

## Spatial structure and interactions inter-and intragrowth stages of *Milicia excelsa* (Welw.) C. C. Berg (Iroko) in the semi-deciduous forest, north-east of Democratic Republic of Congo

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**ABSTRACT:** This study aims to analyse spatial distribution and interactions that can exist between different Growth stages of *Milicia excelsa* (Iroko) and also, between its seedlings and adults of other species in order to provide to forest managers a tool for sustainable management of the natural population of this species. A full inventory was carried out in a semi-deciduous and anthropized forest of Central Africa in the north-east of DR Congo in six hectares with the Cartesian coordinates of all tree individual species taken. Data from this inventory were encoded and statistically analysed using the «ads» package of R Software to determine the point processes observed in this habitat. Results showed that Iroko trees have a random spatial distribution with low aggregations in the ecosystem. Individuals of the same growth stage live in aggregate while those of different growth stage have negative interactions (Competition - repulsion) on non-negligible radius. The diametric structure of its individuals is well balanced but showing a regeneration significantly low.

**KEYWORDS:** Spatial structure, interactions, Growth stages, *Milicia excelsa*, Iroko.

### 1 INTRODUCTION

Increasing degradation of tropical landscapes and the erosion of their biodiversity are currently one of the most crucial environmental problems. Scientists are concerned about this threatening degradation to tropical forests because of their importance in providing both ecological services and functions (production of wood, Non-Timber Forest Products, Carbon sequestration, etc.) that these ecosystems play [1].

According to [2, 3], 200 million hectares of forest are located in the Congo Basin. About 57% of this is covered by tropical rainforest, the second largest tropical forest area in the world after Amazonia. In DR Congo, these forests covered 99 million hectares, or 67% of the national territory with an area of approximately 2 345 000 km<sup>2</sup>. This accounts for 60% of all forests in the Congo Basin [4].

But, it happens that about 83% of these DR Congo's forests are production forests, representing 65% of all Congo Basin production forests. Thus, commercial species have been intensively exploited in the last two decades [5]. Satellite monitoring data have shown that annual rate of deforestation and degradation have doubled in the Congo Basin since 1990 and there is evidence that forests in the basin may reach high rate of deforestation and forest degradation [6].

The sustainable management and preservation of these tropical rainforests is therefore greatly needed and therefore requires a good understanding of their functioning. All solutions which may be proposed today for conserving these forests, such as the setting up of biological reserves, sustainable logging, restoration of degraded forests, etc., necessitates information on the ecology and dynamic of forests populations in these ecosystems [3]. This dynamic integrates over time regeneration processes and can be describe by the diametric structure in their population cluster and range and can also be influenced by interactions between generations [7].

According to [8], the spatial structure of species shows the spatial arrangement of individuals in the forest and constitutes the main theme in forest ecology. Hence t spatial structure analysis can be used in forests descriptions and also gives a general view of population dynamic. Understanding the spatial structure of trees in heterogeneous forests leads to better knowledge of ecosystems and ecological

processes that are involved. Spatial information for each species is vital for foresters a to improve management strategies and / or conservation of tropical species.

About 34 species are logged yearly for timber in DR Congo, of which *Pericopsis elata* (Harms) Van Meeuwen (Afrommosia); *Entandrophragma cylindricum* Sprague (Sapelli) and *Milicia excelsa* (Welw.) C.C. Berg are one of the most important commercial trees in Africa [9].

