

Evaluation of the distribution of *Irvingia gabonensis* in the peripheral zone of Tai national park (South-West, Ivory Coast)

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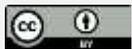
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ABSTRACT

The intensification of human activities in the buffer zone of Tai National Park (PNT) is leading to a progressive transformation of forest habitats and jeopardizing the availability of several plant species of high socio-economic value, including *Irvingia gabonensis*. Highly sought after by local populations, this species is under increasing pressure. This dynamic, combined with habitat fragmentation and the reduction of natural stands, could lead to a progressive decline of the species in certain areas of the park's periphery. In order to identify areas of high occurrence and to provide information useful for guiding conservation, restoration, and sustainable management strategies for the species, its distribution in the PNT's buffer zone was determined. To this end, a targeted inventory and a mobile inventory were adopted. These methods allowed for the identification of 99 individuals in the explored buffer zones of the Park. The largest numbers were found in the Adk and Soubré sectors, with 35 and 33 individuals respectively. These sectors exhibited a normal, bell-shaped diametrical structure, characteristic of a clear balance between regenerative individuals (young trees) and conservation individuals (older trees). This study showed that the Adk and Soubré sectors constitute key areas of high occurrence of *Irvingia gabonensis* in the periphery of the PNT. It also highlights a relatively stable stand structure, useful for guiding conservation and sustainable management actions for the species.

Key words: *Irvingia gabonensis*, Spatial distribution, Periphery, Structure, Conservation

INTRODUCTION

Tropical forests are characterized by exceptional biodiversity and play a fundamental role in the ecological balance and survival of many human societies. For many rural communities, the forest is a source of income, a support for social cohesion, and a space deeply integrated into cultural practices (Joiris, 1998). It thus provides a wide diversity of essential plant resources. However, these natural ecosystems are undergoing progressive degradation due to the intensification of human activities. In this context, the availability of forest plant species depends heavily on resource exploitation methods, but also on the ecological conditions necessary for their maintenance and regeneration (N'Da *et al.*, 2008; Dadjo, 2011).

The problem of the accelerated disappearance of plant resources due to human activities is widely described in the scientific literature. Several studies have shown that agricultural expansion, the exploitation of natural resources, and changes in land use contribute to habitat reduction, habitat fragmentation, and the progressive decline of useful plant populations (Rice and Greenberg, 2000; Oszwald, 2005; Kelatwang and Garzuglia, 2006; Traoré *et al.*, 2011; Dimobe *et al.*, 2012; Adingra *et al.*, 2014). This transformation of landscapes alters the ecological conditions favorable to the growth and survival of species, reducing their capacity for natural renewal. It also influences the spatial distribution of resources, particularly in areas where harvesting is frequent and poorly regulated.

In Côte d'Ivoire, this human pressure has resulted in a marked decrease in forest area, largely due to the intensive exploitation of high-value plant resources (Kouamé, 1998). In the country's forest regions, the growing demand for forest products, combined with the expansion of plantations, is accelerating the degradation of natural environments and jeopardizing the sustainable availability of several plant resources. This situation is a major challenge, as the loss of forest cover not only reduces biodiversity but also directly affects the living conditions of populations dependent on these resources.

In this context, Taï National Park (PNT), renowned for its remarkable biodiversity, faces increasing pressures, particularly from activities carried out in its buffer zone.

Repeated harvesting of non-timber forest products, combined with landscape transformations around the Park, contributes to the weakening of certain plant communities and alters resource availability (Soro *et al.*, 2021). Furthermore, although several studies have emphasized the importance of valuing and preserving plant resources useful to rural communities (Schreckenber *et al.*, 2006; Kouamé *et al.*, 2008; N'Dri *et al.*, 2012; Ouattara *et al.*, 2016), information remains insufficient on the actual spatial distribution of certain key species in areas under high pressure. The lack of precise data on their presence and occurrence limits the ability to effectively guide conservation and management actions.

In the periphery of Taï National Park, the intensification of human activities is leading to a gradual transformation of forest habitats and jeopardizing the availability of several plant species of high socio-economic value, including *Irvingia gabonensis*. Highly sought after by local populations for its kernels, its nutritional importance, and its market value, this species is under increasing pressure due to repeated harvesting, the exploitation of non-timber forest products, and the conversion of natural areas into agricultural land. This dynamic, combined with habitat fragmentation and the reduction of natural stands, could lead to the gradual decline of the species in certain areas surrounding the Park.

