



Research article

Structural study of *Gilbertiodendron dewevrei* mono-dominant forest based on mature individuals in the Masako forest reserve (Tshopo province, Democratic Republic of the Congo)

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Abstract: The goal of the study is to determine the vegetal composition and structure based on mature trees in the Masako Forest Reserve. A transect was installed in a mono-dominant forest with *Gilbertiodendron dewevrei* at 5 km from the guest house. For transect of 2,100 m, we placed a 500 m perpendicular line to the survey to a plot of 2,500 square meters in a *G. dewevrei* forest. An inventory was carried out in an area of 3 ha, consisting of 12 plots of 50 × 50 m. All trees with a diameter equal or greater than 30 cm were inventoried, and divided into eight size classes according to their dbh (diameter at breast height) dimension: <40 cm; 40 to 49.9 cm; 50 to 59.9 cm; 60 to 69.9 cm, 70 to 79.9 cm; 80 to 89.9 cm; 90 to 99.9 cm and ≥ 100 cm. To facilitate the inventory, the survey plots were divided in two subplots of 1,250 m². For the entire forest, we found an overall density of 86.3 stems per hectare of which 63.3 stems/ha belonged to *G. dewevrei*. We also found that the basal area for an individual tree was on average 29.5 m².ha⁻¹ for the entire forest, and 24.2 m².ha⁻¹ for *G. dewevrei*.

Keywords: Mono-dominant forest - *Gilbertiodendron dewevrei* - Masako Forest Reserve.

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INTRODUCTION

Tropical rainforests are among to the most diverse terrestrial ecosystems of the world (Borah 2016), but they also contain zones which are dominated by a single species (mono-dominant forests). These zones pose a great enigma in tropical ecology. The mono-dominance leads to a change in the vegetal composition of the forest in which sun-loving species dominate (Fonty 2011). The high diversity of tree species, which is characteristic for tropical forests, is as well a permanent source of scientific questions as a strong constraint to improve our knowledge of the functioning of the forest ecosystem. The answers explaining the preservation of this diversity oppose the deterministic or stochastic mechanisms maintaining this high diversity (Blanc *et al.* 2003). However, in tropical rainforests, there are areas of low diversity too (Richards *et al.* 1952), where the canopy trees are dominated by one species (Richards *et al.* 1996). When this species reaches 50% of the relative diversity, it is considered to be a mono-dominant species (Hart *et al.* 1989), single-dominant Forest *sensu* (Connel *et al.* 1989).

This is already known and documented in the tropical forests of Asia, where *Drybalonopsa romatica* (Dipterocarpaceae) is considered a mono-dominant species (Reitsma 1988).

In the Congo basin, *Gilbertiodendron dewevrei* (De Wild.) J. Leonard forms extensive stands, which, in some cases, are virtually monophyletic (Whitmore 1984, Gerard 1960, Kouob 2009). Unlike heterogeneous forests, interest on the origin and preservation of mono-dominant tropical forests is recent (Toft *et al.* 2003). It is assumed that the massive and synchronous fruiting, low diaspores predation, tolerance to low light levels, and ecto-mycorrhizal symbiosis would be the basis for the survival of this forest type. Although they only represent a small fraction of the area of tropical forests, mono-dominant stands were described from all around the tropics. These settlements do not conform to the general pattern and it can be assumed that one or more processes controlling diversity have been altered there. Also the understanding of the mechanisms leading to these species imposing their mono-dominance can shed a (negative) light on the processes allowing the coexistence of many species (Gross *et al.* 2000).

According to McGuire (2007), the structure of a *G. dewevrei* forest is the result of the impact of the port and the social temperament of this species on the light factor (Louis 1947). Therefore, we decided to approach the problems by focusing on the *G. dewevrei* forest, where changes are easily noticeable, not only because of its wide distribution in the tropical forest, but also because of its great vegetation diversity.

The structural profiles pose a number of problems, which are sometimes difficult to solve, requiring a lot of time and resources (Mabay 1994). This is also the reason why we based our description of the morphological appearance of the forests on the vegetation composition, vertical and horizontal structure of mature individuals (dbh \geq 30 cm) in the *G. dewevrei* mono-dominant forest. As such, given the extent to which inventories were made, we expected to be closer to the physiological reality, offering one or two structural profiles. This research was motivated by the need to identify the basic data on the structural composition and plant species diversity of the *G. dewevrei* forest, based on mature individuals (dbh \geq 30 cm).

