest study (Kimpouni et al., 2008a).

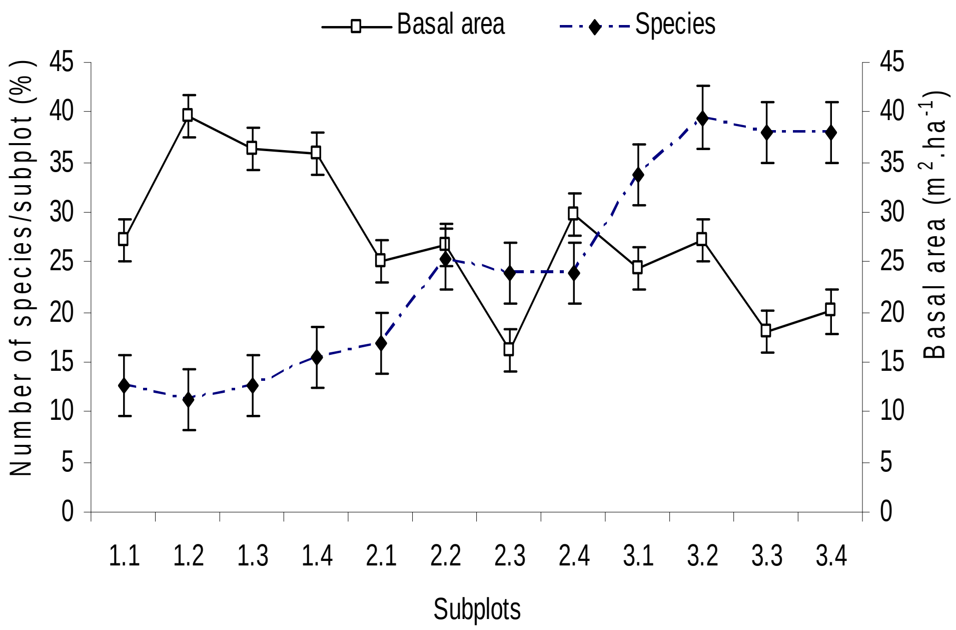

Figure 3: Evolution of basal area according to the number of the species in the subplots.

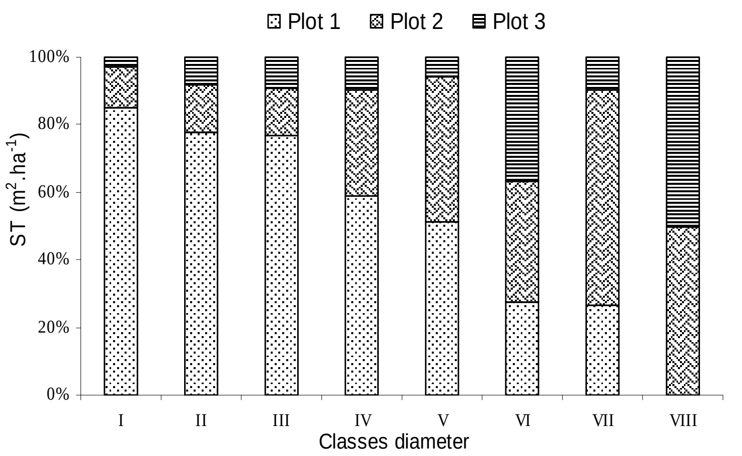

Figure 4: Space occupation of *Aucoumea klaineana* according to the classes of diameter.

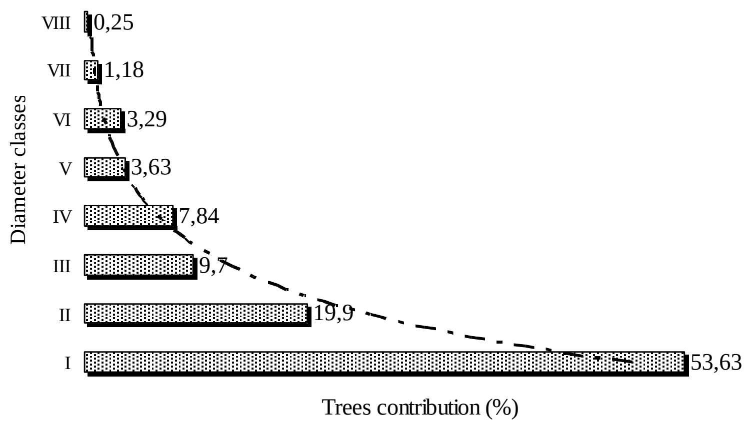

Figure 5: Comparison of the diametric structure of the woody.

