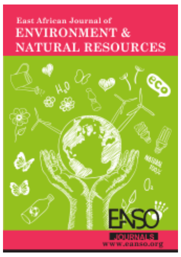

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Original Article

Comparative Study of the Diametric and Spatial Structures of Guarea cedrata (A. Chev.) Pellegr. (Meliaceae) in the Semi-Caducified Forests of the Central Basin Forest Massif (Tshopo Province, DRC, Congo Basin)

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Guarea Cedrata, Diametric and Spatial Structure, Tshopo, DR Congo

ABSTRACT

The comparative study of the diametric and spatial structures of Guarea cedrata (A. Chev.) Pellegr. was carried out in the semi-caducified forests of the Tshopo forest massif in the Democratic Republic of the Congo. For this study, two forest reserves were selected: the Yoko Forest Reserve and the Yangambi Biosphere Reserve, successively located in the Ubundu territory, 32 km southeast of Kisangani and in the Isangi territory, 100 km west of the same city. To conduct the present study, two devices of 200 hectares each, were installed, one in Yoko and the other in Yangambi where all the individuals of Guarea cedrata with dhp $\geq$ 10 cm were measured including their X, Y coordinates. A total of 177 individuals were inventoried within two reserves including 72 individuals, or 0.36 feet/ha in Yoko, and 105 individuals, or 0.525 feet/ha in Yangambi. The total basal area values are respectively 0.0695 m2/ha in Yoko and 0.1712 m2/ha in Yangambi. Both diametric structures are "stretched S" and the spatial distribution is aggregative in Yoko, while random in Yangambi. In general, perch positions and stands are independent from each other; however, there is some dependence at small scale of analysis within the two reserves.

APA CITATION

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INTRODUCTION

African forest ecosystems, especially those of the central basin, are subject to various anthropogenic disturbances. The economy of this basin also depends on agriculture and logging, which leads to the destruction of more than 50% of forest areas (Mangambu, 2002; Achard & Blasco, 2010; Achard et al., 2012; Dibi et al., 2018; Katusi et al. 2022a).

Protected areas such as national parks, reserves, and classified forests, set up for sustainable management of natural resources, are not exempted from these threats. Among the Congolese classified forests, those of the Yangambi Biosphere and the Yoko Forest reserve have been subjected, for several years, not only to the exploitation of timber, but also and above all, to the illicit and continuous removal of various forest resources by local residents for their daily needs, compromising the conservation. Therefore, forest inventories are one of the most important sources of data to study phytodiversity, the establishment of a management plan, and conservation (Lomba, 2011; Katusi et al., 2022a).

In the Tshopo forest massif, the diametric structure of trees, the actual density of woody species, and their natural regeneration, have not yet been fully explored (Katusi et al., 2022b). The comparative study of the diametric and spatial structures of *Guarea cedrata* (A. Chev.) Pellegr. was carried out in the semi-caducified forests of the Tshopo forest massif in the Democratic Republic of Congo (Mangambu, 2002; Katusi et al., 2022a). In the current context of development and sustainable management of natural forest ecosystems in the Kisangani region of Tshopo province, such investigation is necessary.

Therefore, the diametric structure of various forest species sheds light on their regeneration and one can establish for a given species, the diagram of the number of individuals of different diameter classes in order to have an idea on its impact on the forest to ensure a good management (Schnell, 1971; Katusi et al., 2022c). In the Democratic Republic of the Congo, structures of tree population generally are very little known, and especially as several timber companies do not exploit these timbers based on ecological data of species with high market value (Boyemba, 2011; Katusi, 2015; Adeito et al., 2018; Katusi et al., 2022b).

In tropical forests, most studies on spatial distributions of trees show the predominance of aggregated distributions (Hubbell, 1979; Collinet, 1997; He et al., 1997; Condit et al., 2000; Mangambu, 2002; Traissac, 2005; Boyemba, 2011; Lomba; 2011; Menga, 2011; Katusi, 2015; Adeito et al., 2018). But, for many species, these distributions cannot be interpreted from the characteristics of their ecology (soil structures, diaspore projection distances etc.) (Collinet, 1997; Boyemba, 2011; Katusi, 2015), but seem to be related to the interaction results of many mechanisms (He et al, 1997). It should also be well stated that there are relationships between the spatial distribution of trees and certain