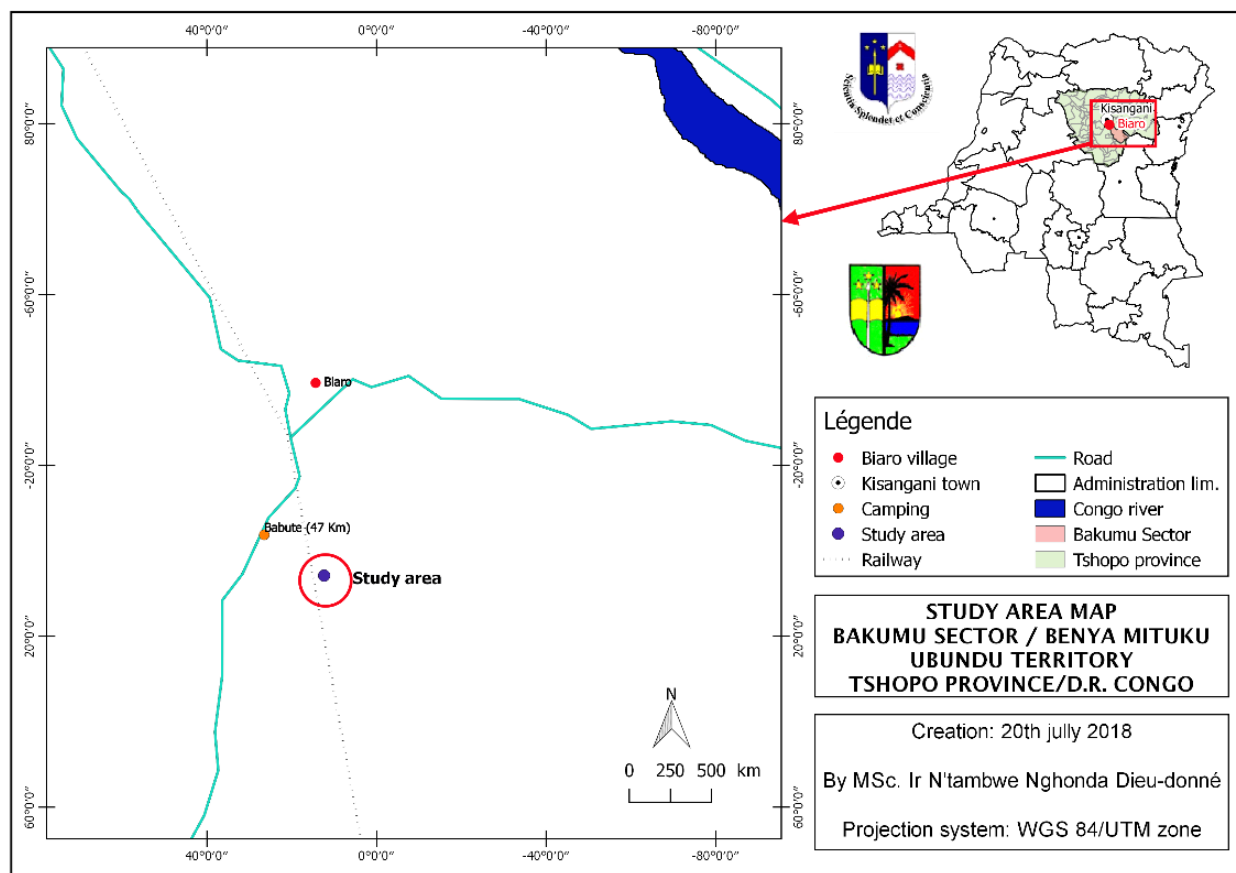
*Milicia excelsa*, has been one of the most logged species for timber which warrant it to be added to IUCN Red List in 1994 as a endangered species. Restrictions and special laws were therefore put against it logging and commercialisation [10]. From 1998 to the present, this species has been considered as in danger of extinction [11]. From the family of *Moraceae*, this species is not widely studied despite its economic importance (i.e for bridges and railings constructions carpentry) and several functions are also derived from it (cultural, medicinal...). Scientific research on it is still fragmentary and several points poorly described. So far literature review shows that existing studies on it are mainly conducted in west and east African countries while Central Africa remains behind, as long as this region is considered today like the main region logging it [3].

The present study therefore aimed to analyze the spatial distribution and interactions that exist between Iroko growth stages; also, between its seedlings and adults' individuals of other species to provide to forest managers a useful tool in support of sustainable population management of this species. Specific objectives are: to determine the spatial structure of each growth stage of Iroko; to analyze the spatial relationships that may exist between the different development stage of the species, and between Iroko population and other tree species by analysing point-process.

## 2 MATERIALS AND METHODS

### 2.1 STUDY AREA

The present study was conducted in a semi-deciduous forest of Central Africa at Biaro, 47 km from Kisangani. It's about 2 km of Babute village, crossing the railway. This forest is located on Ubundu Road, Bakumu-Mangongo Community, Ubundu Territory, Tshopo Province, Democratic Republic of Congo (Figure 1).