MATERIALS AND METHODS

Study site

Our study was performed in the Masako Forest Reserve, which is located about 14 km northeast from the city of Kisangani (DRC) on the old road towards Buta (0° 36' 30.4" N 25° 15' 38.9" E) at an altitude of about 500 m (Sonké 1998). It covers an area of about 2,104 ha of which is occupied by primary forest (Northeast) and at least 2/3 by secondary forests (Northwest). The area was visited during three field trips of ten days (March, April and May 2009).

The structure of mature individuals (dbh \geq 30 cm) and dominant species (depending on the distribution of tree frequencies classes and the diameter structure) are aspects that have been selected to meet our goal: understanding the particular physiological nature of the primary *G. dewevrei* forest in Masako, as these aspects allow the easy identification of the balanced state of a plant formation.

Location of the transect

The transect was traced in the Masako monodominant *G. dewevrei* forest with the main axis directed in a N-S direction and reaching 5 km from the camp site. The forest area was divided into plots and transects arranged to pass through a series of tributaries to characterize and visualize the key areas in the various topographical conditions (Mboengongo 1999).

Description of the transect

Along the 2,100 m main axis of the transect, we drew 500 m long perpendicular lines at 100 m intervals, giving a total of 12 lines (Fig. 1). Along these lines, random plots were selected to survey for *G. dewevrei*. Each of these plots measured 50 × 50 m (2,500 m²).

Data collection

All trees with dbh \geq 30 cm were surveyed and their coordinates (x,y) within the plot, their diameters at a height of 1.30 m above the ground (= breast height [dbh]) were registered.

Data analysis

The structure diversity is defined by a set of parameters (plant diversity, density, distribution, vertical distribution, etc.) and dimensions in the plots as well as by the relationships that may exist between these

parameters. The latter were calculated using the model proposed by (Makana 1989, Gillet *et al.* 1991). Besides of these quantitative analyses, biodiversity indices were also calculated.

Diversity indices

1. Margalef diversity index (D_{Mg})

This index is calculated by the following formula:

$$D_{Mg} = (S-1) / \ln(N).$$

Where, S = number of species and N = total number of individuals.

2. Menhinick diversity index (D_{Mn})

This index is calculated as follows:

$$D_{Mn} = S / \sqrt{N}$$

Where, S = number of species, N = total number of individuals.

3. Simpson diversity index (D_s)

This index measures the probability that two individuals, that were selected by chance, belong to the same species:

$$D_s = \sum p_i^2 \quad \text{with } p_i = n_i/N$$

Where, n_i = number of individuals belonging to a given species i , N = total number of individuals.

4. Shannon-Wiener diversity index

According to Lejoly (1993) and Danais (1982), the Shannon-Wiener index measures the average amount of information presented by the indication of the species of an individual to the collection.

$$H' = -\sum(p_i \ln p_i) \quad \text{with } p_i = n_i/N$$

Where, N = total number of individuals (*i.e.* trunks), n_i = number of individuals belonging to a given species i (between 0 and N), p_i ranges from 0 to 1. S

