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Structural and Dynamic Characterization of *Pycnanthus angolensis* (Welw.) Warb. in the Communal Forest of Doume (East Cameroon)

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Abstract

The study was carried out in the classified forest of the Commune of Doume (East Cameroon), as part of the C2D-PSFE2/DBPV project. It aimed to collect basic data for monitoring the dynamics of the abundant species in the production forest. The permanent plot method allowed for the installation of two plots of 300 m × 300 m each, with nine plots of 100 m × 100 m and counting units (CUs) of 25 m × 25 m. At the end of a systematic inventory in the CUs, the trees were counted, identified and georeferenced. A monitoring device has been installed at 1.30 m from the ground to assess the growth of the species. The results obtained showed that plot 1 is populated by 771 trees divided into 33 species; and plot 2 has 362 trees in 21 species, making a total of 1133 trees in the two samples, with a density of 62.94 trees/ha. In addition, *Pycnanthus angolensis* (Welw.) Warb. is the abundant species in both plots (P1 and P2) with a density of 23.72 stems/ha and 9.94 stems/ha respectively, for a total density of 33.7 trees/ha. The results also show that there is an uneven distribution of individuals by diameter classes, with an average density obtained of 5.9 trees/ha for individuals with a diameter of less than 60 cm while those with a DME greater than 60 cm have an average density of 0.7 trees/ha. These values reflect the abundance of young stems. This abundance ensures the regeneration of populations in the long term. Similarly, *Pycnanthus angolensis* has a significant land occupation in both plots with: 56,414 m^2/ha representing 4/9 of the total population area of plot 1 (9 ha), and 29,878 m^2/ha representing 3/8 of plot 2 (9 ha). The study showed a low frequency of mainly exploited woody species. The diametric surveys of each tree are the basic data for the abundant species. This approach should be applied in all production forests in Cameroon in order to achieve intelligent forest management based on biological knowledge of the timber resource in each biome.

Subject Areas

Ecology, Forestry

Keywords

Permanent Plot, Forest Stands, Dynamics, Biometrics, *Pycnanthus angolensis*, Doume

1. Introduction

Cameroon's forest is the second largest forest in Africa after that of the Democratic Republic of Congo (DRC), *i.e.* about 22.5 million hectares, 17.5 million of which are exploitable [1]. Its exploitation plays a crucial role for its development and remains an obvious path to its economic growth as it contributes nearly 4% to the gross domestic product (GDP) and occupies the third position in terms of foreign exchange earnings [2] [3]. However, despite the adoption of its forestry code, in particular Law No. 94-01 of 20 January 1994 modified by Law No. 2024/008 of 24 July 2024 on the forestry and wildlife regime aimed at guaranteeing its sustainable management, fragmentation and degradation of forests resulting from unsustainable logging remain widespread in Cameroon. Indeed, the quality of management plans in Cameroon is considered to be superior to those in Southeast Asia and Brazil [4] [5], but still needs improvement in order to close loopholes and ensure effective sustainable management [4] [6] in the management inventory procedure. These improvements therefore lie in the quality of the inventory, the forestry potential, the updating of the legal framework (legal framework and regulatory framework) and the parameters of the TIAMA software used by the Ministry of forest and Fauna (MINFOF). Following the decentralization of natural resource management, it has now devolved to the municipalities [7]. [8] indicates that the participation of the various actors in forest management should be taken into account in order to achieve the objectives of sustainable development. The role of communal forestry (permanent domain) is therefore to generate direct financial income through the sustained exploitation of forest resources, ecotourism, conservation; create direct employment and reduce poverty in the decentralized community concerned.

According to [4], species abundance varies considerably between regions, depending on soil and rainfall. As a result, knowledge of the auto-ecology of species is an essential step in the sustainable management of ecosystems, and more particularly in the management of populations of exploited species [9]. Thus, the management of commercial species must take into account the regional typology of forest sites, which will make it possible to identify the different types of ecosystems and the biological characteristics of the vegetation. Unfortunately, the management of commercial species as practiced in production forests in Cameroon does not take into account the regional typology of forest stations. As the forest structure is not known, logging is carried out on the basis of incorrect biometric information that is not up-to-date or that is not specific to that particular forest station. This lack of data limits the dynamic control of forest productions and exploitation history.