**Fig. 1. Localization of the study area**

## 2.2 DATA COLLECTING

A full inventory of all species was carried out on 6 hectares of land which were subdivided into 6 plots of 100 m x 100 m of side, in where trees with DBH  $\geq 10$  cm were measured and their Cartesian coordinates (x) and (y) taken according to Picard and Gourlet-Fleury's model [12] (Figure 2). Seedlings of *M. excelsa* were also inventoried in the underbrush (individuals at  $0 < \text{DBH} < 10$  cm) with their Cartesian coordinates taken. These were classified in S1: Seedlings within 0 - 30 cm of high; S2: Seedlings within 30 - 50 cm; S3: seedlings within 50 - 100 cm; S4: Stem at height  $> 100$  cm to DBH  $< 1$  cm; S5: Stem with  $1 \text{ cm} \leq \text{DBH} < 10$  cm (Installed seedlings).

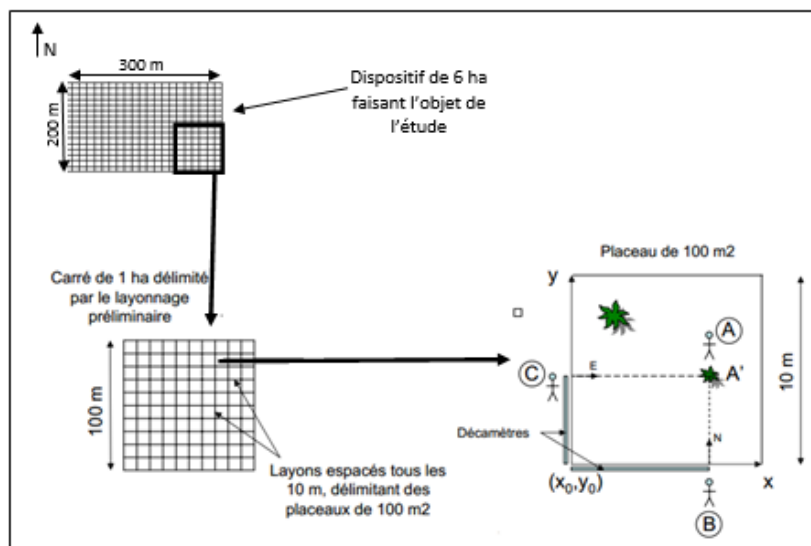


Fig. 2. Illustration of the adapted of Picard and Gourlet-Fleury's model

Source: Picard and Gourlet-Fleury [12]

## 2.3 DATA ANALYSIS

Diametric structure of *M. excelsa*'s population was determined by grouping its individuals in ten-digit classes' interval. Its relative density was estimated by the relation:  $(ne/N) * 100$  where  $ne$  is the number of trees of the species and  $N$  the total number of trees in the plot. Relative frequency was determinate by the ratio  $(fe/Ft) * 100$  while its basal area (AGB) was calculated from the relation:  $(n * \pi D^2) / 4$ . Where  $n$  is the total number of individuals of each species  $\text{ha}^{-1}$  and  $D$  the sum of their diameters at 1.30 m height.

Spatial structure of each growth stages was determined using Ripley's Function  $K(r)$  [13] and her Besag's derived function  $L(r)$  [14]. Three growth stages of Iroko were differentiated by their DBH: Seedlings ( $1 \text{ cm} \leq \text{DBH} < 10$  cm); adults ( $10 \text{ cm} \leq \text{DBH} < 25$ ) and potential Seed-bearers ( $\text{DBH} \geq 25$  cm).  $L_{12}(r)$  derived function from the Ripley's  $K_{12}(r)$  intertype function was used to analyze interactions between growth stages of individuals in the same species, also between *M. excelsa*'s seedlings and individuals of other species. These analyses were done using "ads" package of R Software. 1000 Monte Carlo's simulations were done with 1% of error (99% of confidence level).