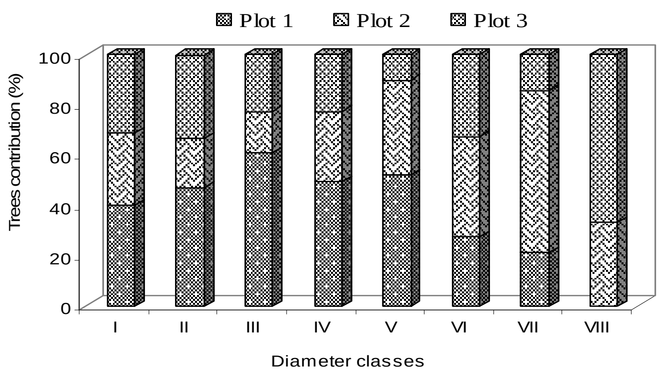

Figure 6: Distribution of the listed trees by diameter class and plot.

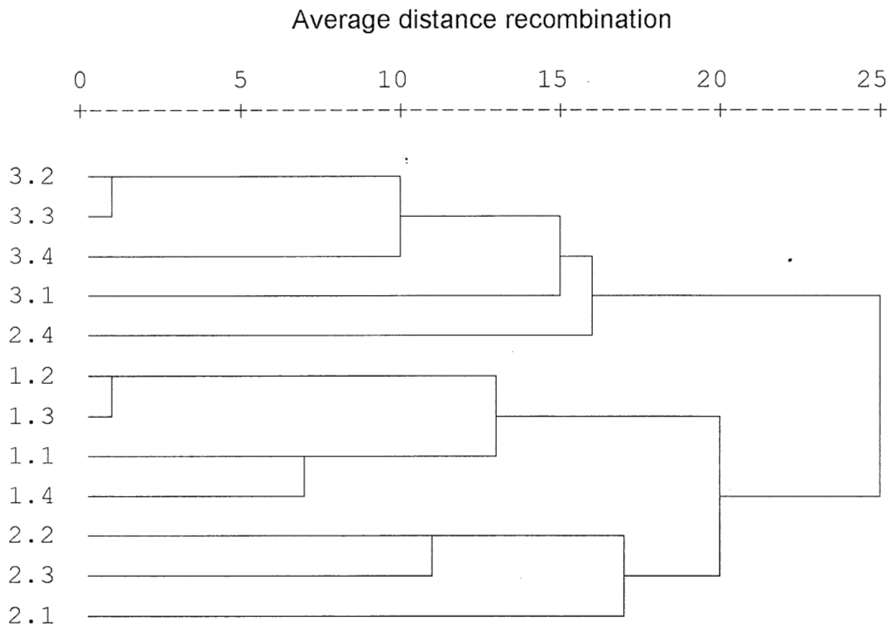

Figure 7: Hierarchical classification of the subplots according to the UPGMA.