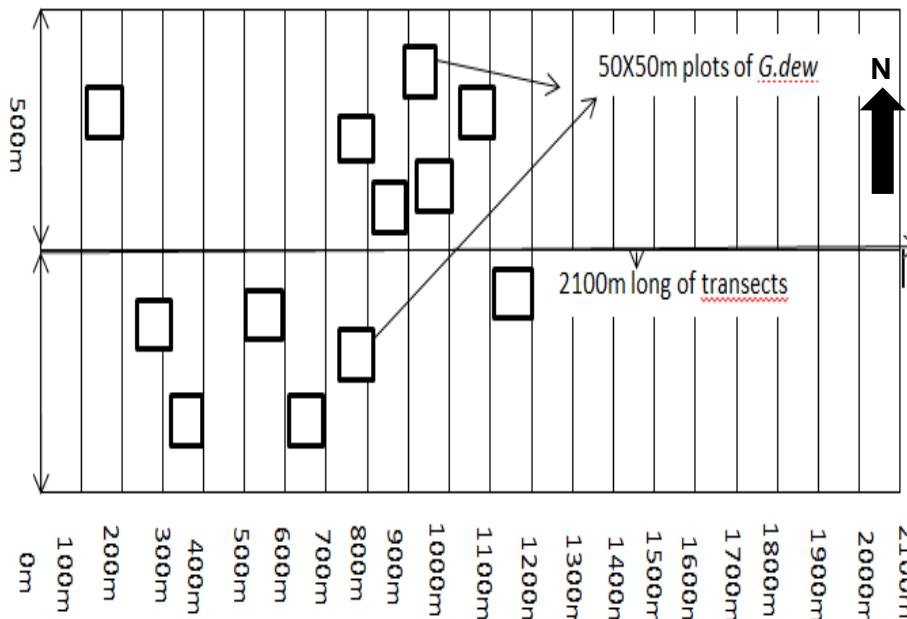


Figure 1. Schematic representation of the sampling plots in the Masako *Gilbertiodendron dewevrei* mono-dominant forest.

Variation Coefficient (VC)

This coefficient is used to compare two standard deviations, especially when the means are different. It also allows us to evaluate the magnitude of dispersion of data. The high value of VC indicates the larger of the dispersion around the mean (Frontier 1993, Legendre *et al.* 1998).

$$VC = \delta \times 100/M$$

Where, δ - variance, M - mean

If $VC < 15\%$, the dispersion is low or less pronounced and the series is homogeneous. If VC is between 15% and 30%, the dispersion is somewhat weak and the series is relatively homogeneous, However, if $VC > 30\%$, the dispersion is most pronounced or high and the distribution is heterogeneous.

Diametric and structural analysis

The total diametric structure or distribution of stems per diameter class is determined by taking into account the individuals of every species (Magurran 2004). This value gives information on the stability of the stands. It can also be calculated for specific species and in that case, it represents the specific structure. The diametric structure indicates the number of stems inventoried by diameter classes. The Cartesian coordinates (x, y) of all individuals *Gilbertiodendron dewevrei* (with dbh \geq 30 cm) were registered to accurately characterize the organization of the trees in each plot. The basal area is expressed in m² (Rollet 1974) is calculated for each individual by means of the formula $ST = \pi D^2 / 4$ where D is the dbh.

Quantitative study

Quantitative determination of the data results in their structural nature consisting of a set of parameters, including the spatial distribution, species density and the relationships that interfere with these (Gounot 1969). The abundance or relative density of a species and a family is calculated as the total number of individuals of a species or family in the sample multiplied by 100:

$$RD_s = (n_s / N) \times 100$$

Where, n_s is the number of individuals for a given species and N is the total number of individuals in the sample.

$$RD_f = (n_f / N) \times 100$$

Where, n_f is the number of individuals for a given family and N is the total number of individuals in the sample.

The relative dominance of a species or family is determined by the basal area occupied by a species or family in total basal area and is multiplied by 100 according to following formula:

$$\int t_s / \int s_t \times 100$$

$$\text{and for the family } \int t_f / \int s_t \times 100$$

Where, $\int t_s$ is the basal area of a species, $\int t_f$ the basal area of a family and $\int S_t$ the total basal area in the sample

Density

Density is defined as the number of stems per surface unit. There are several expressions of density. However, the most commonly used is the number of stems per hectare (N/ha). Unfortunately, this expression of the density does not take into account the size of trees.

RESULTS AND DISCUSSION

Vegetation composition and density

The floristic study in the Masako *G. dewevrei* mono-dominant forest resulted in an overall number of 259 individuals with dbh \geq 30 cm, divided over 36 species, 34 genera, 19 families (Fig. 2).

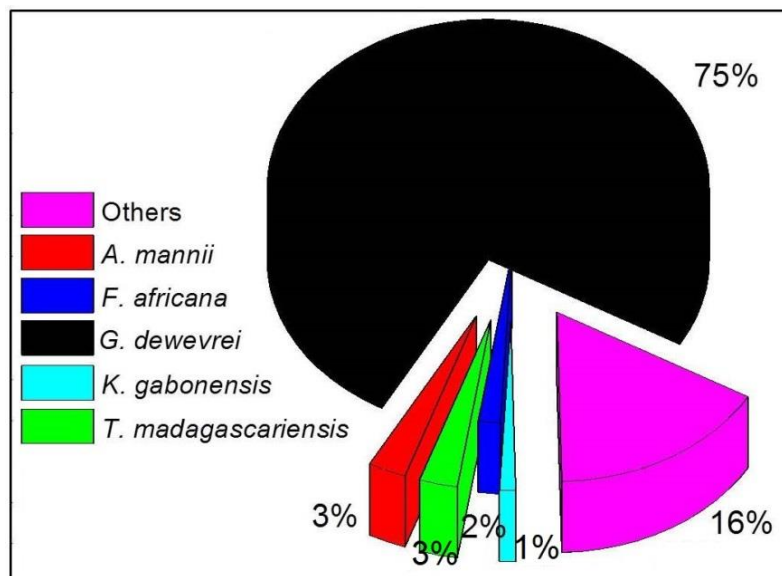


Figure 2. Floristic composition of *Gilbertiodendron dewevrei* mono-dominant forest at the Masako Forest Reserve.

