RESEARCH PAPER

Spatial structure and abundance in the Kahuzi-Biega Mountain vegetation formation in DR Congo (Albertine Rift): Case of *Carapa grandiflora* SPRAGUE and *Symphonia globulifera* L. F. in the resort of Tshivanga

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Abstract

The present study was based on the study of the spatial distribution of two species, notably *Carapa grandiflora* and *Symphonia globulifera*, in the forest of the tourist site of Tshivanga in Kahuzi-Biega National Park on a surface of four considered habitats (hectares). In this study, we have used the nearest neighbor distance method to determine the type of distribution of these species. The study carried out allowed to sample a total of 1741 specimens belonging to 35 species and divided into 22 different families; from which 34 different species were found into the *Carapa grandiflora* population In the *Symphonia globulifera* population, 20 species were identified, divided into 13 families. From the point of view of distribution and abundance, we have noticed that the diametric growth rate for both species decreases from higher diameter classes to lower diameter classes, which implies the appearance of the regression curve (R^2). The analysis of biodiversity for both populations under investigation shows that Equitability_J is equivalent to 0.5 and 0.4, which reflects a monodominance of these two populations. The comparison between diametric structures of specimens of different species within two stands shows a significant difference for the diametric structures of these two stands. The analysis of the spatial distribution of the two populations shows that, the distribution is uniform (regulator) for the *Carapa grandiflora* and in clumped spatial aggregate for the *Symphonia globulifera*. The forest types above presented differ in terms as structure and diversity. Any coherent and objective strategy of sustainable management of forests should integrate their specificities.

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Introduction

In a particular habitat shared by several species, each of the species is usually confined to its own micro habitat or spatial niche because two species in the same general territory cannot usually occupy the same ecological niche for any significant length of time (Gotelli and Chao, 2013). In nature, organisms are neither distributed uniformly nor at random, forming instead some sort of spatial pattern (Bogaert *et al.,* 2004). This is due to various energy inputs, disturbances, and species interactions that result in spatially patchy structures or gradients. This spatial variance in the environment creates diversity in communities of organisms, as well as in the variety of the observed biological and ecological events (Hakizimana *et al.*, 2011). The type of spatial arrangement present may suggest certain interactions within and between species, such as competition, predation, and reproduction (Krebs, 1994). On the other hand, certain spatial patterns may also rule out specific ecological theories previously thought to be true (Ortega-Huerta and Peterson, 2004; Mahamane, 2005).

The research or scavenge on spatial information for every arborescent plant species is more and more considered by the up-fitters as a means to improve the management and the conservation of tropical forest (Hakizimana *et al*., 2011; Gotelli and Colwell, 2011). That is why it is compulsory, in ecology, to understand the related ecological processes and the functioning of forest ecosystems through spatial dispersion studies (spatial structure, Nshimba *et al.,* 2008). This is the reason why, in every plant community, one distinguishes three sorts of configuration or spatial structure (Kumba *et al.,* 2013; Gotelli and Chao, 2013): Regular, random and aggregated (Fig. 1)

The spatial structure of plant species is defined as the result of interactions between specimens, a kind of competition, and their environment according to their biotic and abiotic factors regroupings (Pellegrini, 2002). This spatial structure of species determines the spatial arrangement of specimens in a community and it constitutes a central theme in ecology.

It is one of the first characteristics observed when studying a plant community (Sonke, 2004; Nshimba *et al.*, 2008).Several previous studies have shown that analysis of the spatial structure and abundance of species can serve as a description of forest stands, but also provide sources for the study of their dynamics (Ortega-Huerta and Peterson, 2004; Boyemba, 2011; Nyiramana, 2012). We believe that knowing the spatial structure of specimen's heterogeneous forests can improve not only the knowledge of these environments but also the understanding of the ecological processes involved (mangambu *et al.*, 2013; Shalufa *et al.,* 2014; Desclée *et al.*, 2014.)

Sitting astride on the equator and Sub-Saharan center, the Democratic Republic of the Congo- DRC, with their big 17 plant formations, expands on about 2,345,409km2 and possesses a very rich and varied fauna and flora notably in their Natural reserves and national parks (Mangambu, 2016). Among these national parks one finds the Kahuzi-Biega National Park- KBNP, located at the intersection of Guineo-congolese and Afro-mountainous endemic centers and located next to big clusters in its mountainous part (Mangambu, 2016).Like the majorities of DRC Park, deforestation and fragmentation facilitate poaching in the KBNP. And several species of this Park are exploited and selected according to the preferences of informants (food, medicine, construction, trade, crafts, timber, energy) and among which they mentioned the species, i,e, *Carapa grandiflora* Sprague (Meliaceae) and *Symphonia globulifera* L.f. (Clusiaceae) without regard to their importance in biodiversity (Mangambu *et al.*, 2015; Chalukoma *et al.*, 2015).

The seeds of these two species contribute to the diet of birds and large mammals. The bark and fruits of *Carapa grandiflora* Sprague are eaten by gorillas as a medicine to treat stomach-ache, and *Symphonia globulifera* L.F. fruits are eaten by baboons (*Pan* spp.). The flowers of those two plants constitute one of the best food for many small birds. The latex is used by bees to solder their hives, but also it is used by the neighboring community to mend some of their utensils or home tools such as the cracked calabashes (Mangambu *et al.*, 2015).

Given the importance of tourism in Tshivanga touristic sector, Photo 1 (resort at altitudes between 2050 and 2412 m above sea level and 45 km from Bukavu city), and the importance of these two plants used as food for big baboons.

This work determines the spatial structures and the species abundances in four compartments of four hectares each in order to show their importance to the managers of the site so that they can limit the unfair exploitations in-there, exploitations which negatively impact on the number of species, species and biodiversity running the risk of extinction through that deforestation and echo-system degradation.