It is within this framework that the present study was carried out. It aims to assess the distribution of *Irvingia gabonensis* in the peripheral zone of Taï National Park, in order to better characterize its spatial presence, to identify areas of high occurrence and to provide information useful for guiding conservation, restoration and sustainable management strategies for the resource.

MATERIALS AND METHODS

The plant material used in this study consisted of naturally occurring individuals of *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke), a multipurpose tropical tree species belonging to the family Irvingiaceae. This species is widely distributed in the humid forest zones of West and Central Africa and is highly valued for its edible kernels, timber, and medicinal properties.

All individuals recorded during the study were mature and juvenile trees encountered within the peripheral (buffer) zones of Taï National Park, Côte d'Ivoire. The identification of *I. gabonensis* was carried out in the field with the assistance of experienced local guides and based on key morphological characteristics, including leaf shape, bark texture, fruit morphology, and overall tree architecture.

The sampled individuals represented different growth stages, including regeneration (young individuals), intermediate trees, and mature trees, allowing for a comprehensive assessment of the species' population structure. No artificial planting was conducted during this study; all individuals were naturally established within their respective habitats.

Study area

Located in the southwest of Côte d'Ivoire, at the confluence of the Cavally and Sassandra rivers, Taï National Park lies between the towns of Guiglo, Buyo, San-Pedro and Tabou (OIPR, 2014). Its position is between 5°08' and 6°24' North latitude, and between 6°47' and 7°25' West longitude (Fig. 1).

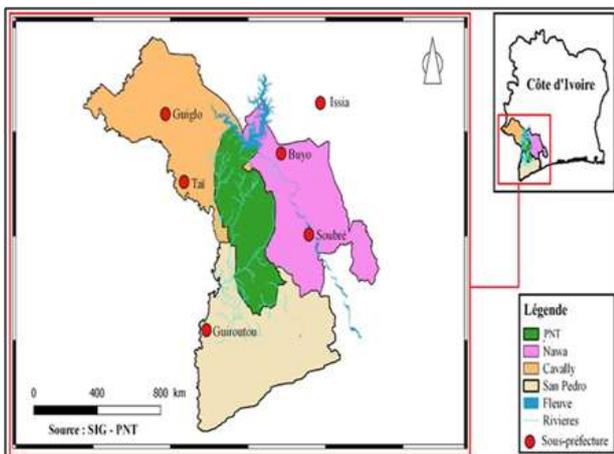


Fig. 1. Location of the study area

The Park is covered by five (5) monitoring sectors: the Adk and Soubré sectors in the Nawa region, the sectors Djapadji and Djouroutou in San Pédro and the Taï sector in Cavally.

The climate of the PNT is subequatorial (OIPR, 2017). According to climate data from 2008 to 2015 provided by

the OIPR, the seasons in the PNT are distributed as follows: two rainy seasons (a major season from March to June and a minor season from September to October) and two dry seasons (a major season from November to February and a minor season from July to August), as shown in Fig. 2. However, there is no month without rain in the PNT. Thus, the dry season is simply a period of lower rainfall.

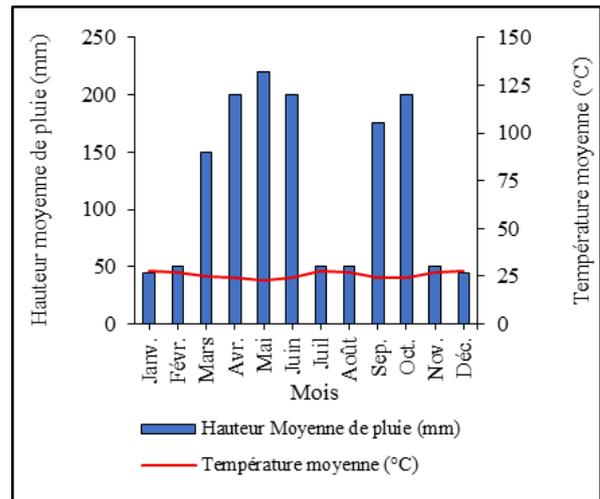


Fig. 2. Ombrothermic diagram of Taï national park between 2008 and 2015

According to Bousquet (1978), there are two main soil types in the PNT. Most of the park has highly saturated ferralitic soils with a thin horizon rich in organic matter. Along the banks of the Méno and Hana rivers, hydromorphic soils with gley and pseudogley are predominant.