The *Gilbertiodendron dewevrei* dominate the sample with 75%, followed by the *Anonidium mannii* and *Trilepisium madagascariensis* with 3% each, followed by the *Funtumia africana* with 2%, *Klainedoxa gabonensis* (1%) and other species are each represented with 16%.

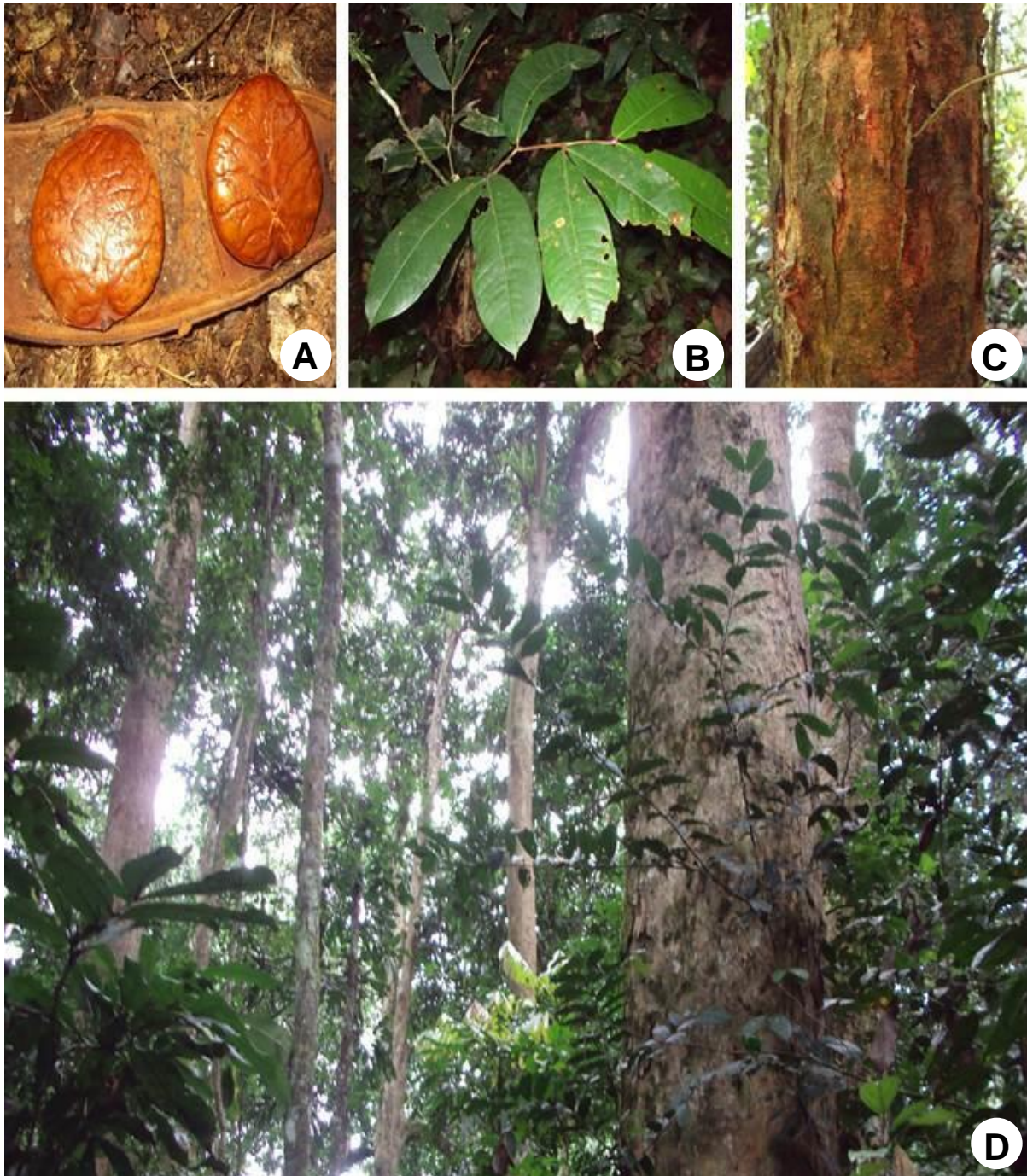


Figure 3. *Gilbertiodendron dewevrei* (De Wild.) J.Leonard: **A**, Seeds; **B**, Seedling; **C**, Stem with bark; **D**, Habitat.