Material and methods

Study Site

Located in the eastern part of the DRC in the Albertine Rift, the Kahuzi-Biega National Park (PNKB) stretches from the Congo River basin near Itebero-Utu to its eastern border in the northwest of Bukavu (Fig. 2).This park originates from 2 highest mountains of this forest, Kahuzi (3326 m) and Biega (2790 m). The international importance of the PNKB was recognized by UNESCO in 1980, as World Heritage, but unfortunately in 1997, this site has been placed on the UNESCO World Heritage List in Danger (Mangambu, 2016).

This study focused on the mountain vegetation formation. In this part of high altitude, the vegetation is composed of six large plant formations (Fischer, 1996). They follow one another according to the altitude in the following way: transition forest (1250-1700 m); mountain rainforest (1700-2400 m); bamboo forest (2400-2600 m); marshes and peat bogs and finally subalpine heathers (beyond 2600 m). Precipitation is very high, but not evenly distributed throughout the year. There are two rainy seasons separated by two dry seasons between May and June, the other between October and December. The average annual temperature is between 0.6 at the summit of Mount Kahuzi, 18°C in the high altitude and 20.5 ° C in the lowland portion (Yamagiwa *et al.*, 2005 after Mangambu, 2016).

Methodology

To test the effect of the range of inventoried species on the spatial distribution, the analysis of the spatial structure was carried out on four plots (two for *Carapa grandiflora* and two others for *Symphonia globulifera*). In each of the plots, we delineated ten, 20 m x 20 m plots to avoid edge effects during data collection. Using the GPS7, the geographical coordinates of the plots were taken 107 and a compass made it possible to orient them. *Dbh* trees and shrubs (*Diameter at height* 10 ≥ 50, 50 ≥ 100, 100 ≥ 150, 150 ≥ 200, ≥ 250) were in the same plots based on circumference measurements and one label was placed on each individual to avoid taking two measurements on a single individual. We sought to know the distance between an individual (tree or shrub) and its nearest neighbor (ri) except herbaceous (Bütler, 2000).

Species identification

The identification of the species collected in the field was made possible thanks to reference herbaria of the Natural Science Research Center of Lwiro and National Botanical Garden of Belgium (BR) and the works of Troupin (1979, 1982 and 1985). The names of flowering plants were verified using works by Lebrun and Stork (1991, 1992, 1995, 1997 and 2010); Bloesch *et al.* (2009) and by systems based on the phylogenetic approach taking into account data from molecular systematic botany (APG III, 2009 and PPG, 2016).

Statistical models for structural studies

Spatial structure analysis models are based on the density of a species in a sample or on the distances between specimens in the community. As part of this study, a statistical model based on distances between specimens was used. It is the model of Clarck and Evans (1954) also called "the nearest neighbor method". The sums of the distances and the sums of the squares of the distances between the feet have been calculated (Gotelli and Colwell, 2012).

Quantitative analysis

We first tested the stand structure of two species (*Carapa grandiflora* and *Symphonia globulifera*) within the plant communities where the plots were established, first by studying the species richness (SAR) which is the total number species observed.

This inventory identified the dominant species. Dominance was calculated according to the Pielou equitability index .The biodiversity indices used in this work are the Shannon, Piélou, Margalef and Simpson indices (Margurran, 2004) by PAST software (Hammer and Ryan, 2013). The linear regression that was applied using the STATISTICA program helped us to report on the degree of diversity of the two species studied.

The results are considered significant if P <0.001 (Larmarange, 2004). We also used other analyzes such as: relative dominance, relative diversity, and ecological value index (Gotelli and Colwell, 2011). The student t test was used to compare the averages. The density was calculated also the comparison of the averages of the abundances was carried out by using Student's t test from software R (version 2.9.2). This test makes it possible to compare the averages of two independent data series.

The distance between an individual and their nearest neighbor (*ri*)

The distance between an individual and their nearest neighbor (*ri*) was measured for all specimens in the study area. The aggregation index of Clark and Evans (R) was obtained by the ratio between the observed mean distance and the distance expected to the nearest neighbor ($\bar{r}_O$) by this formula:

$$\bar{r}o = \frac{\sum_{i-1}^{n} ri}{n}$$

While the expected distance to the nearest neighbor ($\bar{r}_E$) was found by the relation:

$$\bar{r}e = \frac{1}{2\sqrt{D}}$$

Clark and Evans defined the values of the aggregation index (R), the characterization of a spatial distribution (Buttoud, 1991) by the relation:

$$R = \frac{\bar{r}o}{\bar{r}E}$$

The spatial distribution is random if the value of the index (R) is equal to 1; on the other hand, it is aggregated when it is less than 1 and tends to 0 for a uniform distribution, the index approaches an upper limit of about 2.15. A significance test was performed to verify whether the observed distribution was different from the random distribution (Kumba *et al.*, 2013). It is established that for the difference to be significant, the normal standard deviation must be between 1.96 and 2.58. If it is greater than 1.96, there is a deviation of the observed distribution at significance level α = 0.05. And if in addition, it is greater than 2.58, we have to do to a deviation of the distribution at threshold level of significance α = 0.01. The normal standard deviation (C) is obtained by the relation:

$$C = \frac{\bar{r}o - rE}{Sr}$$

Where *Sr*, is the standard error of the distance to the nearest neighbor, and is obtained by the relation:

$$Sr = \frac{0,26136}{\sqrt{nD}}$$

With *n* and *D* respectively the number and density of specimens in the study area.

The values of C equal to 1.96 and 2.58 respectively represent the significance thresholds of α = 0.05 and α = 0.01 (Clark, Evans, 1954).