## 3 RESULTS AND DISCUSSION

### 3.1 FLORISTIC AND DENDROMETRIC CHARACTERISTICS

Two thousand eight-three individuals of different species were inventoried, for 146 species, 111 genera and 35 families. The highest density was 372 individuals  $\text{ha}^{-1}$  found in hectare 4; the lowest was 300 individuals  $\text{ha}^{-1}$  found in hectare 2, with an average of  $347.17 \pm 24.37$  individuals  $\text{ha}^{-1}$ . Among 2083 individuals, 59 individuals of *M. excelsa* were inventoried of which 15 potential seed-bearers, 17 adults and 27 seedlings.

Considering individuals of Iroko with a  $\text{DBH} \geq 10$  cm, a diametric structure in inverted J was observed. When seedlings are included, this species shows a bimodal situation (Figure 3). The diametric structure of seedlings was low in number compared to other upper classes, and shows that the species could regenerate if its required ecological conditions are met, and when ecological conditions became hostile, the regeneration was scarce. Iroko is represented at only 1.54% on the 100% of overall species, with a relative density and a relative frequency of  $1.58 \pm 0.68\%$  and 1, 63% respectively; her basal area of  $0.52 \pm 0.46 \text{ m}^2 \text{ha}^{-1}$  for  $27.03 \text{ m}^2$  in 6 ha overall.

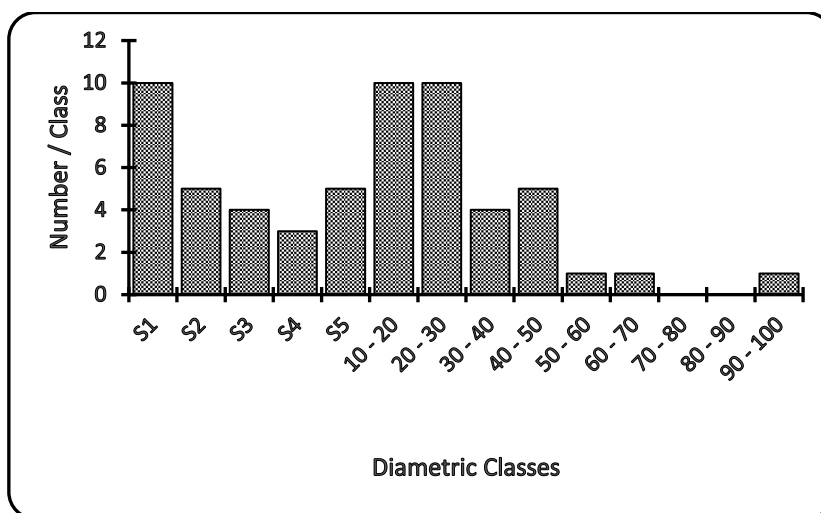


Fig. 3. Diametric structure of *Milicia excelsa*. S1: seedlings within 0 - 30 cm height; S2: seedlings within 30 - 50 cm; S3: seedlings within 50 - 100 cm; S4: Stem at height > 100 cm to DBH <1cm; S5: Stem with 1 cm ≤ DBH <10 cm (Installed seedlings)