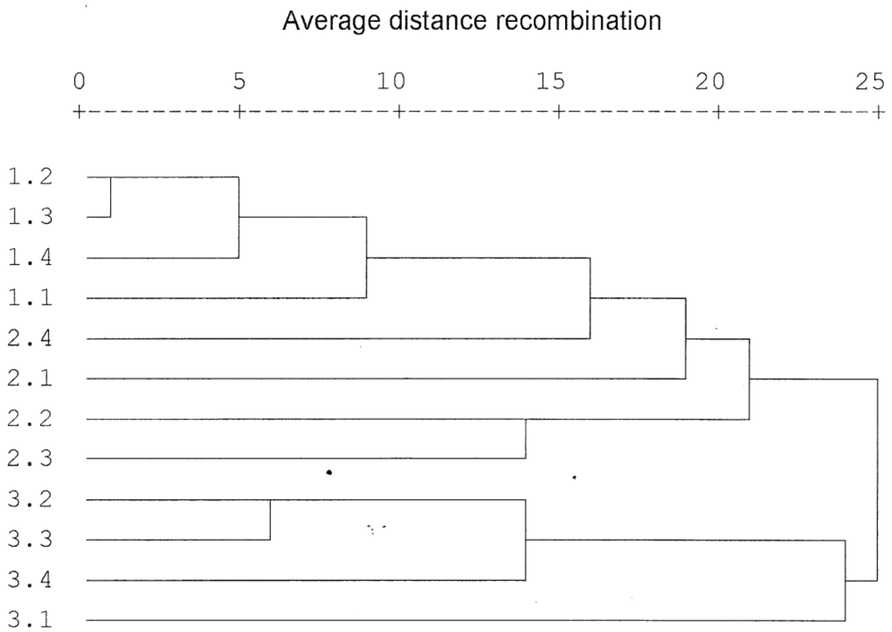

Figure 8: Hierarchical classification of the subplots according to the nearest neighbour.

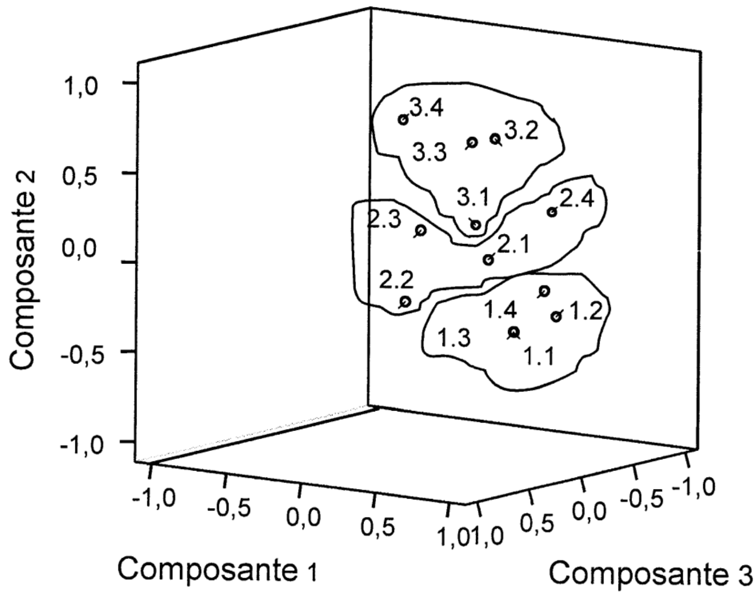

Figure 9: Diagram of components of factors resulting from the main components analysis.

DISCUSSION

Floristic diversity

The whole of this inventory brings out 1186 trees, that is to say 395.3 trees.ha^{-1}, whereas *Aucoumea klaineana* which is dominant poster 42 to 384 trees.ha^{-1} in the plots (Table 3). Within this ecosystem, Kimpouni et al. (2008a, 2008b) show some species with the highest densities. It is about *Aucoumea klaineana* (183.33 trees.ha^{-1}), *Trichilia heudelotii* (43 trees.ha^{-1}), *Sacoglottis gabonensis* (13.33 trees.ha^{-1}) and *Carapa procera* (29.33 trees.ha^{-1}). Without being Co-dominant, this forest is characterized by *Aucoumea klaineana* and *Trichilia heudelotii* (Kimpouni et al., 2008a, 2008b). The number of species raised per unit of area (Table 1), in this forest facies, is much lower than the data marking the tropical forests (Trochain, 1980; Ozenda, 1982; Mosango, 1991; Sonké, 1998; Puig, 2001; Kouka, 2001, 2006; Kimpouni et al., 2008a, 2008b; Gonmadje et al., 2011). This result is the reflection of the clear predominance of *Aucoumea klaineana*, thus representing its strong adaptation to a gregarious development, even social, in its phase of installation and the youthful nature of the facies (Brunck et al., 1990; Puig, 2001; Kimpouni, 2008a, 2008b). These observations are backed up by the index of Green which distinguishes an aggregative character (GI = 0.85) supported by *Aucoumea klaineana* (73.28% of the trees number) in plot 1 and one random distribution in the plots 2 (G = 0.08) and 3 (G = 0.07). In these two last plots, the follow-up of number of *Aucoumea klaineana* trees revealed a clear regression (39.24 and 12.14%) compensated by the appearance of new species, characteristic of the ombrophilous dense forest. The phase dominated by *Aucounea klaineana* would be a transitory element of the Atlantic wet dense forest installation.