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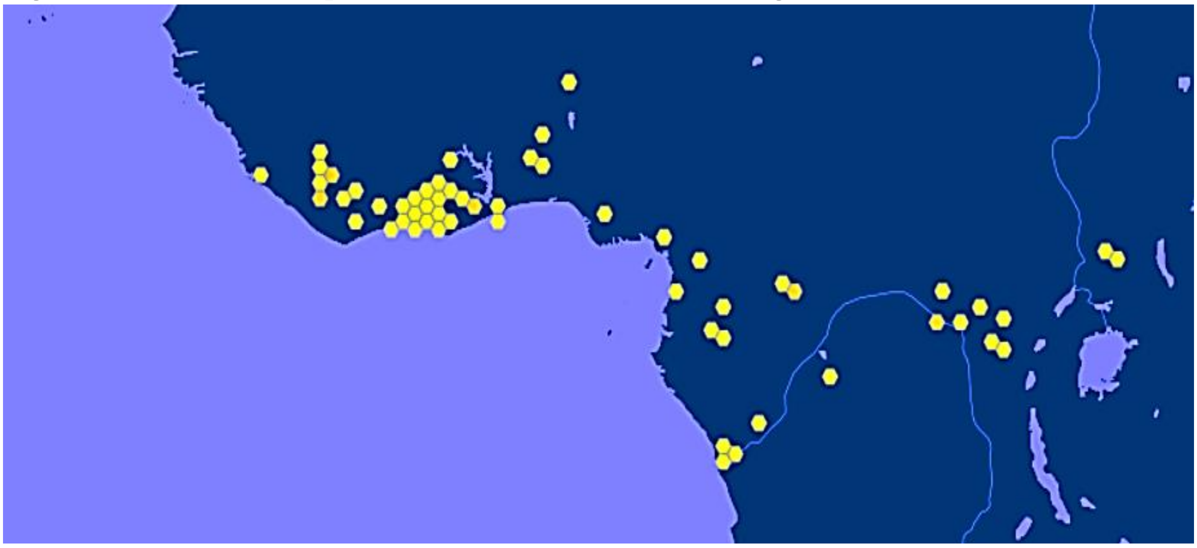
environmental factors, such as light, fertility, and topographic features (Gartlan et al., 1986; Newbery et al., 1986; Baillie et al. 1987; Ashton et al. 2005; Chen et al. 1997; Hubbell et al. 1999; Harms et al. 2001; Hall et al. 2004; Traissac 2005; Jones et al. 2006).

The present study focuses on the demography, diametric structure, and the dispersal of *Guarea cedrata* individuals as well as the interactions between different categories of trees that compose it. *Guarea cedrata* belongs to the subfamily of Melioideae, tribe Guareeae, and appears to be closely related to *Turraeanthus*, which is distinguished by its petals fused to the staminal tube, occurring from Sierra Leone to Uganda, and southward to Gabon and the D.R. Congo (Wilks & Issembe, 2000).

In the field, new leaf shoots are pinkish red in color. Ripe fruits often form at the beginning of the dry season. Seed dissemination is by birds (e.g., hornbills), monkeys, duikers, and porcupines, which feed on the fleshy seed coat (Siepel et al, 2004; De la Mensbruge, 2017, Dibi et al., 2018).

The heartwood is pale pinkish brown at the time of cutting, darkening on exposure to become reddish brown. The minimum exploitable diameter (MED) is 60 cm in Côte d'Ivoire and R.D Congo, 70 cm in Central Africa, and 80 cm in Cameroon and Liberia (CIRAD, 2018). *Guarea cedrata* is valued in home construction, flooring, joinery, interior woodwork, panels, window frames, doors, shipbuilding, vehicle frames, furniture manifacture, cabinetry, decorative boxes, crates, veneers, and plywood (Jiofack-Tafokou, 2018). The decoction or maceration of the bark is taken against stomach aches, food poisoning, and gonorrhea, and as a lotion for kidney pain, postpartum haemorrhage, rheumatism, and leprosy (Neuwinger, 2018). The species is sometimes spared during forest clearing for its use as a shade tree in coffee and cocoa plantations, for example in Cameroon (Hawthorne & Jongkind, 2016).

Figure 1: Distribution map of *Guarea cedrata* (A. Chev.) Pellegr. (Meliaceae)



Source : https://www.gbif.org/fr/species/8252209

During the course of the study, various questions were addressed, including: (i) are the diametric structures of *G. cedrata* individuals the same within two reserves? Are the individuals of this species spatially distributed in the same way within these reserves? And finally, are the positions of the poles dependent on those of the stands within the reserves?

The specific objectives of this study are to characterize: (i) the diametric structures of *G. cedrata* individuals; (ii) their spatial distributions; and finally, (iii) to verify whether or not there is

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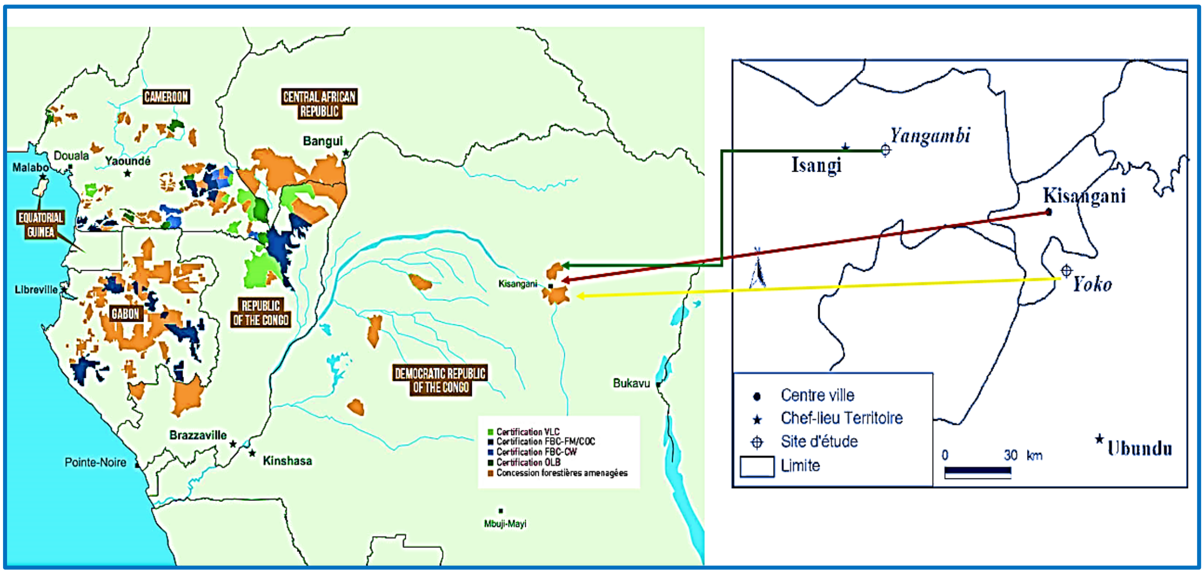
dependence between the positions of the perches and the stands within two reserves.