Considering individuals with DBH ≥ 10 cm, *M. excelsa* showed a curve with inverted J; with a large number of trees in lower diametric classes. This might prove a relay of seedlings to adults, which would guarantee the survival of the species in this habitat. These results are similar to [15, 16, 17]; who also conducted their study on *M. excelsa*. In contrast to [18] who indicated that this type of distribution mainly concerns struggler species (producing regularly a large number of seedlings). This author goes further saying that gamblers species with regeneration related to windfalls, can only have a discontinuous recruitment and their populations are organized in cohort, thus presenting a diametric distribution in bell-shape or bimodal. How then, can hard-gambler species, like Iroko, show an inverted J distribution curve? This situation would be justified by intense anthropic activities and windfalls, which would clear the underbrush and promote Iroko's regeneration in particular and other gamblers species in general. [19], argues that anthropic actions (selective cutting, forest degradation by fragmentation, slash-and-burn agriculture), may cause disturbance in balanced forest ecosystem by generating different distributions than in natural conditions. The overall results of *M. excelsa* (including seedlings) show that the number of its seedlings, in particular those installed (S5), was very low. Projecting future diametric growth and the passage of individuals from lower classes to higher classes (In the hypothesis of low perturbations of current environmental factors, so that the forest tends towards the climax), the curve line of its diametric structure would tend to the bell-shape. The low number of regenerates might be justified by the abundance of *Marantaceae* in this community, which would block seed germination and survival of Iroko's seedlings by their roots and shade they bring, as stipulated by [17, 20, 21]. [22], argue that seedlings of gambler species such as *M. excelsa* survive only in large gaps and area receiving more sunlight. [23], demonstrated that in the underbrush, seedlings of gambler species hardly survive three weeks after their shooting, due to attacks and sunlight insufficient. The obtained relative frequency and relative density for *M. excelsa* are respectively 1.63% and  $1.58 \pm 0.68\%$ . These values were very low compared to the relative frequency and relative density of other species found in the study area; This relative frequency is higher than those found by [17, 19] who conducted their study in the same zone, it being 0.74% to 0.98% and 0.58% respectively. The relative density is far higher to that found by [17], it being 0.289%, higher than that of [19], it being 0.74% and 0.98%. Differences observed for these two parameters could be explained by biotic and abiotic environmental factors which would allow the installation of the large number of *M. excelsa* individuals in the studied area also by the total number of trees inventoried and the area width. [24], found that Iroko density decreases from primary to fallow forest. This could be due to ecological factors (amount of sunlight reaching the ground, competition). The basal area occupied by it, is  $0.52 \pm 0.46 \text{ m}^2 \text{ ha}^{-1}$ . [23] found different values according to the samplings area, it being 0.13 and  $0.17 \text{ m}^2 \text{ ha}^{-1}$  and [19] found 0.41 and  $3.02 \text{ m}^2 \text{ ha}^{-1}$ . This basal area is clearly higher than that of the former, but intermediary to the latter. Moreover, it's function of the number of individuals and especially the diametric values measured for the same species.

### 3.2 POINT PROCESSES IN PLANT COMMUNITY

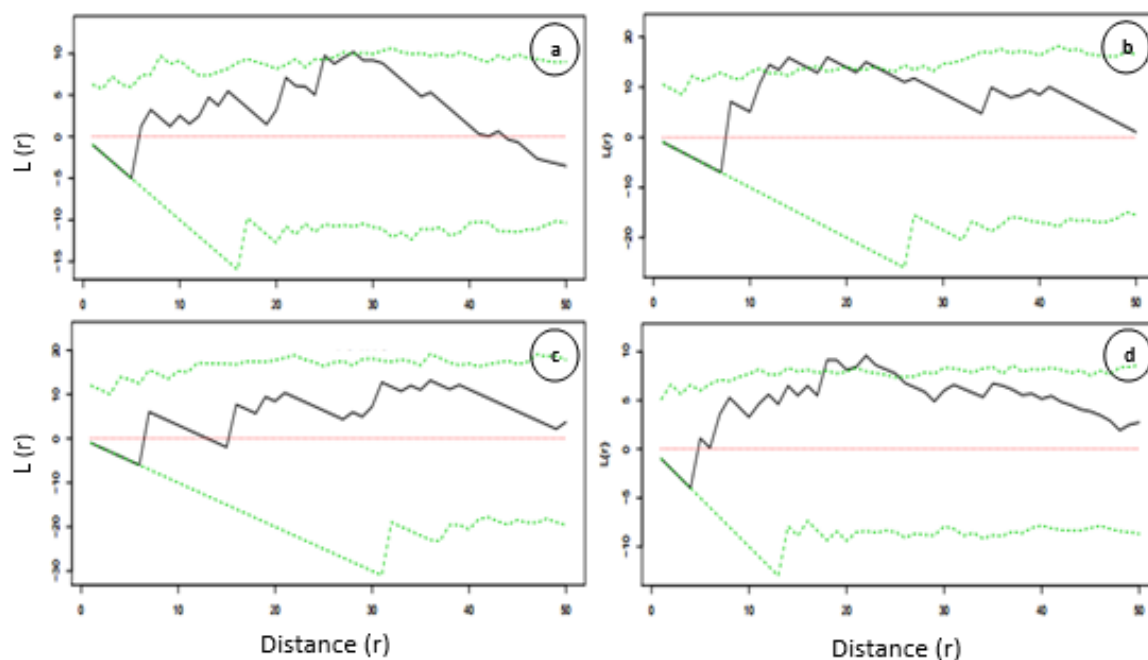
The figure 4 below was made from Cartesian data collected in the field and shows that, some areas have high density of trees and other areas with low or roughly zero density. *M. excelsa*'s trees present some aggregates when they should be considered as a whole without distinction of growth stages, and they are mainly found in lit areas.