Stocking densities of individuals in the Masako G. dewevrei mono-dominant forest

The 3 ha sample area in the Masako *G. dewevrei* mono-dominant forest contained 259 trees with dbh \geq 30 cm. On average, there were 86.3 trees per ha. Of these trees, 190 belonged to *G. dewevrei*, giving an average per hectare of 63.3.

Quantitative analysis of the floral data

The global basal areas for the Masako *G. dewevrei* mono-dominant forest is 29.5 m²/ha and 24.2 m²/ha for *G. dewevrei* individuals.

The species abundance in the G. dewevrei mono-dominant forest at Masako

The current study indicates that the dominant species at Masako are: *Gilbertiodendron dewevrei*, *Musanga cecropioides*, *Anonidium mannii*, *Trilepisium madagascariensis*, *Funtumia africana*, *Klainedoxa gabonensis*, *Petersianthus macrocarpus* and *Panda oleosa* (Fig. 3).

Vegetation structure by diametric class

The diameter distribution of all species combined (total structure) is one of the stand's characteristics reflecting an equilibrium constant, which is the existence wherever moist evergreen forests are in their original state (Fournier *et al.* 1983). To highlight the disturbed state of forest plant community proposed a structural analysis for the species that account for the unbalanced or balanced state of the forest.

Diversity indices

The alpha (α) diversity was calculated using the following indices: Shannon-Wiener, Menhinick, Margalef and Simpson. This allows assessing the diversity of each group, according to the species distribution, more accurately. Margalef index gives the highest value (6.299). This shows that the Masako *G. dewevrei* mono-dominant forest is more diverse in species.

It has a good evenness between the species studied. This demonstrates the dominance of the *G. dewevrei* forest on others in terms of species richness. The Simpson index, meanwhile, shows that the diversity of sites is not so variable because the value obtained (0.458) represents a very low diversity. On the other hand, the Menhinick index, which is based on species richness, presents a distinctly lower value (2.237) relative to Margalef index, where the number of individuals is relatively low. Comparing the Menhinick index with the one from Margalef reveals that both indices almost evolve in the same way.

There is a minor difference at the species level, where the Margalef index results in higher values if there is a higher number of individuals, while that of Menhinick is low. In the current study, the Shannon index is relatively low as it represents the sum of the information given by the frequency of the various species over the 3 ha sampled surface.

Statistical parameters

The data for the *G. dewevrei* trees occurring in the twelve 50 × 50 m sample plots of the Masako *Gilbertiodendron dewevrei* dominated forest are presented in tables 1 and 2.

Table 1. Number of *Gilbertiodendron dewevrei* trees with dbh \geq 30 cm and distribution of diameter registered in the twelve 50 × 50 m sample plots.

Sample plot	Number of trees	Diametric Class	Number of trees
P1	14	30-39,9	31
P2	16	40-49,9	25
P3	16	50-59,9	28
P4	12	60-69,9	30
P5	21	70-79,9	35
P6	23	80-89,9	13
P7	17	90-99,9	10
P8	17	\geq 100	18
P9	17	Total	190
P10	12	Moyenne	23,75
P11	17	Variance	82,21
P12	8	Ecart-type	9,06
Total	190	CV(%)	38,14
Average	15,8		
Variance	16,15		
Standard deviation	4,01		
CV(%)	25,37		

The average number of *G. dewevrei* trees over the sampled plots is 15.8 (Table 1). The values for the individual sample plots are more or less around this average value, with one lower value for P12 and two higher ones for P5 and P6. The coefficient variation is between 15 and 30% indicating that the dispersion is somewhat weak. The distribution of individuals in the different plots is considered relatively homogeneous. This indicates that on average, there are 23.7 *G. dewevrei* trees in each diametric class. However, in most of the diametric classes the number of trees differs considerably from that average. The coefficient variation exceeds 30%,

indicating that the dispersion is strong and that the diametric distribution of *G. dewevrei* should be considered heterogeneous.