This study aims to study the population characteristics of *Pycnanthus angolensis* (Welw.) Warb. (Myristicaceae) in the classified forest of Doume. Specifically, it is a question of: 1) Assessing the potential of the species currently exploited; 2) Studying biometric parameters; 3) Studying the spatial distribution of *Pycnanthus angolensis* (Welw.) Warb.

2. Material and Methods

2.1. Location of the Study Site

The classified forest of the Commune of Doume is located in the Subdivision, Haut Nyong Division, East Region of Cameroon. According to [10], it consists of a Forest Management Unit (FMU) with an area of 45,359 ha, subdivided into two Forest Harvesting Units (UFE): UFE 1 and 2 (**Figure 1**). This study took place in UFE 2, which covers an area of 19,549 ha. UFE 2 is located between 4˚8' and 4˚16' north latitude and 13˚12' and 13˚32' east longitude. The classified forest of the Commune of Doumé is composed of three biotopes: dense humid semi-deciduous forest, wooded savannah and swampy forest [10]. This forest has been exploited in the past by forestry companies such as Fokou [10] and currently by the Cameroon Wood Processing Company (STBC).

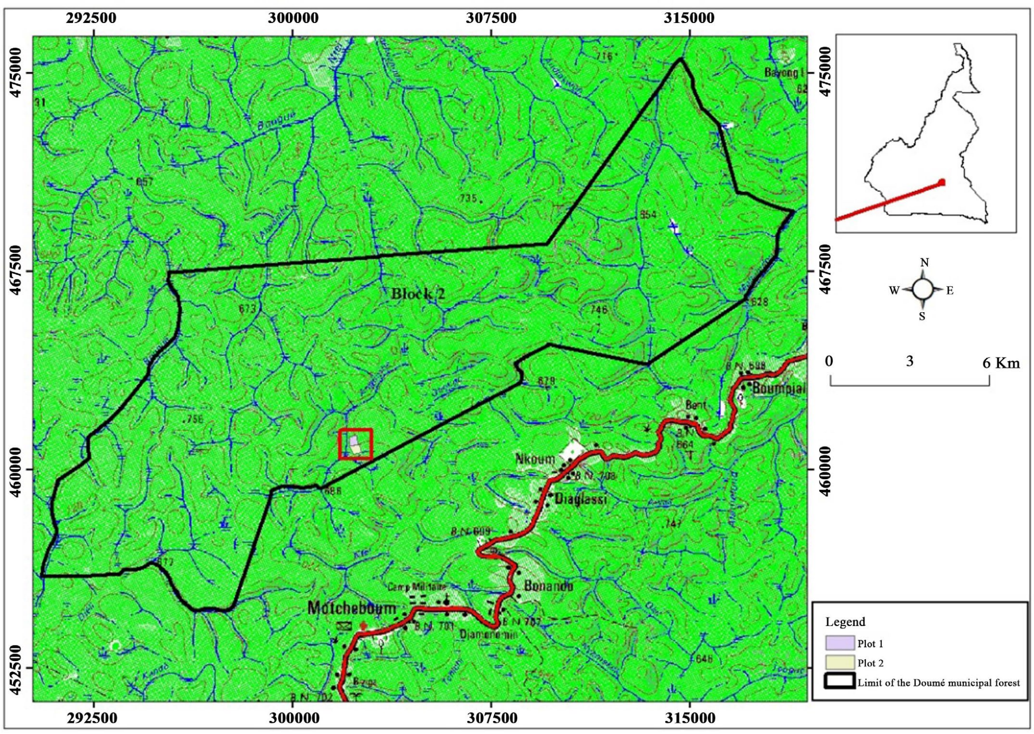

Figure 1. Location of plots in the Doume Communal Forest.