The Park is home to at least 1,350 plant species (Chatelain *et al.*, 2001). Approximately one-third of the national floristic wealth is represented by the PNT (Adou-Yao *et al.*, 2005).

Data collection

Selection of inventory environments

Fifteen villages near the Park were selected. The areas surrounding these villages were considered as inventory plots. According to Wang *et al.* (2022), using the areas surrounding villages as inventory plots facilitates understanding the complex interactions between local communities and their environment. By incorporating the daily practices of the population, this method allows

for a faithful representation of ecological and social dynamics. In each village, sampling sites were chosen randomly.

Individual enumeration and dendrometric measurements

A targeted inventory (Drescher *et al.*, 2021) to a mobile inventory (Aké-Assi, 2002) has allowed the census of individuals of the species.

The targeted method was carried out with the help of local guides. These guides facilitated the precise and rapid identification of the target species, thanks to their in-depth knowledge of the terrain and local species. The roving survey method consisted of traversing the habitats indicated by the guides in all directions. This allowed for the recording of all individuals of the target species in the environment.

Each time an individual tree was encountered, it was marked with a cross using white paint and a brush, and its location was geolocated to avoid having to count it again. The selection of trees to be measured was random (Avery and Burkhart, 2002). The circumference at breast height (dbh) of each tree was measured, and the height was estimated using the drop point method. The drop point method considers two elements: the operator's position and the tree's position. The operator positions themselves at a distance from the tree, a distance assumed to be the drop point of the treetop. A stake is then fixed at this location, and the distance between this stake and the base of the tree, considered the height, is measured using a 1-meter-long stick designed for this purpose. The collected data were recorded on a data sheet.

Data processing

Abundance

Abundance was calculated by counting the total number of individuals observed in each sector of the Park. It was determined using the formuladescribed by Carpaneto *et al.* (2011):

$$A = \sum_{i=1}^n Ni \tag{1}$$

n: total number of sectors studied; *Neither*: number of individuals of the species observed in sector *i*

Diametrical structure

The circumference values of the individuals were transferred into the Excel 2013 spreadsheet, then converted to diameter using the following formula :

$$d = \frac{C}{\pi} \tag{2}$$

d: diameter (m); *C*: measured circumference (cm); $\pi = 3.14$

The individuals were divided into three (3) diameter classes (Table 1). Class 1 grouped the so-called small diameter individuals, class 2, for the medium diameter individuals, and class 3, for the large diameter individuals. Thus, the shape of the resulting histogram made it possible to assess the degree of disappearance or conservation of the species (Inoussa *et al.*, 2013).

Table 1. Distribution of diameter classes

Class	Diameter class interval (cm)	Description
1	0–50 cm	Small-sized trees / young individuals
2	50–100 cm	Medium-sized trees / mature individuals
3	>100 cm	Large-sized trees / old-growth individuals

Generally, three (3) main types of diametral structure are recognized following this pattern : the normal "J"-shaped structure indicates a well-conserved environment with a low state of regeneration; the inverted "J"-shaped structure indicates a disturbed environment with good regeneration potential; and the mixed structure, often bell-shaped (normal or inverted), indicates a balanced environment in terms of conservation and regeneration (Konan *et al.*, 2015). The bell is considered normal when individuals of average diameter are more numerous than individuals of regeneration (small diameter) and conservation (large diameter). It is considered inverted when individuals of average diameter are less numerous than those of regeneration and conservation.

The mean diameter is essential for understanding the distribution of individuals, helps assess competition for resources, and supports regeneration planning. To determine it, the formula used by Fernández and Castillo (2023) was adopted:

$$d_{(m)} = \frac{\sum(di)}{N} \quad (3)$$

di: diameter of each individual; N: total number of individuals

Vertical structure

The heights of the measured individuals were processed using Excel 2013 and grouped into different classes. The average height was also calculated.