Results

Floristic study and Characterization of the two populations

Floristic study

The study carried out allowed sampling a total of 1341 plant specimens belonging to 35 species and divided into 22different families; from which 34 different species were found into the *Carapa grandiflora* Population, with the most diverse families being the Rubiaceae followed by Euphorbiaceae.

Table 1. Distribution and number of specimens from the two studied populations.

NO	Taxa	Pr	A	B	NI/4ha, A		NI/4ha, B	
					Plot I	Plot II	Plot I	Plot II
					20	25	13	15
I	ALANGIACEAE							
1	*Alangium chinense* (Lour.) Harms	I	+	-	0	3	0	0
II	APOCYNACEAE							
2	*Tabernaemontana johnstonii* (Stapf) Pichon	II	+	+	0	2	0	3
III	ARALIACEAE							
3	*Polycias fulva* (Heirn) Harms	I	+	-	0	1	0	0
4	*Schefflera goetzenii* Harms	I	+	-	0	1	0	0
IV	CLUSIACIACEAE							
5	*Chrysophyllum gorungosanum* Engl	II	-	+	0	0	2	13
6	*Harungana montana* Spirlet.	II	+	+	7	0	1	5
7	*Symphonia globulifera* L.f.	II	+	+	0	6	173	189
V	EUPHORBIACEAE							
8	*Macaranga neomildbraediana* Lebrun	II	+	+	38	51	31	20
9	*Alchornea hirtella* Benth.	I	+	+	0	13	0	3
10	*Neoboutonia macrocalyx* Pax	I	+	-	3	7	0	
11	*Sapium ellipticum* (Hochst.) Pax.	I	+	-	0	9	0	
VI	PHYLLATACEAE							
12	*Bridelia micrantha* (Hochst.) Baill	II	+	+	8	0	5	0
VII	FABACEAE							
13	*Albizia adianthifolia* (Schumach.)W.Wight	II	+	+	7	12	1	1
VIII	FLACOURTIACEAE							
14	*Lindackeria kivuensis* Bamps	I	+	-	3	16	0	0
IX	LAURACEAE							
15	*Ocotea usambarensis* Engl.	II	+	+	9	22	1	0
X	LOGANIACEAE							
16	*Nuxia congesta* Fresen	II	+	+	12	36	11	24
17	*Nuxia floribunda* Benth.	II	+	+	2	3	0	6
XI	MAESACEAE							
18	*Maesa lanceolata* Forssk. subsp. *lanceolata*	I	+	-	0	1	0	0
XII	MALVACEAE							
19	*Dombeya torrida* (J. F. Gmel.) Bamps	I	+	-	2	5	0	0
XIII	MELIACEAE							
20	*Carapa grandiflora* Sprague	II	+	+	298	273	10	5
XIV	MONIMOINACEAE							
21	*Xymalos monospora* (Harv.)Baill	II	+	+	1	31	14	16
XV	MORACEAE							
22	*Myrianthus holstii* Engl	II	+	+	2	0	0	6
XVI	MYRSINACEAE							
23	*Rapanea melanophloeus* (L.) Mez	II	+	+	1	8	1	2
XVII	MYRTACEAE							
24	*Syzygium guinnense* D.C.	II	+	+	0	21	15	22
XVIII	OLACACEAE							
25	*Strombosia scheffleri* Engl.	II	+	+	20	49	0	18
XIX	PHYTOLLACCACEAE							
26	*Phytollacca dodecandra* (L) Herit	I	+	-		2	0	0
XX	RIZOPHORACEAE							
27	*Cassipourea ruwensorensis* Alston	II	+	+	4	14	14	45
XXI	RUBIACEAE							
28	*Galiniera coffeoides* Delile	II	+	+	4	0	0	3
29	*Pavetta angolensis* Bridson	II	+	+	3	10	3	10
30	*Trycalisia anomala* E.A. Bruse var. *Montana* Robbrecht	II	+	+		5	0	11

31	*Oxyanthus troupinii* Bridson	I	+	-		10	0	0	0
32	*Pavetta rwandensis* BRIDSON	I	+	-	2	0	0	0
33	*Psychotria mahonii* C.H. WRIGHT.	I	+	-	1	0	0	0
34	*Hirtella Montana* HAUMAN	I	+	-		0	0	0
XXII	SAPINDACEAE							
35	*Allophylus kiwuensis* GILG.	I	+	-	2	0	0	0
	TOTAL	35	34	20	429	608	286	408
	Totaux	35			1037		694	

Legend: A: *Carapa grandiflora* Population, B: *Symphonia globulifera* Population, P: Presence and Absence. Et NI/4ha: Number of specimens in the four considered habitats (hectares).

Table 2. Diversity estimates of two stands studied diversity index stand at *C. grandiflora* stand at *Symphonia globulifera*.

Diversity Indice	Stand at *C. grandiflora*	Stand at *S. globulifera*
Species	34	20
specimens number	1037	694
Dominance_D	0,1454	0,4482
Simpson_1-D	0,8546	0,5518
Shannon_H	2,397	1,226
Margalef	3,967	2,016
Equitability_J	0,5357	0,4779

In the *Symphonia globulifera* population, 20 species were identified, divided into 13 families, with the most diverse family being Rubiaceae followed by Clusiaceae (Table 1).

Characterization of the populations
Characterization of the Carapa grandiflora population
The *Carapa grandiflora* (Photo, 2) stand studied constitutes a semi-open canopy high altitude forest (55% cover). We found that the structural density, stratification are well marked and with a specialization of epiphytism remarkable.

Table 3. Floristic characteristics of the stand at *Carapa grandiflora* floristry stands made.