The vegetation of the study site is composed of woody forest products (*Petersianthus macrocarpus*, *Mansonia altissima*, *Terminalia superba*) that have production potential, and non-timber forest products (*Trichoscypha acuminata* (Amvout), *Ricinodendron heudelotii* (Essezang), raffia, water vines, etc.) [10]. The observations show the presence of lianas and pioneer woody plant species such as *Musanga cecropioides* (Parasolier) which promotes the natural regeneration of the forest. There are rare gaps in the canopy, with an increased potential for young trees (*Mansonia altissima*, *Alstonia boonei*, *Sterculia rhinopetala*). These elements are characteristic of a young secondary forest. The foliage of the trees is generally evergreen. The shrubs of the undergrowth are straight-trunked, evergreen. The herbaceous stratum is quite sparse and concentrated in the gaps of light.

2.2. Data Collection

2.2.1. Selection of the Sampling Area

Random sampling was carried out in the cutting plate n˚2020 of UFE 2 because it has not undergone any exploitation. The installation of permanent plots allowed us to collect data to characterize the structure and distribution of stands. The permanent plot method was used for the installation of two permanent plots of 300 m × 300 m [11]. In each 9 ha plot, there are nine plots of 100 m × 100 m with counting units of 0.625 ha (25 m × 25 m) (**Figure 2**).

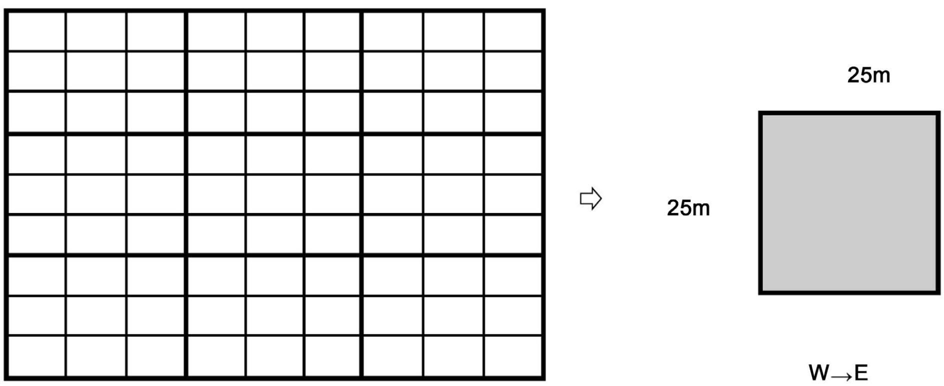

Figure 2. Configuration of 9 ha plots [300 m × 300 m] (left) and counting unit [25 m × 25 m] (right). The numbers of the counting units follow the West-East orientation.

2.2.2. Inventory

The inventory was carried out in a west-east orientation in each counting unit. It made it possible to census, identify and georeference all the individuals of *Pycnanthus angolensis* with a minimum diameter of 10 cm, at 1.30 m from the ground. The collection of biometric (diameter) and geographic data has facilitated the analysis of the distribution and distribution of this species. In order to better appreciate the phenomenon studied, direct observations were made in order to make a description of the vegetation and the nature of the substrate of the species. To understand the distribution of the species in the plots, the dynamics monitoring parameters were installed on each tree of the species at 1.30 m from the ground in order to carry out the dendrometric readings necessary for the monitoring of the dynamics in the permanent plots.

2.3. Data Analysis

The data collected made it possible to determine the following parameters:

Density (N, trees/ha) is the number of trees (n) in an area (s) per hectare. It makes it possible to evaluate the density of juvenile individuals and that of adult individuals in each of the biotopes.

$$N = n/s$$

The total basal area (GT) of the individual monitored in the squares per sample:

$$GT = \sum\left[D^2 \times (\Pi/4)\right]$$

The spatial distribution of *Pycnanthus angolensis* gives the positioning of the different individuals of the species in the monitoring plots.