The vertical structure of the trees was assessed by distributing the stems (individuals) into three (3) height classes (Table 2). This distribution allowed for a comparison of individual heights in each sector of the Park (Konan *et al.*, 2015). Thus, class 1 represents the shortest trees, class 2 the medium-height trees, and class 3 the tallest trees.

Table 2. Determining height classes based on species

Class	Height class interval (m)	Description
1	0–15 m	Short-height species / understory vegetation
2	15–30 m	Medium-height species / sub-canopy trees
3	>30 m	Tall species / canopy and emergent trees

The shape of the histogram resulting from this distribution allowed us to assess the vertical structure of the stand (environment). A normal "J"-shaped structure indicates an environment with few short individuals compared to tall individuals, while an inverted "J"-shaped structure indicates an environment where short individuals are more numerous than tall ones. A mixed structure indicates an environment with a balanced distribution of the two categories of individuals.

The average height of a tree stand is essential for assessing vertical structure, estimating timber volume, and monitoring tree growth. This measurement helps to understand height distribution, evaluate competition for light, and optimize forest resource management. It also provides information on the regeneration and health of forest stands and helps to analyze the impact of environmental changes and human interventions on the forest. To estimate this parameter, the following formula was adopted (Zhao *et al.*, 2022):

$$H_{(m)} = \frac{\sum(Hi)}{N} \quad (4)$$

Hi: height of individual i; N: total number of individuals

Statistical analyses

Principal Component Analysis (PCA) made it possible to establish the relationship between the abundance of individuals and the sectors of the Park.

RESULTS

Abundance of individuals by sector

A total of 99 individuals were recorded in the explored peripheral areas of the Park. The largest number were found in the Adk and Soubré sectors, with 35 and 33 individuals respectively (Fig. 3). Conversely, very few individuals were encountered in the Djouroutou and Djapadji sectors (8 individuals each).

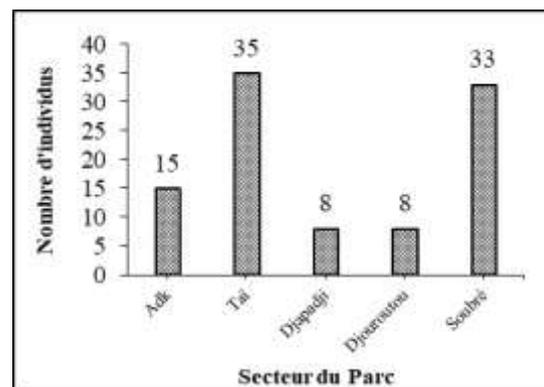


Fig. 3. Distribution of individuals counted by sector of the Park

Relationship between the sectors of the park

Principal Component Analysis (PCA), performed using the abundance of recorded individuals, was described by axes F1 and F2, with 100% of the information (Fig. 4). This analysis revealed that *I. gabonensis* was correlated with the ADK and Soubré sectors, with a strong correlation to the Soubré sector.

Diametral and vertical structures

In the Tai sector, the distribution of individual diameters exhibited a mixed diametral structure in the shape of a normal bell (Fig. 5). This shape reflects a better representation of intermediate classes (class 2) compared to the extreme classes devoted to young trees (class 1) and old trees (class 3).

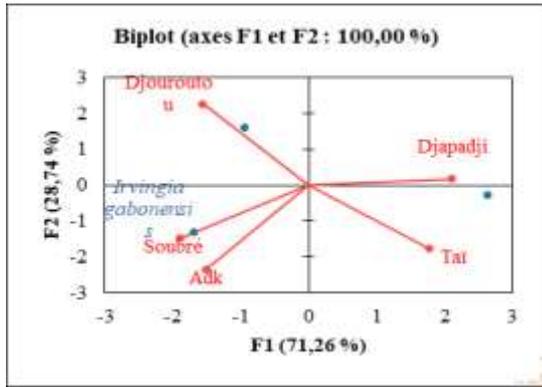


Fig. 4. Relationship between the different sectors of the park based on the abundance of individuals counted