MATERIALS AND METHODS

Study Sites

The studies were conducted on two sites near Kisangani in one at Yangambi located in the territory of Isangi, 100 km west of the city, between 0° 38' and 1° 10' N, 24° 16' and 25° 08' E, and the other at Yoko located in the Ubundu territory, 32 km southeast of Kisangani, between 0° 15' and 0° 20' N, 25° 14' and 25° 20' E (Boyemba, 2011; Katusi et al., 2021) (*Figure 1*). Located in the equatorial zone, both sites enjoy an equatorial climate with an average monthly temperature ranging from 22.4 to 29.3 °C, with an annual average near 25 °C, and annual rainfall ranging from 1500 to 2000 mm, with an average of 1750 mm (Mangambu, 2002).

Figure 2: Location of two sites in relation to the city of Kisangani



The tropical forest of the Congo Basin, also known as the "second green lung" of the planet, after the Amazon (https://www.atibt.org/fr/media/35/cartographie-des-forets-tropicales-dans-le-bassin-du-congo).

The Survey

Two devices of two hundred hectares each were installed, one in Yangambi Biosphere Reserve and the other in Yoko Forest Reserve. All *G. cedrata* individuals with a dhp ≥10 cm at 1.30 m above ground were inventoried, and their x and y Cartesian coordinates were taken (Boyemba, 2011; Katusi, 2015; Adeito et al., 2018; Katusi et al., 2021).

$$L(r) = \sqrt{\frac{K(r)}{\pi}} - r$$

With K(r): Ripley function, r: radius of the aggregates and π: 3.14. Aggregate ($L(r) > 0$) and regular ($L(r) < 0$) processes, the curves lie above and below the confidence envelope, respectively. For a random process (following a Poisson distribution), $L(r) = 0$ at all distances from r, and the L(r) curve remains within the confidence interval. The confidence interval is calculated at a 5% risk, from 100 simulations, by the Monte Carlo method (Pelissier & Goreaud, 2001). The analysis is made possible from mapped data of different stands of *Guarea cedrata* (diameter ≥ 10 cm) using Cartesian coordinates x, y

For the spatial dependence between perches and stands, the intertype method of Traissac (2005) was applied to analyse the relationships between individual categories. The hypothesis tested focuses on the independence of the two distributions. The principle is derived from Ripley's method (1977) and the calculation is based on the function K12fun of the package ads, using the software R version 2.5, according to the equation:

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$$\hat{L}_{12}(r) = \sqrt{\frac{\hat{K}_{12}(r)}{\pi}} - r$$

Like K(r), the function K1.2 (r) is interpreted by the function L1.2 (r) (Besag, 1977; Goreaud, 2000): L1.2 (r) = 0 reflects independence between perches and stands (curve passes within the confidence envelope); L1.2 (r) > 0 reflects attraction between perches and stands (curve passes above the confidence envelope) and conversely L1.2 (r) < 0 corresponds to the "repulsion" between perches and stands (curve passes below the confidence envelope).

RESULTS

Density

Over the two sites, 105 individuals, or 0.525 feet/ha were counted at Yangambi (including 60 individuals from the perches, or 0.3 feet/ha: 0.185 ft/ha for perch 1 and 0.115 ft/ha for perch 2 and 45 trees or 0.23 ft/ha) and 72 individuals, or 0.36 ft/ha at Yoko (54 perch individuals, or 0.27 ft/ha: 0.18 ft/ha for perch 1 and 0.09 for perch 2 and 18 trees, or 0.09 ft/ha) (*Table 1*). Using the Chi-square test to compare the density of different tree categories within two reserves, there is a significant difference (χ^2= 136; dl = 2, p-value = 0.04 < 0.05).

Table 1: Population densities of *Guarea cedrata*

Sites	Area (ha)	dhp	Workforce	Density (N ind./ha)
Yangambi	200	10 cm ≤ dhp < 30 cm	37	0,185
		30 cm ≤ dhp < 60 cm	23	0,115
		dhp ≥ 60 cm	45	0,225
		Total	105	0,525
Yoko	200	10 cm ≤ dhp < 30 cm	36	0,180
		30 cm ≤ dhp < 60 cm	18	0,09
		dhp ≥ 60 cm	18	0,09
		Total	72	0,36

perch1 (10 cm ≤ dhp < 30 cm); perch 2 (30 cm ≤ dhp < 60 cm) and futa? (dhp ≥ 60 cm) on the study sites; dhp (diameter at breast height); N ind = number of individuals, and ha: hectare.