Relative abundance (R) provides information on the quantity relative to the number of individuals of a given species per unit area or volume in relation to the total number of individuals of all species. It has the following formula:

$$Ar = \left(Aa/N\right) \times 100$$

where N = total number of individuals.

The Green's index (GI) is used to estimate the distribution of trees of a given species in a given forest stand and is calculated by the formula:

$$IG = \left(IB - 1\right)/\left(n - 1\right)$$

where n = mean number of trees in stand plots and IB = Blackman's index.

The Blackman Index (IB) is used to characterize the nature of the distribution of populations as a function of time. It is calculated by the formula:

$$IB = SN^2/N$$

where N = average of the density of the species in the stand; SN = variance in the density of the species in the stand.

Green's index is between −1 and 1. It has been interpreted as follows: $GI < 0$, the species given to a regular distribution; $GI = 0$, the species given to a random distribution; $GI > 0$, the species given to an aggregative distribution. This index made it possible to assess the distribution of the target species after its identification [12]. The spatial analysis provided information on the arrangement of the trees in the installed plots.

3. Results

3.1. Potential of Currently Exploited Species

A total of 1133 priority or commercial trees grouped into 33 forest species were identified. Ilomba (*Pycnanthus angolensis*) is the species in abundance with a population of 606 individuals or 53.5%; followed by Lotofa (*Sterculia rhinopetala*) with 99 individuals (8.7%). Rare species were Moabi (*Baillonella toxisperma*) with 0.7%; Iroko (*Milicia excelsa*) 0.4% and Bibolo (*Lovoa trichilioides*) with 0.3%. The average number of trees in the stand is 34. As far as species diversity is concerned, Shannon's index H' = 0.35 and Pielou's equitability index: E = 0.07. This result demonstrates an imbalance in numbers between the different populations. This reflects the presence of a majority species in the sampled plots.

3.2. Abundant Specie: Ilomba (*Pycnanthus angolensis* (Welw.) Warb.)

The results of the inventory carried out in plot 1 show that Ilomba (*Pycnanthus angolensis*) is the majority species with a density of 47.44 stems/ha, with a relative abundance of 55.38%. Also, the same trend was observed in plot 2 with a density of 19.88 stems/ha, and a relative abundance of 49.44%. The Pielou equitability index (E = 0.07) justifies the abundance of Ilomba individuals in the stand with an average relative abundance of 53.5%. Ilomba is a commercial and useful species in the production industry for sawing, veneer and plywood manufacturing. It is therefore important to monitor its dynamics in the samples in order to improve the calculation of its "possibility" and its reconstitution rate.

3.3. Biometrics Study

3.3.1. Distribution by Diameter Class

The class [10 - 20[is the mode of the distribution series with a frequent value of 16.59% in the samples. The number of individuals observed by diameter class shows a high dominance of trees with a DME less than 60 cm (**Figure 3**). The cumulative size of the Ilomba population in all classes is 530 trees, *i.e.* an average density of 5.9 trees/ha representing 7/8 of the total Ilomba population in the areas studied. On the other hand, trees with a DME greater than 60 cm have a population of 76 stems, with an average density of 0.7 trees/ha. The different numbers distributed by diameter class demonstrate an abundance of juvenile individuals of Ilomba in the plots. **Figure 3** illustrates the distribution curve of the evolution of Ilomba population dynamics according to diameter classes. Examination of the overall population structure shows a decrease following the inverted "J" structure [10 - 20[to [40 - 50[. It reflects a long-term regeneration of the species. Nevertheless, the peak observed in the class [40 - 50[describes a potential recruitment of individuals from the previous class due to the absence of exploitation. In addition, the intervals [50 - 60[to [70 - 80[with relatively abundant numbers characterize a population with a slowed growth. The classes [80 - 90[to [110 - 120[are poorly represented and their structures show that population growth is slowing. In the samples, the largest diameter measured has a value of 110 cm. This leads to a limit on the growth of the species which could not exceed this diameter.