The installation of *Syzygium guineense*, indet 2, *Irvingia gabonensis, Cleistanthus* sp., *Magnistipula cf butayei*, *Picralima nitida, Baphia laurifolia, Millettia versicolor, Uapaca heudelotii, Baphiopsis cf parvifolia,* *Santiria trimera*, *Sorindeia gilletii*, *Synsepalum longecuneatum*, indet 4, *Psychotria* sp., *Macaranga monandra*, *Erythrophleum suaveolens* and *Anthonotha* sp. Which are the characteristic species of the littoral forest is the proof of the changes in the floristic composition after the *Aucoumea klaineana* phase. In addition to these well marked trends, one belongs to the gatherings of less importance whose species have weak floristic affinities. As for the phytosociological aspect, *Aucoumea klaineana*, *Trichilia heudelotii* and *Carapa procera* establish a floristic unit characteristic of this facies. The majority of species is characterized by a weak interdependence affinity. This behaviour is a major symbol which testifies to the small degree of functional stability and impact strength of this still young ecosystem (Bond and Chase, 2002; Giller and O' Donovan, 2002; Loreau et al., 2002; Caldeira et al., 2005; Wallington et al., 2005; Mikkelson, 2009). In spite of these observations, it is interesting to say that they are of this fact characteristics of the typical sublittorale forest described by Cusset (1989). This analysis makes it possible to underling the progressive change of the flora following its enrichment characteristic in species of the wet dense forest of the littoral (Cusset, 1989; Hecketsweiler, 1990; Hecketsweiler and Mokoko-Ikonga, 1991; Doumenge, 1992).

Distribution of taxa in diameter classes

The variation of the average diameter of the $d^{1.30}$ presents according to a gradient growing of the face pioneer, trained by individuals of low diameter, towards "the older" interior of the forest and thus equipped with subjects for the more modest diameter (Table 2). Thus, the type clearly dominated by *Aucoumea klaineana* observed in the first plot, in relation to the face pioneer, becomes more heterogeneous and diversified thereafter during its evolution (plots two and three). Lastly, the evolution of the densities of the diametric structure shows that this forest facies almost does not abound in specimen of large diameter. Very little of them falls under the classes of average diameter of exploitability (DME ≥ 60 cm).

Inventories of the specimens of diameter lower than 10 cm, carried out by Doumenge (1992) in the old forest formations confirm the youthful characteristic of this woody facies, following by the absence of young plants in the plots. It acts at many first stages of installation of the forest with *Aucoumea klaineana*, with is a transitory facies of the littoral forest, and not of a regeneration of this one within a stable system (Mosango, 1991; Peters, 1997). This evolution of the diametric structure (Figure 5) is in narrow correlation with the stage of development of the studied forest facies, on the one hand, and the gregarious trend of *Aucoumea klaineana*, on the other hand (Hecketsweiler and Mokoko-Ikonga, 1991; Doumenge, 1992). The combination of these parameters explains gregarious type "plurienne" which the curve of distribution of the classes of diameters (Doumenge, 1992) displays.

The floristic evolution follows two narrowly correlated parameters, but evolving in opposite direction. It is the very strong density of *Aucoumea klaineana* and the small degree of specific diversity, in particular in plot 1. However, a significant decrease of the density of *Aucoumea klaineana* accompanied by a species enrichment, from where acquisition by the forest facies of a high degree of structural complexity and heterogeneity (Namur, 1978). Moreover, they mark the trend of a functional stability of the system (Bond and Chase, 2002; Giller and O'Donovan, 2002; Loreau, 2002; Wallington et al., 2005; Caldeira et al., 2005; Mikkelson, 2009). In a concomitant way, the reduction in the density of *Aucoumea klaineana* is compensated, in the evolution of the forest facies, by the increase in $d^{1.30}$ of trees. The skewness coefficient reveals a weak proportion of the trees of small diameter in the three plots. However, a critical analysis of the values of the skewness coefficient between the plots, shows that the trees of large diameters are more numerous in plot 1 (G = 2.10^{-2}) than in the two others, where this coefficient is respectively of 7.10^{-4} and 4.10^{-3} (Figure 6). This result is in conformity with the mode of development of *Aucoumea klaineana* and with its heliophilous character. Indeed, it is said that *Aucoumea klaineana* which is a pioneer species with rapid growth, is not competitive opposite a competition intra or interspecific (Leroy-Deval, 1973; Brunck et al., 1990; Fuhr, 1999; Kimpouni, 2008a). Almost monodominant in the plot 1 which is still youthful, its density decrease as one goes towards the interior of the forest, therefore towards the most advanced stages.