Floristic character	Placettes effectuées	
	Plot I	Plot II
Taxonomic luxuriance	20	25
Tree/plant luxuriance	13	15
Schrub luxuriance	7	10
Averagere coverage (%)	49,6 ± 79,3	58,3 ±81,8
Average height of de la canopy (m)	15,5 ±46,5	11,5±40,5

The constituent forest species are large, evergreen. Shade species (tolerant sciaphytic) dominate, both in the upper and lower strata. Following the vertical structure of the vegetation, the tree layer is dominated by *Carapa grandiflora, Macaranga neomildbraediana, Strombosia scheffleri, Nuxia congesta, Ocotea usambarensis* and *Syzygium guineense* (Table 1).

The trunks and cymes of trees in this stand in the lower tree layer are almost all invaded by many epiphytes such as *Lepisorus excavatus, Loxogramma abyssica* and *Asplenium sandersonii*.

The shrub layer is represented by certain species such as Nuxia floribunda, *Ardizia kivuensis, Trycalisia anomala* var. *montana* and *Xymalos monospora*.

**Table 4.** Structural analysis of *Symphonia globulifera* planting.

Floristic character	Plots concerned	
	Plot I	Plot II
Taxonomic luxuriance	13	15
Tree/plant luxuriance	12	11
Schrub luxuriance	1	4
Averagere coverage (%)	29,6 ± 72,3	58,3±69,8
Average height of de la canopy (m)	16,5±36,5	8,5±32

Table 5. Parameters calculated for the application of the nearest neighbor distance method. Calculated parameters.

| Calculated parameters	*Carapa grandiflora*	*Symphonia globulifera*
N (number of specimens /2ha)	571	362
P (number of specimens x m^{-2})	0,210	0,121
$r_{i\min}$ (m)	1,71	0,9
$r_{i\max}$ (m)	28,1	11,2
$\overline{r}_O$ (m)	5,2	4,4
$\overline{r}_E$ (m)	4,21	5,11
R	1,32	0,83
S_r	0,31	0,17
c	4,72	2,21

Legend: n: the number of specimens in the study area; *p*: the density of the population; r_i : the distance to the nearest neighbor for the individual *i*; $r_{i\min}$ and $r_{i\max}$: respectively the minimum and maximum distances; $\overline{r}_O$: the average distance observed to the nearest neighbor; $\overline{r}_E$: the expected distance to the nearest neighbor; *R*: the aggregation index; S_r : the standard error of the expected distance to the nearest neighbor and *c*: the normal standard deviation.

Besides these species, we can also find some accompanying species like *Harungana montana, Maesa lanceolata* and *Lindackeria kivuensis* (Table 1). Herbaceous strata do not contain xero-heliophilic species, they are generally very discontinuous or even nil.
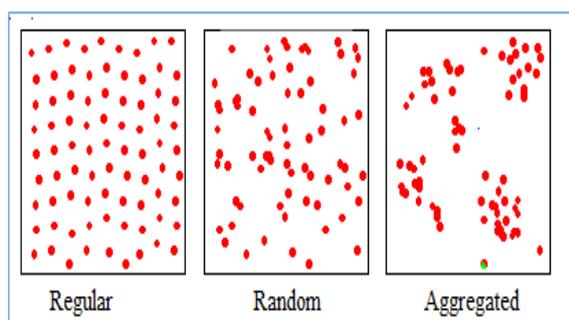
Fig. 1. Three types of spatial distribution.

Characterization of the Symphonia globulifera population

The *Symphonia globulifera* (photo 3) is a forest from high altitude to a semi-open canopy (55%). Many species of shade or tolerant; however, more intense radiation promotes the maintenance of light species in the upper strata. There has also been a greater congestion of the lower strata. The foliage of the elements of the upper strata is less developed and tends towards the lauriform type, especially in the highest horizons of the forest (quality of the radiation). There is also a high atmospheric humidity, relatively low temperature, mature mountain soil, covered with abundant litter and good decomposition and deep humus penetration. The tree strata following its vertical structure is dominated by *Symphonia globulifera, Cassipourea ruwensorensis, Macaranga neomildbraediana, Syzygium guineense,* and *Xymalos monospora.*
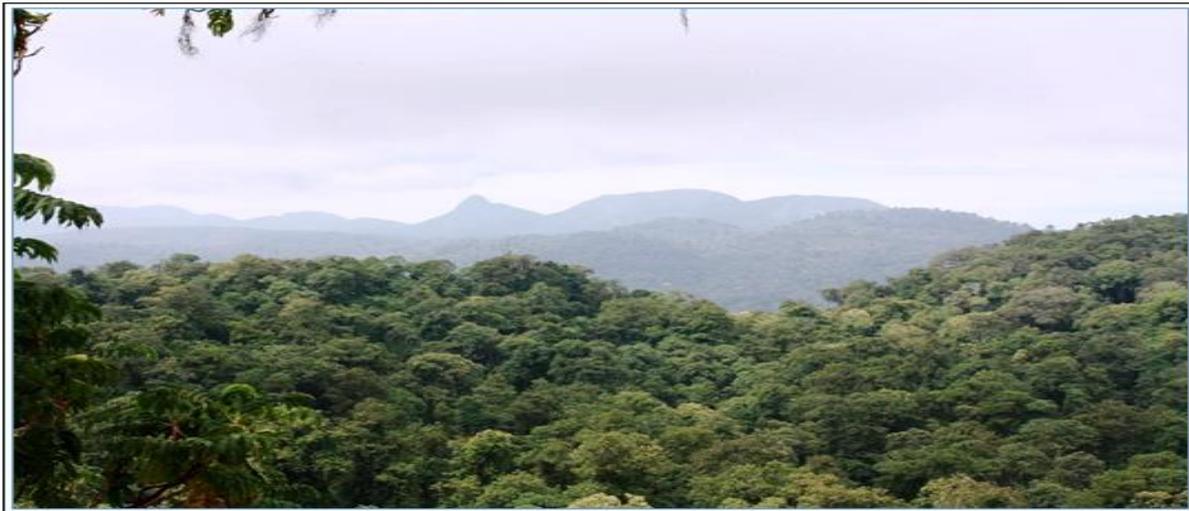
Photo 1. Landscape of Tshivanga Resort at Kahuzi-Biega National Park (Photo Mangambu).