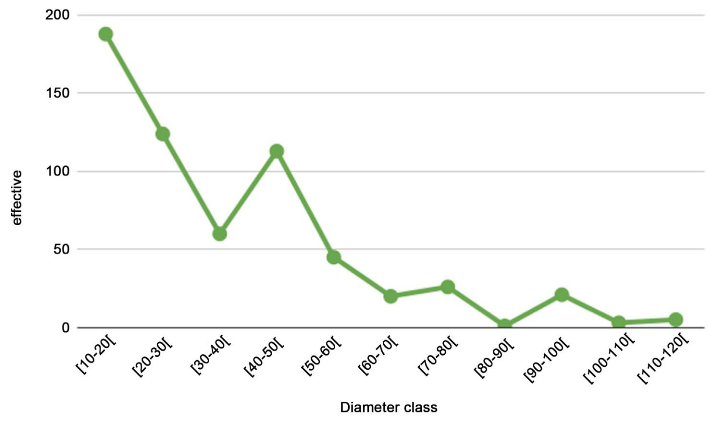

Figure 3. Ilomba distribution curve by diameter class.

3.3.2. Basal Area

This parameter made it possible to quantify the competition between the trees in the different plots. **Figure 4** presents the results of the land cover (g_{tn}) of the Ilomba population in each plot. In plot 1, there is a Peak population occupancy in plot 2, with a basal area (G_{T2}) of 12,843 m^2/ha (3/5 of the total area). Plot 5, gt5 = 10,673 m^2/ha also characterises a significant amount of Ilomba occupation (1/2 of the total surface). The gt7 and gt8 plots have a low distribution of the species with values of 3,098 m^2/ha (1/4 of the total area) and 3,014 m^2/ha (1/3 of the total area) respectively. This low distribution is explained by the competition with the other species of the different quadras for nutrients and light rays. The total basal area of Ilomba in plot 1 is 56,414 m^2/ha, representing 4/9 of the total area.

In plot 2, gt1 and gt2 show a significant land occupation of Ilomba numbers with an identical ratio of 2/3, *i.e.* gt1 = 7.971 m^2/ha and gt2 = 8.301 m^2/ha. In addition, in the plots, gt4 (1/2 of the total area) and gt5 (2/7 of the total area) show an average occupation of the plants of (**Figure 4**). The plots gt3 (1/3 of the total area), gt6 (1/3 of the total area), gt7 (1/2 of the total area) and gt8 (zero ratio) show strong competition between Ilomba individuals and other species in these different areas. Plot 9 does not have any Ilomba stems. The total basal area of Ilomba in plot 2 is 29,878 m^2/ha representing 3/8 of the total area.

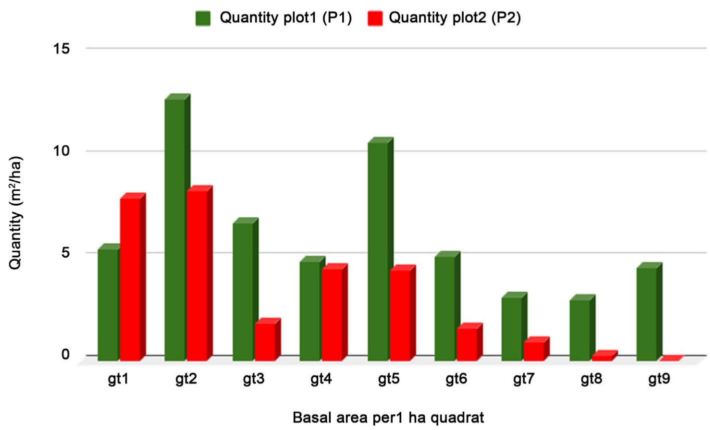

Figure 4. Graphic distribution of basal area P (Plot 1 [green] and Plot 2 [red]).