From *Table 1*, it can be observed that the density of trees is almost 1.5 times higher in Yangambi than in Yoko.

Tree Diameter

Large diameter individuals are more observed in Yangambi than in Yoko. The highest extreme values of the dhp are 152.9 cm in Yangami, and 111.5 cm in Yoko. The minimum values are 10.3 cm in Yangambi and 10 cm in Yoko respectively. Across the two sites, *Figure 3* shows that 50% of *G. cedrata* individuals have dhp varying between 32 and 80 cm in Yangambi, and from 20 and 50 cm in Yoko. Applying the Wilcoxon test (W) to compare the mean diameters of *G. cedrata* individuals within two reserves, a highly significant difference (Wilcoxon: W = 4658.5; p= 0.009 < 0.01) is observed (see *Figure 3*).

The box represents the interval in which 50% of the basal areas are clustered and the thick bar inside the box indicates the median basal area; the bar below indicates the minimum basal area, while the bar above indicates the maximum basal area. The point underneath represents the extreme upper value in relation to the mean basal area and is not taken into account.

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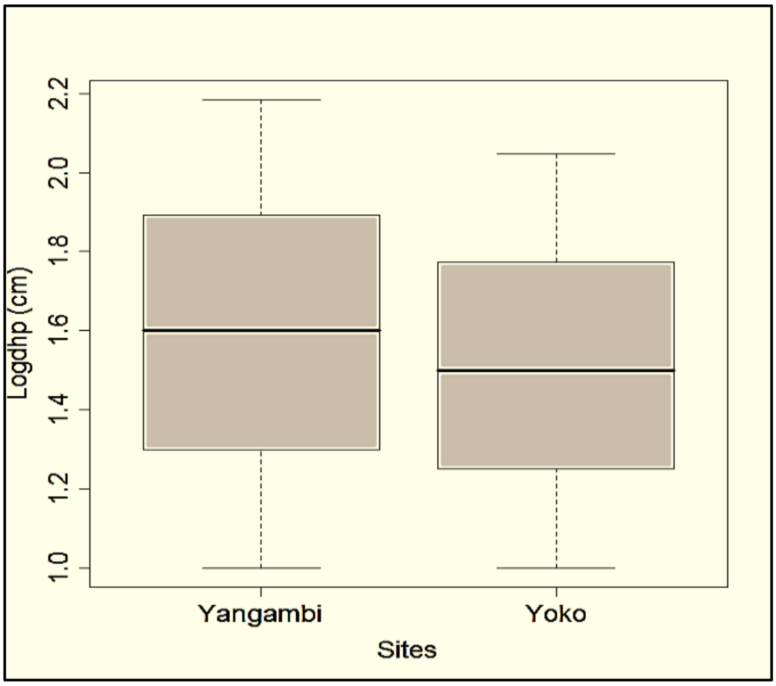
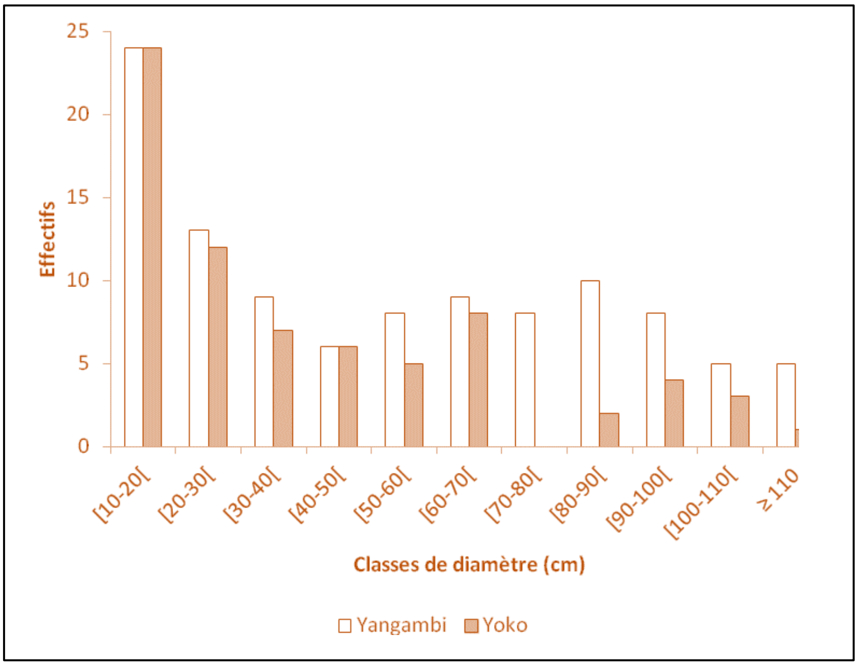
Figure 3: Dispersion of basal area values of *Guarea cedrata* individuals in different diameter classes



Diametric Structure

Both diametric structures are in a stretched "S" pattern, with the number of individuals decreasing to the [40-50[cm class with a first bump at the [50-60[cm class, and a second bump at the [80-90[cm class, and then decreasing thereafter at the Yangambi site. On the Yoko site, it decreases to the [50-60[cm class with a first bump at the [60-70[cm level and a second bump at the [90-100[cm level, and then decreases thereafter (*Figure 4*). To meet the requirements of the Chi-square (χ^2) test, individuals were grouped into 7 diameter classes instead of 11 classes. Applying the Chi-square (χ^2) test to compare the two diametric structures, there was observed no significant difference within two reserves ($\chi^2 = 9.9$; p= 0.013 > 0.05) in the two sites (See *Figure 4*).