In the shrub layer we can find species like *Chassalia subochreata, Clutia abysinica, Myrianthus holstii, Trycalisia anomala* var. *montana, Xymalosmonospora*. And in the Herbaceous layer the species *Mimilopsis solmsii* also abounds seedlings of species like *Sericostachys scandens* and *Symphonia globulifera*.

Biodiversity estimates

These two species (*Carapa grandiflora* and *Symphonia globulifera*), were very abundant compared to others. Among the 1.731specimens, 1037 specimens were inventoried in the *Carapa grandiflora* of which it represents 55.06% of the inventoried specimens.

Fig. 2. Kahuzi-Biega National Park (MANGAMBU, 2016 "encircled area shows our place of study").

It is followed by the species *Macaranga neomildbraediana* with 8.58 % and *Strombosia scheffleri* with 6.65 % (Table 1). In that of *Symphonia globulifera*, 694 specimens were inventoried, accounting for 52.2% overall, followed by *Cassipourea ruwensorensis* (8.5%) and *Macaranga neomildbraediana* (7.4%) of the overall weighting for

our two plots, Table 1).Overall, the Shannon index, as well as those of Margalef and Simpson, are higher in the mountainous forests of KBNP (Table 2). This stipulates a high specificity and equitability within these stands. The Pielou equitability (Equitability_J) index is respectively 0.7 and 0.5 for both stands (Table 2).

Structural characterization and diameter analysis of the Carapa grandiflora stand

We have noted the species richness and average recovery of the *Carapa grandiflora* stand at the tree and shrub strata. The results presented in Table 1 and 3 show a high number of trees and shrubs compared to Parcel I.

Photo 2. Seen from the forest at *Carapa grandiflora* in the Tshivanga station at PNKB (photo Mangambu).

The diameter classes are not the same in the two performed plots (Fig. 3). In plot 1, we find that diameter classes of 10≥50 and those of 200≥250 have a higher number of specimens compared to all other classes. In this distribution, the regression curve $R^2 = 0.59$, which is less significant. On the other hand, in plot II, the diameter class of 10≥50 (dominated by *Nuxia congesta* and *Pavetta rwandensis*) has more inspecimens in this plot followed by 50≥100 (dominated by *Cassipourea ruwensorensis*, *Macaranga neomildbraediana*, *Tabernaemontana johnstonii* and *Syzygium guineense*) and finally the class of over 250 with a low proportion in specimens of *Carapa grandiflora* only.

The regression curve $R^2 = 0.76$ is also significant (Fig.3).The overall results show the proportions of specimens in diameter classes in this stand. The number of specimens decreases with the increase in diameter, which shows a relation between the numbers of two directly adjacent classes.

Analysis of the diametric and structural characters of Symphonia globulifera planting

The results presented in Table 1 and 4 show that the structure and the average recovering ofvegetation at the level of planting shrubbing and arborescent strata. They stipulate that plot I contains a higher number of plants than plot II. For the schrubs one realizes a contrary case: plot II contains more specimens than plot I, this, maybe, being accounted for by several holes or much break-through in plot II.

The diametric analysis in *Symphonia globulifera* planting plots (Fig. 4) stipulates that in plot I, the classes of 10≥50, 50≥100 and 100≥150 present a higher number ofCassipourea ruwensorensis, *Macaranga neomildbraediana, Xymalos monospora* specimens and some feet of *Symphonia globulifera*). The frequency goes on decreasing as long as one passes from classes of small diameter (specimens the class of 10≥50 dbh) to classes of bigger diameter (specimens of the 50 ≥150dbh cm class).
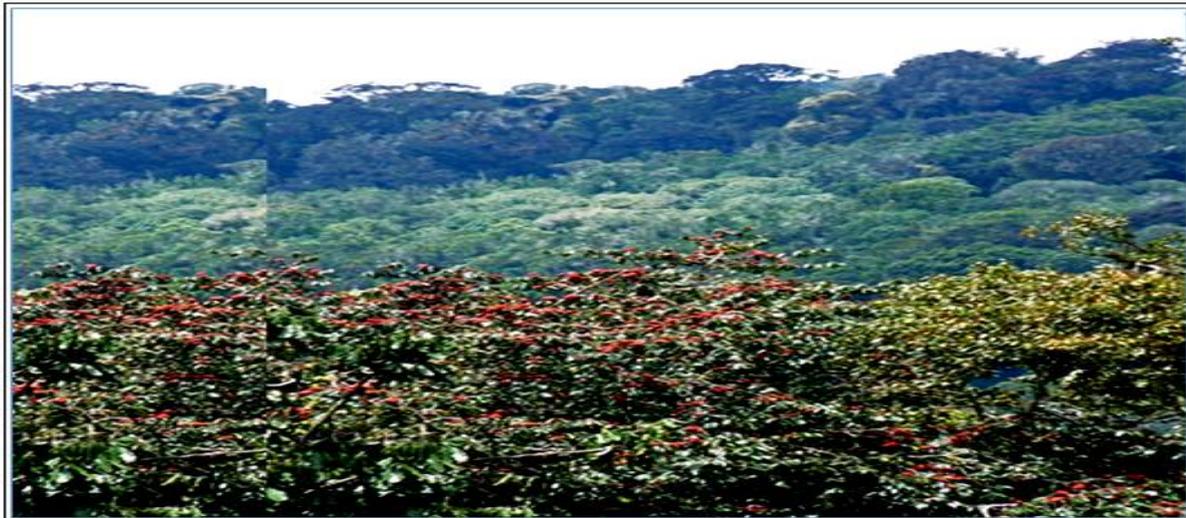
Photo 3. Seen from the *Symphonia globulifera* stand in the vicinity of Saba-Saba in the Tshivanga station at PNKB (Photo Rwabika).