3.3.3. Nature of the Substrate and Estimation of Distribution

The nature of the substrate can have a major influence on the development and geographical distribution of Ilomba. Thus, 03 categories of substrate (solid ground, flooded marshy environment, and flooded marshy environment with raffias) were identified and measured according to the soil structure of the environment (exclusive, almost exclusive, little). These characteristics have been used to classify the distribution of Ilomba (**Table 1**). The numbers of Ilomba occupying the different basal areas also depend on the soil structure. In plot 1 (P1), plots 1 and 4 have almost firm soil, but there is a slight marshy structure that is less flooded. In addition, plots 2, 5, 7, 8 and 9 are made up of firm ground while plot 3 has firm ground with enclaves of savannah. In plot 2 (P2), plots 1, 2, 3, 4, 5 and 6 have firm ground with clearly visible clearings. Plots 7 and 8 contain marshy soil, but plot 9 has marshy soil flooded with raffias. The occupation of Ilomba depends on the type of soil in the plots. In addition to being a "non-pioneer heliophilic" and evergreen, it grows favourably on dry land. Since the conditions of the environment are favourable at the time of its growth, Ilomba can be described as an indigenous species.

Table 1. Soil structure in sample plots.

1 ha plots (Pt)	Firm Ground		Flooded marshy environment		Flooded marshy environment with raffias	
	P1	P2	P1	P2	P1	P2
plot 1	++	+++	+	/	/	/
plot 2	+++	+++	/	/	/	/
plot 3	+++	+++	/	/	/	/
plot 4	++	+++	+	/	/	/
plot 5	+++	+++	/	/	/	/
plot 6	+++	+++	/	/	/	/
plot 7	+++	+	/	++	/	/
plot 8	+++	+	/	++	/	/
plot 9	+++	/	/	/	/	+++

(+++) Exclusive (homogeneous); (++) quasi-exclusive (not very heterogeneous); (+) little (very heterogeneous).

3.4. Distribution of *Pycnanthus angolensis*

The Green's index (GI) was used to measure and then analyze the distribution of the abundant species in the plots studied. The results show that Ilomba has a total density of 33.7 trees/ha with a GI = 0.009. The GI value obtained (0.009) shows that the trees of this species are distributed in an aggregative way, *i.e.* the trees are distributed in small groups in the two plots. The spatial analysis (**Figure 5**) shows a random distribution of Ilomba trees (*Pycnanthus angolensis*) in the plots studied.