Fig. 4. Spatial distribution of all inventoried trees and Iroko's trees according to their distributions in different stages of development. The dimensions of the study plot are expressed in meters

### 3.2.1 SPATIAL DISTRIBUTION OF MILICIA EXCELSA INDIVIDUALS

Generally, different growth stages of *Milicia excelsa* have a random spatial distribution on the whole of the study plot. Seedlings showed a relative aggregation in a circle of 25 m radius, with a maximum deviation distance and a deviation value near zero (Figure 5a). For adults, aggregates are clearly visible in three ranges of radius: between 12 and 16 m; 18 and 20 m, and between 21 and 22 m (Figure 5b); the maximum deviation distance was 19 m, with a deviation value of about 2. Seed-bearers show also a random spatial distribution (Figure 5c). The curve line of *M. excelsa* individuals with a DBH  $\geq 10$  cm shows a random spatial distribution over the whole of the study plot, an aggregation appears when considering a range of radius between 18 and 25 m; the maximum deviation distance being 22 m with a deviation of at least 2.5 (Figure 5d).



**Fig. 5.** Spatial distribution of Iroko (a): distribution of seedlings, (b): adults, (c): seed-bearers, and (d): All Iroko's trees with DBH  $\geq 10$  cm. Black lines show the estimate of  $L(r)$  for the cloud of points considered; Green lines represent 99% confidence level under the null hypothesis of random distribution; Dashed red lines show the theoretical value of  $L(r)$  under the null hypothesis; The distance ( $r$ ) is in meters

Different growth stages of this species generally have a random spatial distribution over the whole of the study's plot; with low aggregation levels, even when individuals with DBH  $\geq 10$  cm are taken together. This results do not corroborate those of [17, 25] who worked respectively on *M. excelsa* and *Pterocarpus erinaceus* Poir., and found that these two gambler species are gregarious. This divergence may be explained by the maturation of the habitat; the confidence level rate used when analysing data. [8, 18] showed that the spatial structure of the population results from its own structure related to its mode of dissemination, its response to environmental conditions and its interactions with other species. [19], reported that it's not excluded that a species shows an intermediate distribution if the forest is still growing, but at the climax, it going to show its real distribution; furthermore he added that the mature forest is composed of trees which have already reached their maximum development and all competitive interactions have already taken place. In addition, [26] suggested that *M. excelsa* is a non-gregarious species.

### 3.2.2 INTRA-SPECIFIC (MILICIA EXCELSA) AND INTERSPECIFIC INTERACTIONS

It is observed that individuals of the same growth stage and in each growth, stage live in attraction on a short radius especially in stark independence. In the seedling growth stage, an attraction is observed in a radius varying between 0 to 11 m with a relativity between 20 and 37 m (Figure 6a). This situation is almost similar to other growth stages, but with a clear attraction range in adult growth stage, with a radius varying from 0 to 30 m (Figure 6b).

By analyzing curves lines (Figures 7a, 7b and 7c), it appears that seedlings have a very high degree of independence in comparison of adults and seed-bearers. The same situation was also observed between adults and seed-bearers. However, a clear repulsion, showing negative competitions on the rare resources of the biotope has been observed on a scope of 13 m, 6 m, 4 m, respectively between seedlings - adults and; seedlings - seed-bearers, and between adults - seed-bearers. Concerning interaction between Iroko's seedlings and others trees species, a clear repulsive interaction has been observed. This cohabitation results in competition of other adult species on *Milicia excelsa*'s seedlings, in a radius going to 0 until 4 m, with a deviation of 0.4 (Figure 7d). Outside this interval, trees live in complete independence.