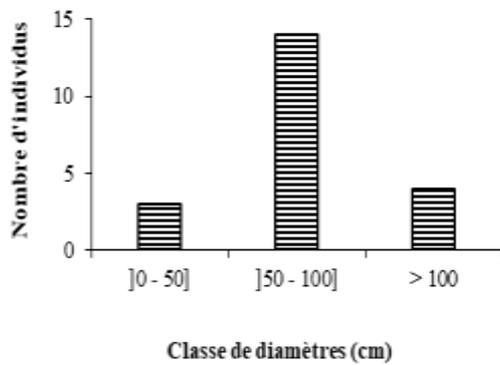


Fig. 5. Diametrical distribution histograms of individuals from the Tai sector

The vertical structure, which had an inverted "J" shape, indicated a predominance of short individuals (class 1) over medium and tall individuals (class 2 and class 3 respectively), as shown in Fig. 6.

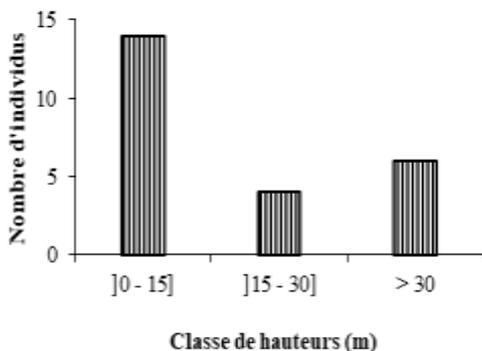


Fig. 6. Vertical distribution histograms of individuals in the Tai sector

In the Adk sector, the distribution of individual diameters revealed a mixed diametral structure in the shape of a

normal bell (Fig. 7). This shape reflects a low representation of trees of intermediate diameter (class 2) compared to those of small (class 1) and large (class 3) diameters.

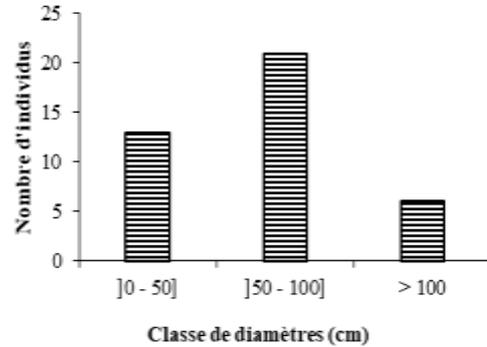


Fig. 7. Diametrical distribution histograms of individuals in the Adk sector

Regarding the vertical (height) distribution, the individuals exhibited an inverted "J" shape structure, indicating a predominance of individuals of short heights (Fig. 8).

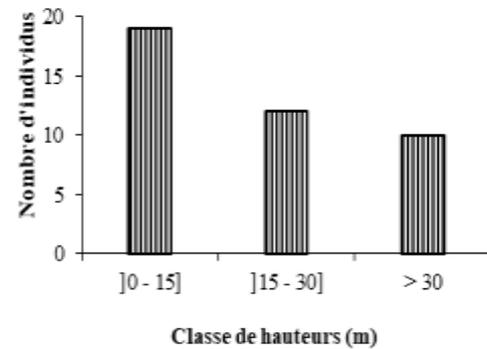


Fig. 8. Vertical distribution histograms of individuals in the Adk sector

In the Djapadji sector, the distribution of individual diameters presented an inverted "J" shape structure, indicating a predominance of extreme classes over the intermediate class (Fig. 9).

In terms of vertical distribution, the individuals exhibited a normal "J" shaped vertical structure, indicating good representation of trees of maximum heights (Fig. 10).

In the Djouroutou sector, the distribution of individual diameters showed a normal "J" shaped structure (Fig. 11),

with a predominance of individuals with very large diameters (Class 3).