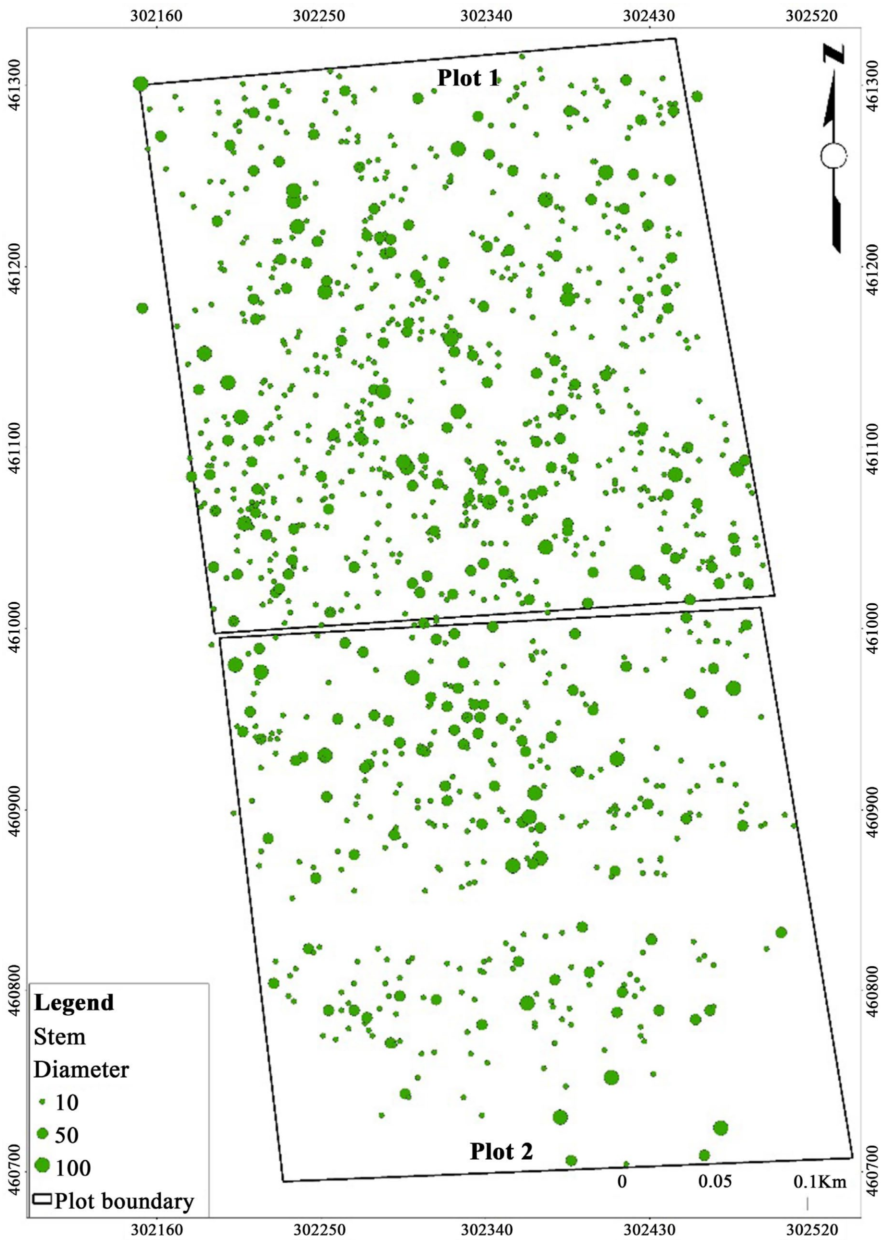

Figure 5. Spatial distribution of Ilomba in the plots.

4. Discussion

A total of 1133 trees with an average number of 34 trees, representing 33 species in all the plots were recorded. While [13] in a similar study obtained an average of 346.8 - 426.8 trees representing 198 species in eight plots of 9 ha respectively in Loundoungou (4 plots) and Mokabi (4 plots) in Congo. The stand organization parameters used are the origin of the stand, the treatment of the stands, the consistency of the stands, the stage of the stands, and the composition of the stands. The results clearly show the dominance of the young stage of the species inventoried in the installed plots. Species distribution is controlled by light availability and soil moisture. These environmental factors (light, water and minerals) define competition between individuals and justify the treatment of populations resulting in diameter classes. The results of this inventory illustrate the dominance of the young stage of the species inventoried in the plots installed. The values of the Shannon index (0.35) and the Pielou Coefficient of Equitability (0.07) show a low species richness in the Doume communal forest (FCDO) because the different species identified in the established plots are unevenly represented in terms of individuals. This result is consistent with that of [10], who shows a fairly diverse forest stand in the FCDO in the Forest Management Plan.

All the species recorded are commercial and appear in the FCDO's management plan and annual operating plans (PAO). The families of identified forest species such as Myristicaceae (*Pycnanthus angolensis*), Sterculiaceae (*Sterculia rhinopetala*, *Mansonia altissima*, *Triplochiton scleroxylon*), Combretaceae (Terminalia superba) are identical to those described by [4] who shows the families of woody species in a study of diametric growth by forest type in Cameroon. The abundance of vines, parasol trees (*Musanga cecropioides*) and young stems attests that we are in a young secondary forest. The low rate of representativeness of the forest species mainly exploited like *Baillonella toxisperma*, *Triplochiton scleroxylon*, *Milicia excelsa*, *Lovoa trichiloides*, *Terminalia superba* and *Mansonia altissima*, shows an overexploitation of these wooded species by skimming. Similar observations were made by [10] during the presentation of the logging history of the Doume communal forest.