Basal area analysis

The means value of basal area of the studied forest facies is understood in the interval (23 to 50 $m^2.ha^{-1}$) allowed like characteristic of the tropical dense forest formations (Trochain, 1980; Ozenda, 1982; Mosango, 1991). The juxtaposition of the curves of the evolution of basal area and specific diversity (Figure 3), illustrates perfectly the youthful character of this formation. A positive correlation is noted in all the classes of diameter between the two ecological parameters (density and basal area) which give an account of the structure of the forest facies (Namur, 1978; Doumenge, 1992). This report is also valid when these parameters are applied to the species taken individually (Figure 4 and Table 3). The comparative study of basal area and the number of species within subplots, watch that these two parameters have an opposite tendency. The basal area decreases as rises specific diversity.

The report of basal area (ST) on the density (D) calculated by Kimpouni et al. (2008a) watch clearly that this woody formation is mainly made up of the individuals of low diameter (ST/D < 1). This ecological parameter puts forward more taxa than the least represented in the inventory and characterizing dynamics with the phase after *Aucoumea klaineana* (Doumenge, 1992). Among the taxa constitutive of the littoral forest, we quote *Pseudospondias longifolia*, *Anthonotha* sp., *Afzelia bipendensis*, *Erythrophleum suaveolens*, *Magnistipula cf butayei*, *Allanblackia floribunda*, *Irvingia gabonensis*, *Syzygium guineense*, *Panda oleosa*, *Psydrax palma*, *Pausinystalia yohimbe*, *Grewia coriacea*, *Vitex cf grandifolia*. This report, which characterizes not only the trees of large diameter, also makes it possible to confirm the diametric evolution, on the one hand, and, on the other hand, the dynamics of the structure and the future change of the floristic composition of the forest ecosystem (Doumenge, 1992). These observations are confirmed by the follow-up of the ecological parameters of *Aucoumea klaineana*, in particular the report ST/D which value is lower than 1 (Table 3). This analysis confirms the passage of a facies with *Aucoumea klaineana* with another where Fabaceae are the main feature.

The floristic composition of the facies being definitely dominated by *Aucoumea klaineana* (183.3 $trees.ha^{-1}$), *Trichilia heudelotii* (42 $trees.ha^{-1}$), *Carapa procera* (29.3 $trees.ha^{-1}$) and *Sacoglottis gabonensis* (13.3 $trees.ha^{-1}$), the compared study of their density and their basal area (Figure 6) shows a concomitant and proportional evolution of the two parameters. The most abundant taxa are almost, in all the cases, best represented in the occupation of space (basal area). This data reflects the coherence observed between the densities and the analysis of the classes of diameter. Indeed, the classes of diameter which are characterized by low densities show the most restricted basal area. In addition, it confirms the youthful feature of the studied system, and puts in more one accent on its evolutionary dynamics, in particular of the phase after *Aucoumea klaineana* (Kimpouni et al., 2008b).

The follow-up of basal area of the three plots shows that this parameter is decreasing, from the edge towards the interior of the forest, and the values vary from 34.79 to 22.4

$m^2.ha^{-1}$ of plot 1 at plot 3 (Table 1). This evolution of basal area which is opposed to that of the densities of *Aucoumea klaineana*, marks the pioneer character of the forest on the one hand, and confirms the low level of functional stability of the forest facies on the other hand (Bond and Chase, 2002; Giller and O'Donovan, 2002; Wallington et al., 2005; Caldeira et al., 2005; Mikkelson, 2009). In relation to the evolution of basal area, we can emphasise that the oldest plots are those that present the low values and conversely more the floristic high degree of diversity (Figure 3).