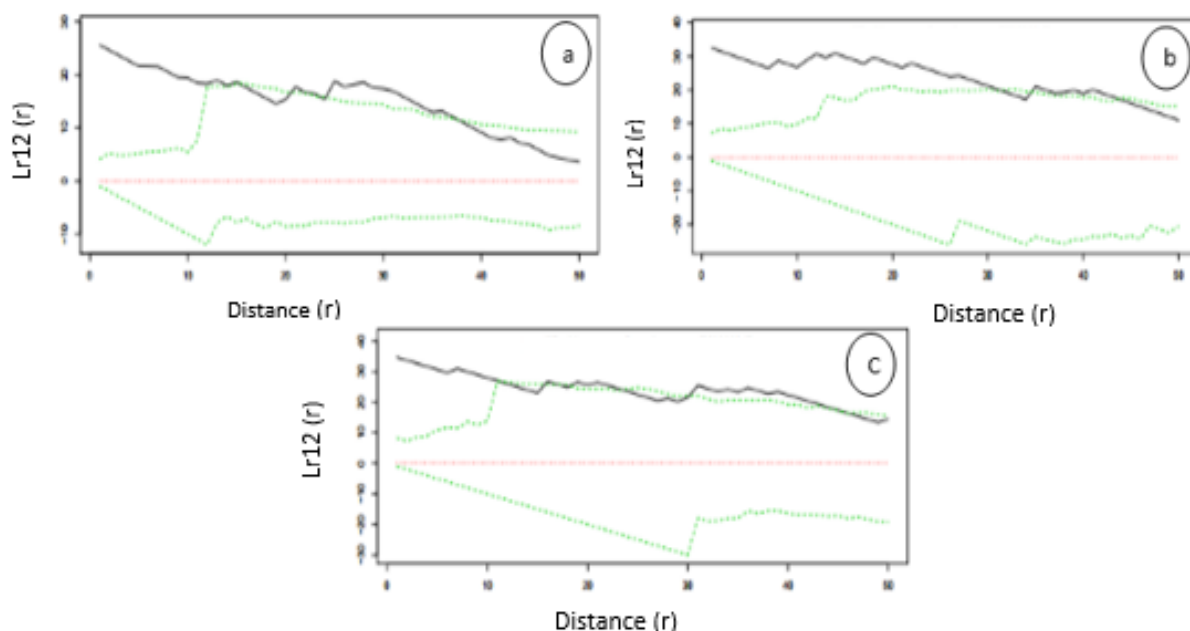


Fig. 6. Interactions into Growth stages of Iroko. (a): Seedlings - Seedlings; (b): Adults - Adults; (c): Seed-bearers - Seed-bearers. The solid black line represents the estimate of  $L_{12}(r)$  for the cloud of points considered. Black lines show the estimate of  $L_{12}(r)$  for the cloud of points considered. Green lines represent 99% confidence level under the null hypothesis of random distribution. Dashed red lines show the theoretical value of  $L_{12}(r)$  under the null hypothesis. The distance  $(r)$  is in meters