They are followed by the 200≥250 class that contains specimens of *Symphoniaglobulifera* species and some feet of *Syzygiumguineense.* This is the reason why the fall graph is not very significant (R^2= 0.46). On the other hand, in stand II, theclasses of 10≥50 diameter and the one of more than 250 have a higher individual number and they are dominated by *Symphonia globulifera* species and some feet of *Carapa grandiflora* species and followed by 50≥100 class. The fall graph is not significant as well (R^2= 0,521). With regard only to the *Symphonia globulifera* species, it decreases with the increasing diameter class. For stand in general, the comparative analysis of the distribution of the proportions of the frequencies of the different diameter classes is not balanced. Diameter classes therefore do not share equitably the proportions of tree specimens because these values of the index of equitability are close to zero.

Density and basal area
Density and basal area of the stand at Carapa grandiflora
A total of 1037 specimens (for all 34 species) were inventoried: 429 for Plot I and 608 for Plot II. They represent respectively an average basal area of 49.81 2000 m²/ha. Stands of two plots (I and II) with a high density of *Carapa grandiflora* (55.06) have a larger basal area of (1314.31) and p <0.0089.

This result confirms the dominance of this species as an individual in the stand. It is followed by the species *Macaranga neomildbraediana*. Its density is (15.53), basal area is 189.26 and p <0.0069. It is followed by the species *Strombosia scheffleri* 106 84.12 which has a density of (10.35), basal area (84.12) and p <0.0062. Note also that the majority of species in both stands have p> 0.005.

Density and basal area of the Symphonia globulifera stand
A total of 694 specimens (for all 20 species) were inventoried: for plot I, 173specimens for plot II, 189specimens were inventoried. They represent an average basal area of 40.9 and the stands of two high density plots (I and II) are *Symphonia globulifera* (52.16) with a larger basal area of (1891.50) and a density p <0.0089. This result confirms the dominance of this species as an individual in the stand. It is followed by the species *Cassipourea ruwensorensis*. Its density is (8.5) and p <0.005. It is followed by the species *Macaranga neomildbraediana* which has a density of (7.38) and p <0.0062. Note also that the majority of species in both stands have p> 0.005 <0.005.

Parameters of spatial distributions
In a plant community, there are three kinds of configurations or spatial dispersion: random spatial

dispersion, in aggregates (or in clusters) and uniform (or regular) dispersion. The spatial distribution parameter results are found in Table 1 and5, which pertains to the application of the nearest neighbor

distance method. The minimum distances of the two species are similar; the difference between averages is mainly influenced by the maximum value of 28.1 m observed for *Carapa grandiflora*.
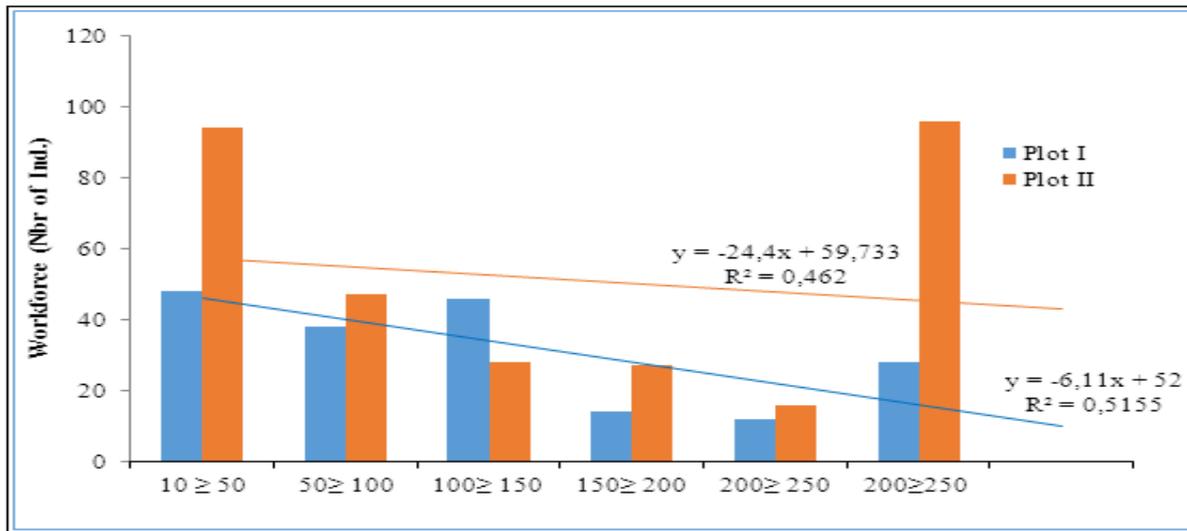
Fig. 4. Diametric distribution histogram of plant/tree specimens in both *Symphonia globulifera* stands.