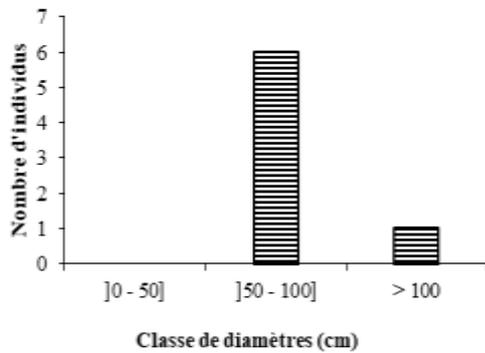


Fig. 9. Diametrical distribution histograms of individuals in the Djapadji sector

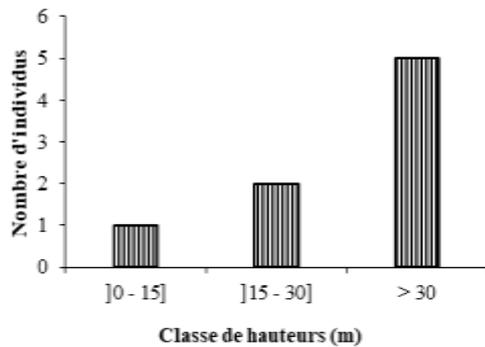


Fig. 10. Vertical distribution histograms of individuals in the Djapadji sector

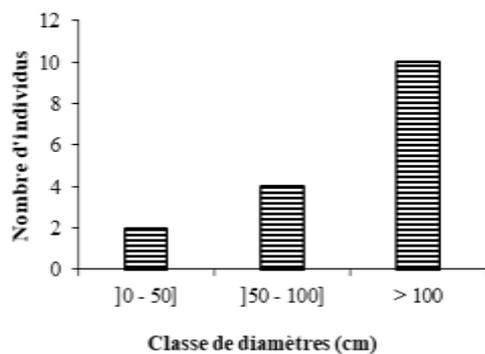


Fig. 11. Diametrical distribution histograms of individuals from the Djouroutou sector

The vertical structure of the individuals was presented in the form of a normal "J" (Fig. 12). This structure reflects a predominance of tall individuals (Class 3), indicating mature forest composition with stable canopy dominance.

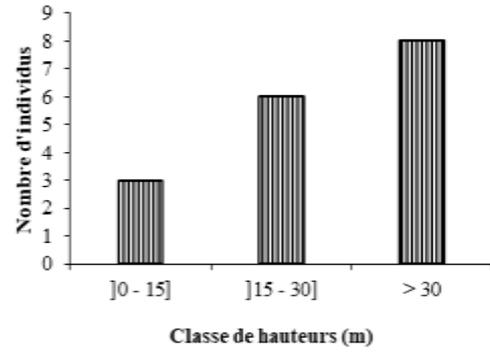


Fig. 12. Vertical distribution histograms of individuals in the Djouroutou sector

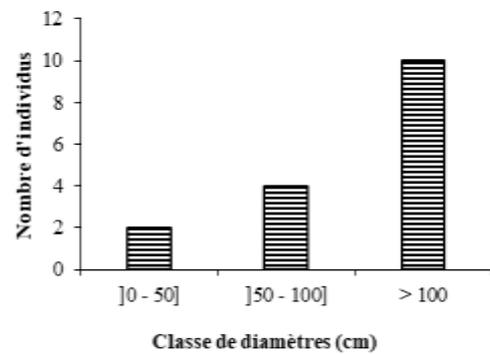


Fig. 13. Diametrical distribution histograms of individuals in the Soubré sector

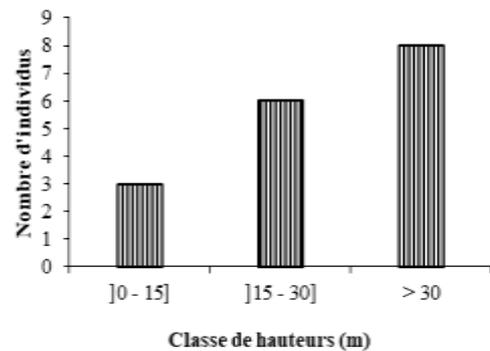


Fig. 14. Vertical distribution histograms of individuals in the Soubré sector

In the Soubré sector, the diametrical (Fig. 13) and vertical (Fig. 14) structures of the individuals appeared in the form of a normal "J", indicating a predominance of individuals with large diameters and great heights.