Figure 4: Diametric distribution of *Guarea cedrata* populations at dhp ≥ 10 cm.



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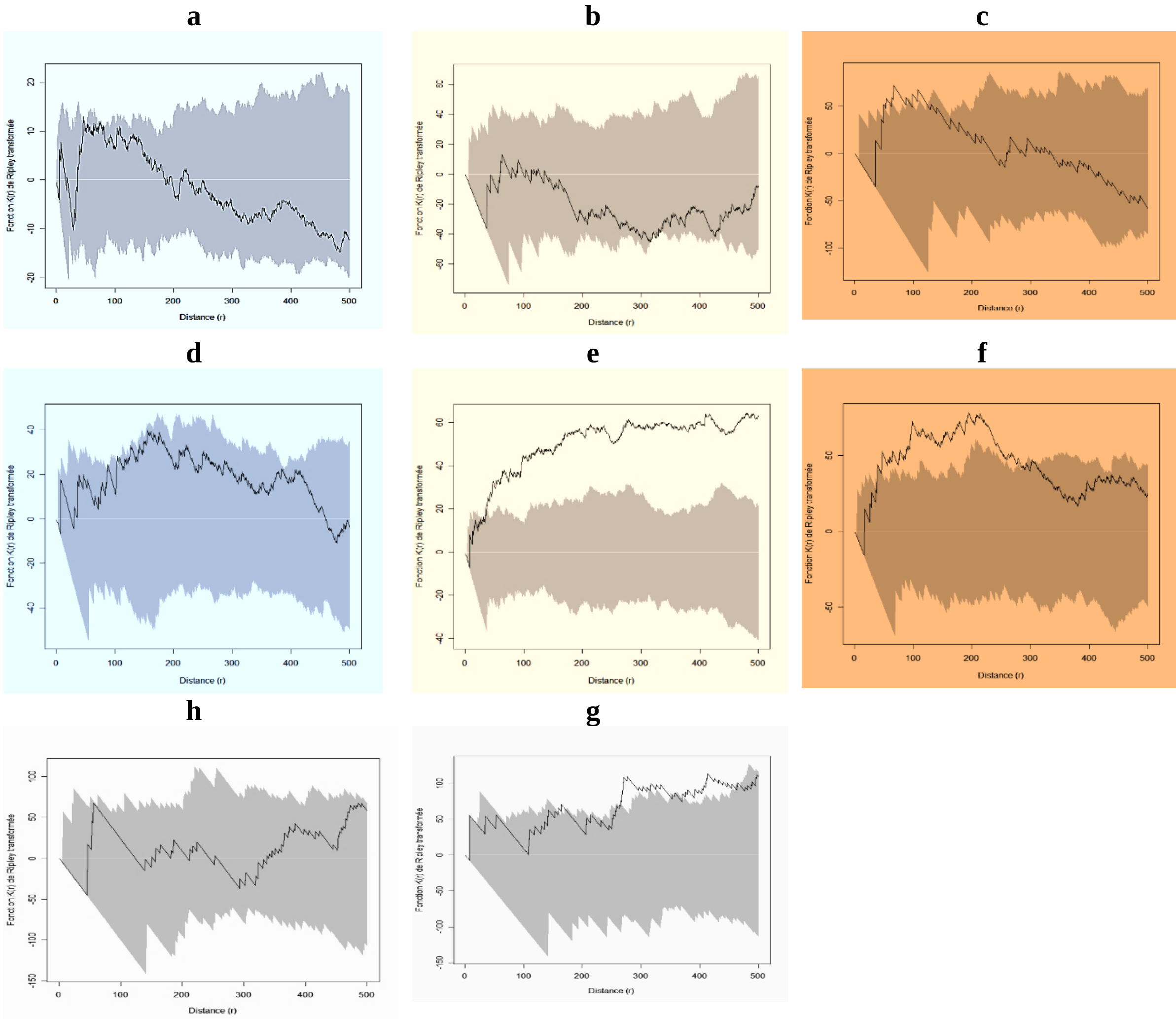
Spatial Characterization of Perches and Stands (Ripley's K (r) function)

The spatial distribution of all *G. cedrata* individuals at dhp ≥ 10 cm shows a random distribution at Yangambi (*Figure 5a*) while at Yoko, it is random from 0 to 50 m of analysed distance and then, aggregated beyond 50 m of analysed distance (K(r) > 25 m; *Figure 5e*).

When categorizing individuals, perch1 are significantly random throughout the analysis distance at Yangambi (*Figure 5b*) while at Yoko, they are random from 0 to 50 m and then 280 m to 500 m, and aggregated from 50 to 280 m of the analysis distance (K(r) > 50 m; *Figure 5f*). The perches 2 are random from 0 to 70 m and then from 130 m to 500 m while aggregated from 70 to 130 m of the analysis distance (K(r) > 50 m; *Figure 5c*) at Yangambi while at Yoko they are significantly random (*Figure 5g*). On the other hand, stands are significantly random in Yangambi (*Figure 5d*) while in Yoko, are random from 0 to 170 m and then from 190 to 280 m and finally, beyond 470 m and aggregated from 170 to 190 m and then from 280 to 470 m of the analysis distance (K (r) > 50 m (*Figure 5h*).