From its pioneer characters and heliophilous, *Aucoumea klaineana* is less competitive in the process of natural regeneration under dense forest cover (Doumenge, 1992; Puig, 2001). This behaviour can explain the regression of the density of *Aucoumea klaineana* in the old plots on the one hand, and on the other hand, the proliferation of the woody species characteristic of the littoral forest in the underwood, of these same plots.

Floristic affinities of the subplots

The matrix of proximity of subplots generated with software SPSS, according to the correlation of similarity of Jaccard (Table 4), shows that very little subplots have a degree of affinity to the top of 50%. The recorded floristic uniformity characterizes four subplots distributed by couple in plots 1 and 3. This matrix of similarity highlights the existence of under facies, in the flora of this forest with *Aucoumea klaineana* of the Congolese littoral. Their presence holds of the great variation that one notes in the floral composition of plots and predicts floristic changes futures (Kimpouni et al., 2008a, 2008b).

Hierarchical classification of the subplots

The hierarchical classification centred on the floristic composition of subplots (Figures 7 and 8) is obtained by data processing by using software SPSS version 13.0. It is based on the Jaccard similarity coefficient. The regrouping of subplots is based on “average linkage” or UPGMA and the “nearest neighbour” or single linkage. The analysis of hierarchical classification identifies a regrouping of subplots in two great entities centred on plots 1 and 3. The subplots of plot 2 being distributed in the two groups to differing degree, the floristic composition of this plot would be intermediate between two others (Figures 7 and 8). The variability recorded in floristic affinities within plots, is translated on the level of the species by a regrouping which should symbolize characteristic facies or under facies. The ascending hierarchical classification relating to the presence-absence of the species show some regroupings generally marking the species of plots 3 and 2 (Figure 9).

Spatial distribution of the subplots

Spatial distribution of subplots studied, according to the principal components analysis, releases 3 axes. The edging values and the percentages of the variance, explained by the three components, are taken again in Table 5. These parameters give the summary of the diagram of components of the three factors explained to the matrix. The analyzed data symbolize a rough matrix of 12 floristic statements for 71 species. Just like ascending hierarchical classification, this analysis is based on the presence-absence of taxa.

Analysis of the diagram in components of three factors (1, 2, 3) confirms the floristic affinities already raised by hierarchical classification and the matrix of similarity. Moreover, this study certifies and explains the results obtained by the classical ecology analyses (Kimpouni et al., 2008a, 2008b). Moreover, the main components analysis (Figure 9) highlights the three plots consisted of 12 subplots, while marking their small degree of floristic uniqueness. The subplots of the plots 2, by their affinity with subplots of plot 1 and 3, would characterize an intermediate facies between the two plots mentioned above.

Conclusion

This study on the floristic evolution of the facies with *Aucoumea klaineana* in the Congolese littoral shows a transitory link of the installation of the littoral forest. In this facies, *Aucoumea klaineana* which is the dominant species sees its density decreasing as the system gains in age. After this reduction in the density of *Aucoumea klaineana*, one raises an increase in $d^{1.30}$ of trees, on the one hand, and, on the other hand, the system acquires a floristic heterogeneity and a higher structural complexity. These phenomena confer to the ecosystem a greater functional stability from where there is from where there is a a high degree of impact strength. The various ecological parameters made it possible to show that this pioneer ecosystem which is with the departure dominated by *Aucoumea klaineana,* transforms into a unit where *Aucoumea klaineanna* is not more the absolute reference. Indeed, *Aucoumea klaineana* being a heliophilous species and with rapid growth, isless competitive and is badly adapted to an adequate regeneration in the undergrowth. As the facies grows in maturity, this species gives up its seat to the woody species with slow growth and adapted better to the new ecological conditions of the habitat. The multivariate analysis, in particular hierarchical classification, indicates that this system is still youthful, in its floristic composition in ligneous species. Developing at the southern end of the geographical area of *Aucoumea klaineana*, the floristic composition and structural complexity diverge from those of the Gabonese forests. In keeping with the existence supposed of the "biafréenne" forest on the Congolese littoral, this study cancels the development of this kind of forest in extreme cases southern of the area of *Aucoumea klaineana*.

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