The abundance of Ilomba (*Pycnanthus angolensis*), 427 trees in P1 and 179 stems in P2, with a total of 606 individuals is the most dominant. [13] in a similar study in Loundoungou and Mokabi in Congo, obtained 820 trees, 1076 trees, 776 trees and 720 Ilomba trees respectively per block (4 plots of 9 ha). The results of the evolution of forest stands demonstrate a strong disturbance impact on the forest in the past. This severe disturbance could also justify the growth and abundance of *Pycnanthus angolensis* because the environmental conditions are favorable for its rapid growth. This observation is identical to those described by [14]. The appearance frequency of this species in all the sampled areas is 53.5%. [4], in a study of diametric growth studies by forest type in the semi-deciduous forest in Cameroon, found a higher value of 73% of Ilomba. By comparing these results, the frequency value of the species' appearance is significant in the semi-deciduous forest. This high frequency therefore justifies its habitat in this biome.

The stems of Ilomba have an average basal area of 56,414 m^2/ha representing 4/9 of the total population area of plot 1 (9 ha), and 29,878 m^2/ha representing 3/8 of the total area of stands in plot 2 (9 ha). This variability of the diametric structure of Ilomba measured at 1.30 m from the ground demonstrates its important and majority occupation in the sampled areas. The nature of the substrate shows that the occupation of Ilomba depends on the type of soil in the plots. In addition to being a "non-pioneer heliophilic" and evergreen [15] [16], Ilomba grows favourably on dry land. The results of this study show that *Pycnanthus angolensis* is an indigenous species due to the conditions (degraded environment, light, water, minerals, soil) favorable to its development. The very disproportionate variation in numbers by diametric class observed is similar to the erratic type classified by [16] after a study of growth dynamics in African dense forest stands.

The distribution of trees and the distribution of Ilomba is aggregative (GI = 0.009) [17], having worked on the structural and ecological characteristics of commercial populations in southern Benin, demonstrated that Ilomba has an aggregative distribution in the samples. Despite the total density of 33.7 stems/ha, the Green's index (0.009) obtained tends towards zero value. Similarly, spatial analysis shows a distinct and hazardous organization of Ilomba individuals in the plots. This type of spatial organization reflects a random distribution of Ilomba stems because its distribution observed in the field shows a random distribution in the stand. Thus, the spatial distribution of Ilomba in the plots and the value of GI (0.009) obtained justifies this aggregative distribution with a random distribution.

5. Conclusion

The general objective of this work was to study the vegetation of the FCDO through the installation of permanent plots for the collection of basic data for the monitoring of the dynamics of forest stands. As a result, a total of 1133 priority or commercial trees grouped into 33 forest species were identified in all the plots (9 ha × 2). Ilomba (*Pycnanthus angolensis*) is the species in abundance with a population of 606 individuals or 53.5% (P1 = 427 and P2 = 179). The analysis of the structure of *Pycnanthus angolensis* shows the organization of a predominantly young population and a more or less dense consistency of screens. The variability of the diametric structure attests to a young forest with an average density of 5.9 trees/ha, individuals with a diameter of less than 60 cm, while those with a DME greater than 60 cm have an average density of 0.7 trees/ha. The analysis of the basal area of *Pycnanthus angolensis* shows an average land occupancy, namely 56,414 m^2/ha in plot 1 and 29,878 m^2/ha in plot 2. The Green's index obtained (0.009) attests to an aggregative distribution and distribution of this commercial species. Monitoring of *Pycnanthus angolensis* must be done in other production forests in order to know its dynamics for a better calculation of its possibility for intelligent management and sustainable exploitation of this commercial species.

Authors' Contributions

J.C.M. collected the data, analysed and prepared the manuscript; M. M. MB. A. suggested project direction and provided support in the planning stages; H.A. supervised the work, contributed to the design of the work, and discussed and edited drafts with R.L.N.M and J.Y.N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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