Figure 5: Transformed Ripley's K (r) function of *G. cedrata*



The K (r) curve shows a characteristic peak for a value of r approximately corresponding to the radius of the aggregates. The confidence interval of the null hypothesis (ash coloured) is calculated at the 5% risk of error, from 100 simulations, by the Monte Carlo method. The white line represents the theoretical curve and the black line the observed values of the function (a; b; c and d for the site_Yangambi and e; f; g and h for the site Yoko).

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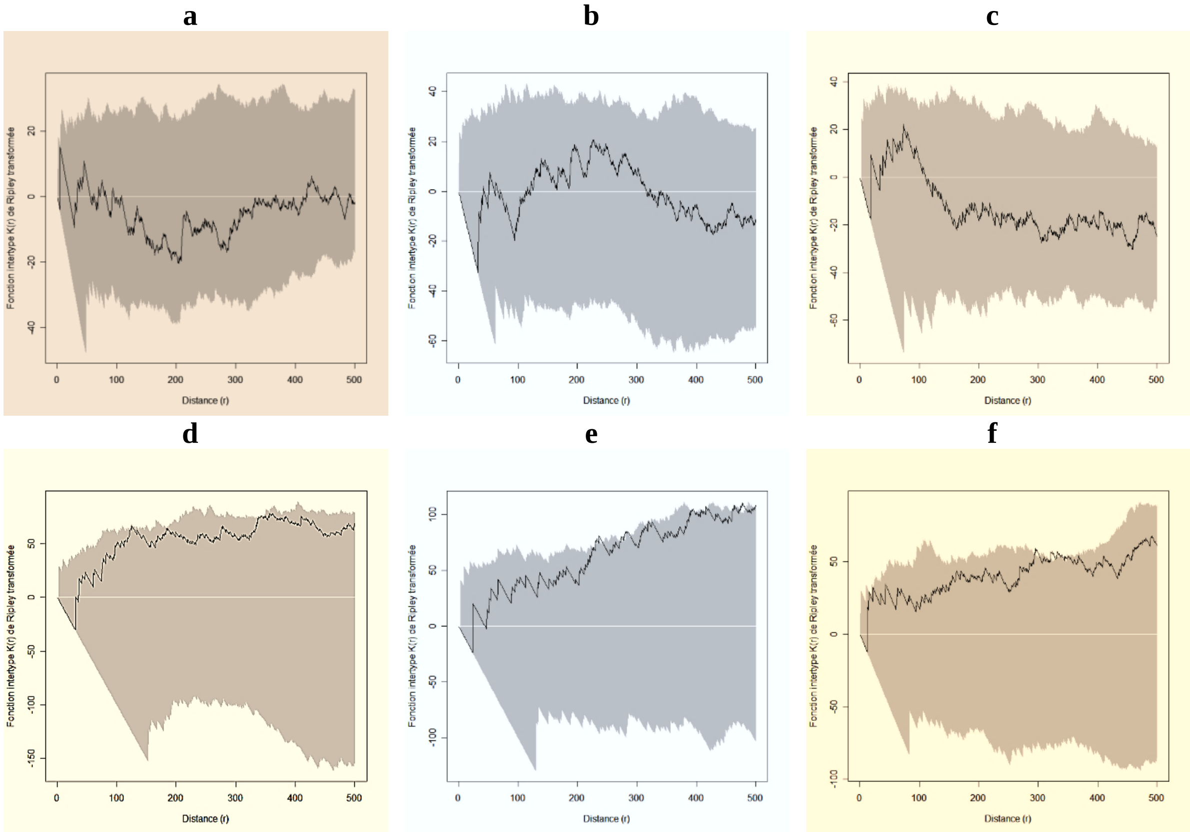
Spatial Relationship Between Perches and Stands (Ripley's K_{12} Function)

Under natural conditions in Yangambi, it can be observed that perches 1 are independent of the stands (*Figure 6a*) while in Yoko, we observe a tendency to attraction between 340 and 360 m radius, it is however difficult to conclude a significant dependence because the K12(r) curve almost merges with the upper limit of the confidence interval (*Figure 6d*). Between the perches 2 and the stands, there is some repulsion between 0 and 50 m radius in Yangambi (*Figure 6b*), while in Yoko between 0 and 20 m radius (*Figure 6e*); however, in both sites, it is difficult to conclude a significant repulsion because the K12(r) curves practically merge with the lower limit of the confidence interval.

But exceptionally, at Yoko, some attraction is observed between perch 2 and the forest stands at small analysis distances ranging from 240 to 250 m; 290 to 300 m and 470 to 485 m although the K12(r) curve merges with the upper limit of the confidence interval. Finally, between perch 1 and perch 2, there is some repulsion from 0 to 40 m radius at Yangambi (*Figure 6c*) while at Yoko, some attraction between 280-290 m and then from 340 to 360 m radius (*Figure 6f*). *The theoretical curve, the curve in black or the observed values of the function (a; b; c and d for the Yangambi site and e; f; g and h for the Yoko site)*

Figure 6: Intertype analysis of *Guarea cedrata* perch 1, perch 2, and groves in the inventory sites.