The average exceeds the expected value for *Carapa grandiflora* and is exceeded by the expected value for *Symphonia globulifera*. For *Carapa grandiflora*, the observed distance is 12.6% greater than expected and for *Symphonia globulifera*, the distance is 6.2% smaller than expected. This indicates a regular distribution for *Carapagrandiflora* and aggregated for *Symphonia globulifera*. Normal standard deviations indicate that the spatial distributions of the two species are significantly different from a random distribution because their respective c values are well above the threshold for $\alpha = 0.05$. In addition, for *Carapa grandiflora*, there is a deviation greater than the value of c for $\alpha = 0.01$. The results show that the species *Carapa grandiflora* has a high cumulative frequency with respect to the species of *Symphonia globulifera*, this difference being explained by the fact that *C. grandiflora* has a greater maximum distance

$(r_{i\max})$ of 28, 1 with respect to *S. globulifera* whose

$r_{i\max}$ ri is 11.2 (Fig. 5).

Discussion

Structural abundance and dominance of taxa
Although species richness is the most popular and intuitive measure for characterizing diversity, the

section Species Richness Estimation emphasizes that it is a very difficult parameter to estimate reliably from small samples, especially for hyper diverse assemblages with many rare species. Species richness also does not measure the evenness of the species abundance distribution (Gotelli and Chao, .2013). Over the span of many decades, ecologists have proposed a plethora of diversity measures that incorporate both species richness and evenness, using both parametric and nonparametric approaches (Magurran, 2004). The number of species in an assemblage is the most basic and natural measure of diversity. Many important theories in community ecology, including island biogeography, intermediate disturbance, keystone and foundational species effects, neutral theory, and metacommunity dynamics make quantitative predictions about species number that can be tested with field observations and experiments in community ecology (Gotelli and Chao, .2013). It is in accordance with the results of our simulation. By comparing the specific diversity of our two stands, the Pielou equitability index for *Carapa grandiflora* is equal to 0.7 and 0.5 for *Symphonia globulifera*. This result proves that both stands have the mesological and ethological characteristics of mountain forests.

Ecologically, these observations could be explained either by the variation or the heterogeneity of the characteristics of the environment, or by the genetic characters allowing a tendency to the association between species, or again by the type of diaspores and their mode of dispersion, or by the ectomycorrhizal characters of the observed species (Desclée *et al.*, 2014).
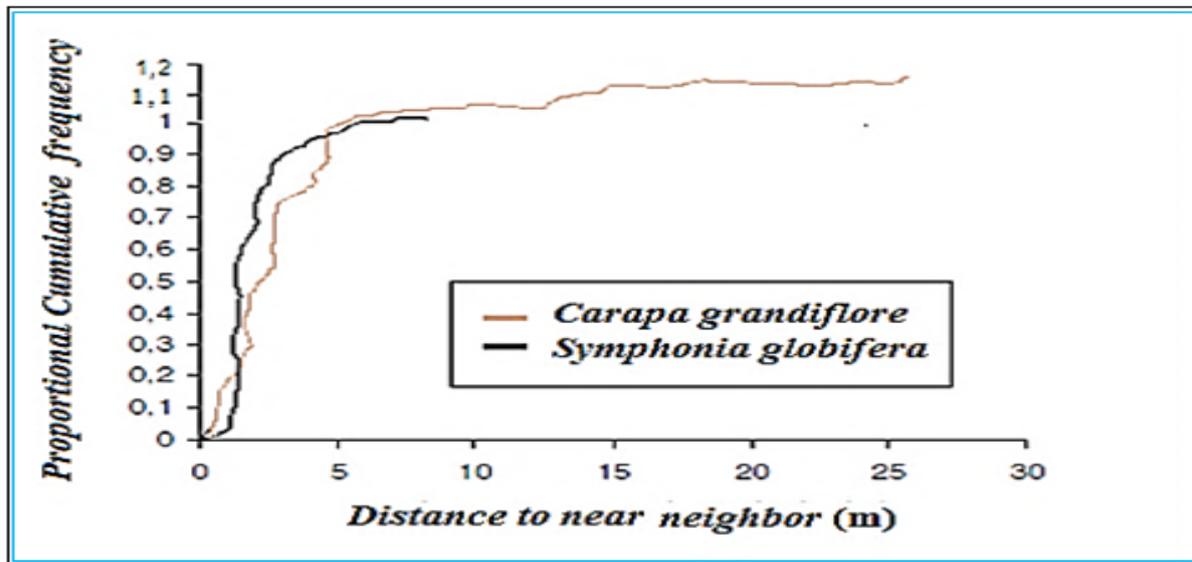
Fig. 5. Graph showing cumulative distributions "*r* imin (m) and *r* imax (m)" of nearest neighbor distances for *Carapa grandiflora* and *Symphonia globulifera*.

In addition, the spatial structure determines the local environment around each tree (especially the number of neighbors) and therefore its growing conditions. This local environment modifies the expression of natural processes such as growth, mortality and stand regeneration. This can lead to a monodominant local composition (Sonké, 2004; Gotelli and Colwell, 2011).These results are similar to those of Masumbuko *et al.* (2008) and Mazambi (2013), who did the work in this region. These authors further specify that density is a particularly important concept in forest management because it provides information on the degree of occupation of space by the settlement. For the Simpson index, it was found that there is a very significant difference between *C. grandiflora* and *S. globulifera* stands. It is thought that this is also in relation to the number of taxa, the first stand is more diverse than the second.

Diametric structure and floristic diversity
Several researchers have set themselves the task of determining the diametric structure of tropical forests to elicit these negative effects. We can cite the case of the works of Nshimba *et al.* (2008), Masumbuko *et al* (2008), Mazambi (2013) and many others.