DISCUSSION

The floristic inventory conducted identified a total of 99 individuals across the entire surveyed peripheral zone of

the Park. The Adk and Soubré sectors stood out in particular, with 35 and 33 individuals respectively. This trend could be explained by the fact that these sectors benefited from a plant distribution project led by the Ivorian Office of Parks and Reserves (OIPR) in 2014. Furthermore, a 2016 study on the impact of agroforestry projects in the peripheral zones of national parks showed that distributing forest species to local communities can have a positive effect on their abundance. This practice promotes regeneration and contributes to better management of natural resources (Kouadio *et al.*, 2016). Thus, the concentration of individuals observed in the Adk and Soubré sectors could be interpreted as a success of this project, which has improved the presence of these species in these areas. Previous studies have also revealed that reforestation projects can significantly increase the abundance of specific species in the intervention areas. For example, a 2015 study in Cameroon on the effects of agroforestry projects showed an increase in the abundance of targeted species in areas that benefited from planned tree distribution, highlighting the importance of conservation and agroforestry actions for the regeneration of forest plants (Issouf *et al.*, 2019).

Principal Component Analysis (PCA) based on individual abundance reveals a strong correlation between individuals and the Adk sector. This result could be influenced by ecological factors. This observed dominance is consistent with previous studies conducted in similar areas in West Africa. In Ghana in 2019, a study on the abundance of forest trees in forest-savanna transition zones showed that the distribution of plant species can be strongly influenced by local ecological characteristics, such as soil type, humidity, and temperature (Issifu *et al.*, 2019). This could explain why more individuals were found in these sectors compared to other sectors.

The results of the analysis of the diametrical and vertical distributions of the individuals recorded in the Park sectors revealed particular structures. Indeed, the Adk and Soubré sectors exhibited a mixed diametrical structure, often described as a normal "bell" shape, where the balance between regeneration individuals (young trees) and conservation individuals (older trees) is

evident. This configuration is often linked to balanced forest management and an environment favorable to the growth of different tree categories. The Taï and Adk sectors were distinguished by a high presence of small trees, characterized by an inverted "J" structure. This distribution of diametrical structures in the Taï and Adk sectors corresponds to an active regeneration dynamic of mature trees, which could suggest a relatively stable growth and renewal cycle. Similar results were obtained by Ndong *et al.* (2017) in a study conducted in Central Africa. These authors observed a mixed structure, with a balance between regeneration and conservation in well-managed forests. The abundance of young trees (*I. gabonensis*) in these areas could also reflect reforestation interventions carried out by the OIPR. In contrast, the Djouroutou, Djapadji, and Soubré areas exhibited a more homogeneous diametrical structure, dominated by normal "J" shapes, where adult individuals (conservation) are in the majority compared to young individuals (regeneration). This structure could indicate a lack of natural regeneration or management focused on the conservation of mature trees. A study in the Democratic Republic of Congo (DRC), conducted by Bolia *et al.* (2019), showed similar structures in areas where harvesting pressure on adult trees was low, leading to a predominance of mature individuals in the population. The situation observed in the Djouroutou, Djapadji, and Soubré sectors could be the result of overharvesting, linked to cultural and socio-economic factors. For example, dietary preferences for certain species in different ethnic communities could influence their relative abundance in a given area. The scarcity of these species in these sectors makes them difficult to access, which increases the penetration of local residents into the Park. Indeed, according to Dossou *et al.* (2012), the exploitation of source species depends on their availability and accessibility. However, the importance given to a species does not always depend on its availability, but rather on its capacity to meet the needs of the population in different categories of uses (Dossou, 2010; Lougbegnon *et al.*, 2011).

CONCLUSION

Analysis of individual abundance, diametrical and vertical structures has provided a better understanding of

the distribution of *Irvingia gabonensis* on the periphery of the PNT (National Park of Tunisia). Indeed, the Taï and Soubré sectors stand out for their high abundance, partly attributable to reforestation projects carried out by the OIPR (Ivorian Office of Parks and Reserves). Notable differences were observed between the five (5) sectors of the Park regarding species dominance and regeneration, parameters influenced by ecological factors and anthropogenic pressures.

Ultimately, these results offer promising avenues for improving vegetative propagation techniques for *I. gabonensis*. They indicate that the use of forest substrates, particularly those enriched with compost, is a promising option for optimizing the success rate of cuttings. However, further studies on rooting dynamics, long-term plant growth, and the durability of these substrates are needed to strengthen the reliability and applicability of this method in domestication and development programs for the species.

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