The black curve represents the observed values of the K1.2(r) index and the grey area represents the limits of the confidence interval of the null hypothesis (independence hypothesis) (a; b and c for Yangambi plot and e; f and g for Yoko plot).

DISCUSSION

Several plant species are threatened by habitat transformation, overexploitation, introduction of invasive alien species, pollution, and climate change, and are in danger of extinction. The disappearance of so much significant biological diversity represents one of the greatest challenges

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for the global community: to halt the depletion of plant diversity which is essential to meet present and future human needs.

The methodological approach applied to the present study has been evaluated as effective by several authors who addressed the same subject (Traissac, 2005; Picard, 2008). In addition to quantitative analyses including density, diametric structure and basal area, the methodological approach considered both the X and Y coordinates of each individual at dhp ≥ 10 cm. The approach therefore enabled the researcher to characterize the spatial distribution by Ripley's K(r) function on one side, and to appreciate the interactions between individuals of different categories (perch 1, perch 2 and futaies) through Ripley's K1.2 function on the other side.

Demographic Analysis

G. cedrata species is fairly widespread, but only occurs in low densities and is usually restricted to undisturbed forest. The species is listed as Vulnerable(V) on the IUCN Red List due to habitat loss and degradation, as well as selective logging. In general, exploitation levels are moderate but *G. cedrata* sometimes suffers from its similarity to other commercial species such as *Entandrophragma angolense* (Welw.) C.DC (Adeito et al., 2018).

Inventories of individuals with dbh ≥ 10 cm on an area of 200 ha successively in Yangambi and Yoko showed that the density is 0.36 stems/ha in Yoko and 0.525 stems/ha, or an average of 0.45 feet/ha. It should be noted that large individuals of *G. cedrata* are present only at low densities in the forest. For example, in Liberia, densities of less than 1 to 16 boles of more than 60 cm in diameter per km² have been observed. In some areas of Côte d'Ivoire, 1 harvestable tree per 12-16 ha was counted, and the average wood volume in Côte d'Ivoire forests is estimated to be 0.3 m³/ha. In southern Cameroon, the average density of *Guarea* spp. over 60 cm in diameter is 0.03-0.14 per ha. In Uganda, large individuals are uncommon, and in many areas, the individuals have become very rare (De La Mensbruge, 2017). These results corroborate the present study results on the demographic population of *G. cedrata* species in the forest massif around Kisangani.

By comparing present data with those of some exploited species from the 400 ha pre-inventory in Yoko (DRC) (Picard, 2008; Lomba, 2011), such as *Gilbertiodendron dewevrei* (5.69 stems/ha), *Prioria balsamifera* (3.0975 stems/ha), *Prioria oxyphylla* (2.6775 stems/ha), *Pterocarpus soyauxii* (0.9750 stems/ ha) and *Pericopsis elata* (0, 58 stems/ha), it was observed that *G. cedrata* is less represented than *Pericopsis elata* which is classified among the most endangered species by CITES (Boyemba, 2011). In Africa, Debroux (1998) evaluated the density of *Entandrophragma cylindricum* (3 stems/ha); Doucet (2003) and highlighted that of *Aucoumea klaineana* (4.2 stems/ha) and *Paraberlinia bifoliolata* (5.2 stems/ha) and Menga (2011), *Millettia laurentii* (2.8 stems/ha). From all these results, *G. cedrata* is a vulnerable species which survival requires a rational and sustainable exploitation.

Dendrometric Characterization

The only parameter used in the present study is the diameter taken at 1.30 m from the ground and not the different tree heights (bole height, butt height and crown height). The basal area is 0.0695 m²/ha in Yoko and 0.2407 m²/ha in Yangambi. From these different values, it has been observed that the individuals are on average larger in Yangambi than in Yoko. Indeed, these large diameters may be related to the early establishment of the stand in Yangambi (Forni, 1997). Similar results were observed by Menga et al. (2012) for the species *Millettia laurentii* in the Bandundu province of the Democratic Republic of the Congo.

As for the shape of the curve, individuals of *G. cedrata* show a "stretched S" structure within the two sites. This structure shows that the diametric distribution is balanced, i.e., we observe a decrease in numbers up to class 4, then a first hump with a peak at class 6, and a second hump with a peak at class 8 in the Yangambi site, while in the Yoko site, there is a drop in numbers up to class 5, then a first hump with a peak at class 6,

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with no number at class 7 and a second hump with a peak at class 9.

The presence of humps in a decreasing structure could be due to the variations in growth rates and mortality rates from one class to another (Debroux, 1998) and, young stems are generally quite well represented. This may explain, depending on the circumstances of each forest, that the structure of *G. cedrata* individuals can shift from an exponential curve (favourable conditions) to a bell-shaped curve (unfavourable conditions) (Demarquez, 2000; Degueret, 2002; Gorbert, 2002; Doucet, 2003; Katusi, 2015). This type of structure is characteristic of species that are less demanding of light in young stages, but nevertheless, require better light conditions at some stage of their development to reach their mature stage (Hawthorn, 1995; Doucet et al., 1996; Traissac, 2005; Kouadio, 2008; Katusi, 2015). These patterns reflect a kind of transition between moderate heliophilic and moderate sciaphilic character (Demarquez, 2000; Degueret, 2002; Doucet, 2003; Katusi et al., 2022b).