All these worlds had concluded that the diametric distributions of all the tree species of a stand, have a common look. In other words, they claim that the number of specimens per diameter class decreases almost in the same way when one moves successively from small diameter classes to higher classes (Boyemba, 2011). So we can say that there is a relation between the numbers of two directly adjacent classes. In undisturbed tropical rain forests, numbers of specimens decline with increasing diameters. With respect to our study, we found that the diametric growth rate of *Carapa grandiflora* and *Symphonia globulifera* in their natural conditions, the number of specimens decreases from higher diameter classes to lower diameter classes and vice versa. This implies the appearance of the regression curve R2 to a maximum and then decreasing or a look of "*inverted J*" as appropriate. These results are similar to those found by Mazambi (2013), Boyemba (2011), Kumbu *et al.* (2013) who determined an "inverted J" structure for their studied species.

Aggregate and regular distribution, spatial distribution model

JAN and PAVEL (1997) presented models of development of spatial patterns of natural even-aged forest stands over time. Under their modelling assumptions they have shown that both random and aggregated spatial patterns are preserved over time and a regular (lattice) spatial pattern tends to change into a random spatial pattern. These conclusions are given for a single generation of trees; no new individuals are permitted to arise during the time of development (Anderson, 1971). A homogeneous area is considered. There is, however, a lot of field data indicating that even-aged population of trees, shrubs and herbs tend to decrease the intensity of aggregation in the course of self-thinning, being initially distributed in clumps or tend to nearly regular distribution (Gotelli and Colwell, 2001).

The species *Symphonia globulifera* has an aggregated structure and has an aggregation index R = 0.89 for the two established plots (4 hectares) which is close to a random distribution. And a uniform spatial structure for *Carapa grandiflora* with an aggregation index R = 1.32 for a 4-hectare study area. And Nyiramana (2012) found the same result in Rwanda in the mountainous forest of Nyungwe National Park. These results are consistent with several studies that have shown a predominance of aggregated and uniformly distributed species in tropical forests such as Mazambi (2013) that applied Bütler's (2000) T-Square Sampling procedure to determine the aggregate spatial distribution of *Prunusafricana* in the Kigogo mountain forest, east of the DRC, who finds that its species has an aggregated spatial structure in this forest.

These results are also similar to that of Masumbuko *et al*. (2008) who applied the T-square Sampling procedure to characterize the spatial structure of *Syzygium guineense* in Kahuzi-Biega National Park and found that this species had an aggregated spatial structure, in the Nyamuhambaza-Tshivanga sector; and which indicates that this difference makes it possible to ensure that the grouping is stable apart from any other disturbances that may occur in the medium.

These observed differences are justified by the fact that all these works are done in different environments. They are also explained by the presence of nutrients in the soil and also by their ecological niches.

Nshimba (2008) who used the same method of Clark and Evans' closest neighbor to characterize the spatial structure of *Gilbertiodendron dewevrei* and *Coelocaryon botryoides* in the flooded forest of Mbiye Island near Kisangani and found an aggregated distribution for the species *Gilbertiodendron dewevrei* and a uniform spatial dispersion for *Coelocaryon botryoides*. Our two aggregated and uniform species showed very high densities in the studied forest: 55.06for *Carapa grandiflora* and a density of 52.16for *Symphonia globulifera*. Boyemba (2011), who studies the ecology of *Pericopsis elata*, an Aggregated African Rainforest tree, determines the local scale of *Pericopsis elata* and says that the species is heliophilic to anemochoric dispersal, has a complete aggregated spatial distribution. He then declares that there are aggregates up to 1 ha and distant from each other by a hundred meters. *Pericopsis elata* (Fabaceae) is an important disturbance marker. This species needs large gaps to regenerate and settle in dense forests.

Spatial structure: indicative of ecological factors
The spatial structure is considered indicative of the basic ecological factors of the presence and dispersion of species. The aggregation index (**R**) values showed a different spatial distribution between the two species. The normal standard deviation check identified these differences as significant. The competition observed between the two species in question probably led *Carapa grandiflora* towards a more uniform distribution. The high density of specimens for this species could be expected because the *Tshivanga* forest corresponds to its natural habitat. By the same methodology we found that *Symphonia globulifera* had an aggregated or gregarious spatial dispersion. The fact of not considering a margin in the application of the technique of Clark and Evans (1954) could not skew the conclusions given that an aggregated distribution was observed for *Symphonia globulifera* and also seen the number of distances used for parameter calculations.

Conclusion

Sustainable management of Kahuzi-Biega Park forests collides partially with the misunderstanding of their functioning. Spatial patterns of floristic diversity the two population were investigated following a descriptive and explanatory approach. In trees layers of mixed forests, factors influencing floristic variations, diversity, dominance was evaluated. Our results have demonstrated that, from the point of view of distribution and abundance, the diametric growth rate for both species decreases from higher diameter classes to lower diameter ones, which implies the appearance of the regression curve. The study carried out allowed to sample a total of 1741 plant specimens belonging to 35 species and divided into 22 different families; from which 34 different species were found into the *Carapa grandiflora* population. In the *Symphonia globulifera* population, 20 species were identified, divided into 13 families. At the level of the analysis of the spatial distribution, *Carapa grandiflora* species has a uniform distribution and *Symphonia globulifera* is a species has aggregated distribution.

The context of conservation of these species, and in the way of the management of biological diversity for the maintenance of these stands very useful in the diet and auto medical of great apes Park, authorities will be requested to fully conserve these two studied stands. Because the installation of increasingly evolved habitats can be interpreted both from the structural point of view, indicating physiognomic transformations that have appeared over successive stages and qualitatively, by highlighting the plants that appear when one dynamic stage succeeds another.

The combined interpretation of the stratification of the grouping and the distribution of its species according to their Eco sociological affinities makes it possible to announce the tree evolution towards a stage corresponding to the ecological potentialities of the site. Thus, we have seen that the rainforest species emerge by forming the very loose canopy in both stands. In this sense, the studies are carried out in the whole mountain area of the KBNP to draw a good approach and to understand in the spatial structure and Abundance of these species.

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