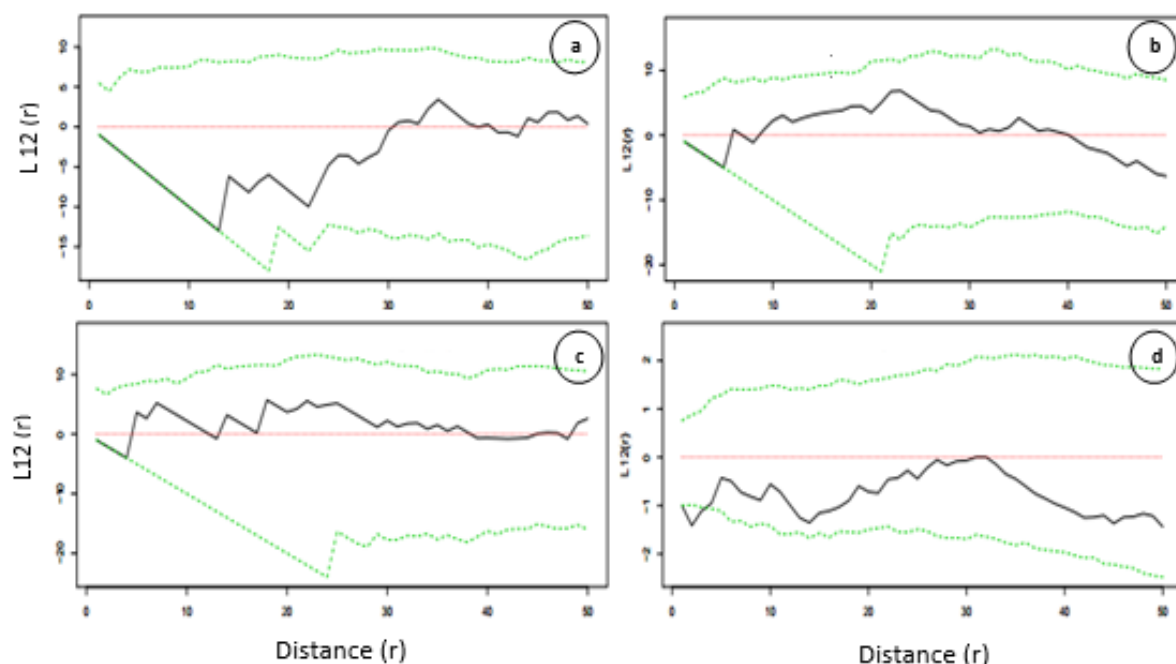


Fig. 7. *Milicia excelsa's* growth stages interactions. (a): seedlings - adults; (b): seedlings - seed-bearers; (c): adults - seed-bearers. And (d): between Iroko's seedlings and individuals of other species. The solid black line represents the estimate of  $L_{12}(r)$  for the cloud of points considered. Black lines show the estimate of  $L_{12}(r)$  for the cloud of points considered. Green lines represent 99% confidence level under the null hypothesis of random distribution. Dashed red lines show the theoretical value of  $L_{12}(r)$  under the null hypothesis. The distance  $(r)$  is in meters

The obtained results on intra-stage growth interactions show an attraction over ranges of lower values of radius but with however a great independence. Interstage growth interactions present a significant negative competitive interactions (repulsion) but also with stark independences. The range of this competition is however large between seedlings - adults, and is minimal between seedlings - seed-bearers and adults - seed-bearers. Deviation distances are short and the maximum deviation values are near to zero. The competition

between Iroko's seedlings and other species trees is clearly in a short range, with a short deviation distance, but a slightly high maximum deviation value. This result corroborates the study of [25], who found a repulsion between seedlings and seed-bearers of *Pterocarpus erinaceus* Poir., and negative interactions between seedlings and other species individuals. It has been shown that the spatial distribution is the result of interactions between species with its abiotic environment (edaphic preference, adaptation to different sunlight intensities) and biotic environment (interspecific competition, predation and dissemination by animals). This can condition the way in which the species uses resources of the environment (intra-specific competition), and how the species is itself used as resources (density-dependent predation) [18].

#### **4 CONCLUSION AND RECOMMENDATIONS**

The aim of this study was to analyze the spatial distribution and interactions that can exist between different *Milicia excelsa*'s growth stages; but also, between its seedlings and adults of other species.

An inventory of all tree species and particularly individuals of Iroko (including seedlings) with their Cartesian coordinates was made in six (6) hectares at 47 km from Kisangani on Ubundu road. Data from the field sampling were captured in Excel, and statistically analyzed with different tests by using R software.

Results show that *Milicia excelsa* has an inverted J structure and is represented only at 1.54% on the 100% of species inventoried in the studied area. Its relative density, relative frequency and the basal area are relatively very low, respectively  $1.58 \pm 0.68\%$ , 1,63% and  $0.52 \pm 0.46 \text{ m}^2 \text{ ha}^{-1}$ .

There was a random spatial distribution of trees in different growth stages even on a large scale and attractive interactions have been observed between trees of the same growth stage, but in different growth stages and between *M. excelsa*'s seedlings with other trees species negative interactions were observed. Moreover, the structure and density of *M. excelsa* were low, indicating a poor regeneration for this species. A species with low regeneration, requires a sustainable exploitation, for maintaining its population in the habitat.

#### **DISCLOSURE**

The research project was conducted under the supervision of Professors Nshimba Hippolyte and Katusi Roger. The project was run as N'tambwe Nghonda's research project.

#### **CONFLICTS OF INTEREST**

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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