In other words, the seedlings of the *G. cedrata* species prefer to settle in the undergrowth until their growth is inhibited by lack of light and, according to Oldeman and Van Dijk, (1991), the species *G. cedrata* could be described as "strugglers". Similar results have been observed in Cameroon for *Baillonella toxisperma* (Debroux, 1998); in Gabon for the species *Paraberlinia bifoliota* (Marc, 2000; Doucet, 2003), *Afzelia bipendensis*, *Berlinia bracteosa*, *Entandrophragma cylindricum, Hallea ledermannii, Khaya ivorense, Prioria oxyphylla* and *Pterocarpus soyauxii* (Doucet, 2003) and in Paracou for *Qualea rosea* (Gourlet-Fleury, 2000).

Spatial Characterization

The spread of diaspores partly influences the spatial distribution of several species Gautier-Hion et al, 1985; Cabrera & Gignoux, 1990; Loubry, 1993; 1994; Collinet , 1997; Menga, 2011), to their natural regeneration modality (Puig et al., 1989; Bariteau,1993; Ribbens et al., 1994 Pascal, 1995; Boyemba, 2011), micro-environmental conditions (Puig et al., 1989; Sabatien et al., 1997; Clark et al., 1998; Condit et al., 2000) and soil structures (Forget, 1988; Puig et al, 1989; Barthes, 1991; Boyemba 2011; Katusi, 2015) that are sometimes susceptible to large variations over short distances (Darrieu De Madron, 1989; Koukou, 1994; Katusi et al., 2022a).

In the present study, the spatial characterization of *Guarea* individuals is heterogeneous within the two study sites. It is significantly aggregated in Yoko, while random in Yangambi. This difference is thought to be related to the topography of the terrain, which is more rugged in Yoko than in Yangambi where almost the entire study area is on the plateau. Similar result was observed on *Millettia laurentii* (Menga, 2011) where the species is either aggregated in some plots; aggregated and random and significantly random in others. However, significantly heterogeneous aggregated spatial structure over a range including the maximum analysis distance (*Figure 6e*) was observed in species such as *Virola micheli, Discoryna guianensis and Qualea rosea* (Flores, 2005), *Pericopsis elata* (Picard 2008; Boyemba, 2011; Lomba, 2011).

Individual Size Affects Repair and Spatial Interaction

Apart from the spatial distribution of all individuals with dhp ≥ 10 cm (Cf *Figures 5a and 4e*), the aggregation or not of species would be related to the size of the individuals that compose them. As a reminder, Guarea individuals were grouped into three tree categories namely, perch 1 (10 cm ≤ dhp < 30 cm); perch 2 (30 cm ≤ dhp < 60 cm) and finally, futaies (dhp ≥ 60 cm). Using Ripley's K (r) function to characterize each category of trees and this to allow to verify the influence of each of them on the establishment of aggregates or not within two sites. By considering first, all the individuals with dhp ≥ 10 cm of *G. cedrata* within the site of Yangambi, we observed that they are distributed in a random way. But by categorizing them, one could detect that, the perches 2 present an aggregation at small scale of analysis (Cf *Figure 5c*) and which, is marked by

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the distribution of the perches 1 and stands (Cf *Figures 5b and 4d*) while in Yoko, the perches 2 are distributed in a random way (Cf *Figure 6g*). But this distribution is masked by those of the perches 1 and the stands which are aggregated (Cf *Figures 5f and 5h)*.

Using Ripley's K1.2 (r) function to test for independence, interaction and/or repulsion of different categories of trees, it could be largely observed that the positions of different categories of trees were independent of each other. However, some interactions were observed between tree categories (see *Figures 6d* and *6e)* and repulsions (see *Figures 6b* and *6e*) at small scales, although in most cases, the curves merge with the confidence intervals.

CONCLUSION

The recurrent exploitation of plant species for the production of timber, handicrafts, and the various constructions of houses by the riparian populations and the installation of agricultural plots, have strongly disturbed the flora and woody vegetation of the forest of two reserves where the present study was carried out in the central basin in the province of Tshopo in DR Congo. In the Yangambi Biosphere Reserve, the management of this forest is based on the enrichment of certain zones by the creation of forest plantations based on silvicultural techniques, has strongly further contributed to the disturbance. All these anthropogenic actions have led to an impoverishment of the woody plant community.

The study showed that the density of *G. cedrata* populations is much higher in Yangambi than in Yoko and the same is true for the basal area value. Diameter averages showed that individuals are larger in Yangambi than in Yoko and the diametric structures are "stretched S", characteristic of good regeneration in both reserves. Spatial distribution is aggregated at Yoko while it is random at Yangambi. In general, the positions of perches and stands within the two reserves are independent each other; however, there is some dependence at small scales of analysis.

Based on the results of the present study, human activities constitute a real threat to the preservation of natural resources and the biodiversity in this forest formation. The overexploitation of such species has led to the scarcity of seed trees and, consequently, to a decrease in seed production causing a real problem of regeneration within this forest massif. In addition, a call on the leaders of the Democratic Republic of the Congo (DRC) to fully participate in the international approach of sustainable management of forest ecosystems and the fight against poverty through the legislation of the management of production forests, because one of its objectives is the sustainable development and the improvement of the living conditions of local communities, with respect of their rights to use biodiversity within the framework of a sustainable management of forest resources.

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