Over the 12 sampled plots, there were on average 21.6 trees with dbh ≥ 30 cm. The low value registered for P12 confirms the low value for *G. dewevrei* trees. This is also the case for the high values in P5 and P6, although these are less extreme than found for *G. dewevrei*. The coefficient variation is low (less than 15 %), indicating that the plots form a homogenous sample.

Table 2 shows that in the *G. dewevrei* forest, there were on average 32.4 trees in each of the diametric classes. With the exception of classes 50 to 79.9 cm, most classes have a value which is quite different from the average value. As was already shown in figure 4 the smaller classes have a much higher number of trees, and the larger classes have a much lower number. The tree class of ≥ 100 cm contains an elevated number of trees, which might be explained as being the result of including a much wider range of diameters, with trees up to 136, 6 cm the coefficient variation exceeds 30%, confirming the heterogeneity of the sampled plots in relation to the diameter of the trees.

Table 2. Number of trees with dbh ≥ 30 cm and diameter distribution registered in the twelve 50 \times 50 m sample plots.

Sample plot	Number of trees	Diametric Class	Number of trees
P1	22	30-39,9	65
P2	23	40-49,9	40
P3	20	50-59,9	35
P4	23	60-69,9	33
P5	24	70-79,9	35
P6	26	80-89,9	18
P7	19	90-99,9	10
P8	21	≥ 100	23
P9	19	Total	259
P10	21	Moyenne	32,375
P11	23	Variance	124,07
P12	18	Ecart-type	11,13
Total	259	CV(%)	34,37
Average	21,58		
Variance	5,53		
Standard deviation	2,35		
CV(%)	10,88		

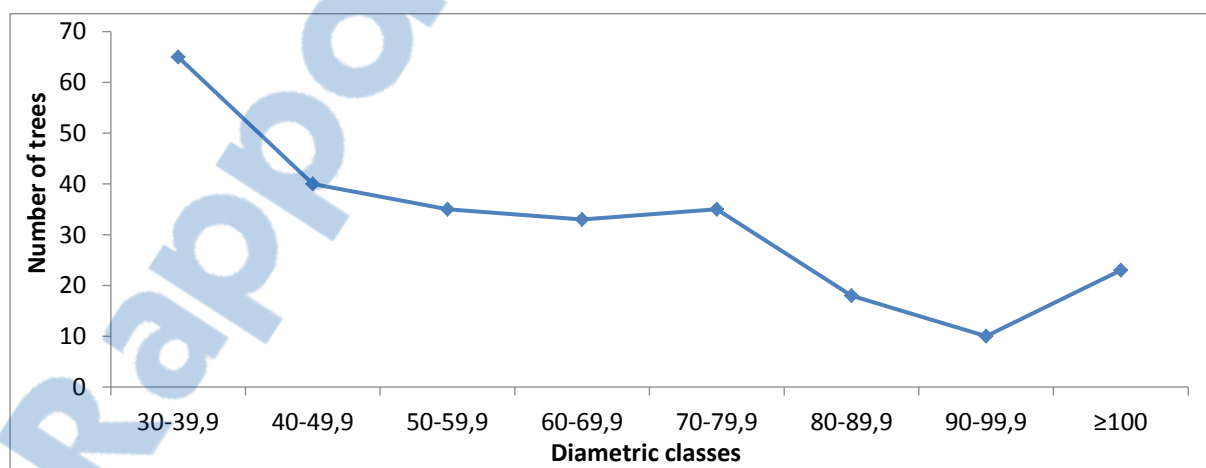


Figure 4. Vegetation structure by diametric class at Masako forest reserve.

The present study revealed that the sample area (3 ha) in the Masako *G. dewevrei* mono-dominant forest contained 259 trees with dbh ≥ 30 cm. On average, there were 86.3 trees per ha. Of these trees, 190 belonged to *G. dewevrei*, giving an average per hectare of 63.3. Lomba (2007), working in the *G. dewevrei* mono-dominant forest at Yoko, found 97 trees with dbh ≥ 30 cm in a 3 ha plot, resulting in an average of 32.3 trees per ha. 74 of the trees belonged to *G. dewevrei* (or 24.7 ha⁻¹). These numbers indicate that at Yoko fewer mature trees were occurring, both for all species combined and for *G. dewevrei* separately. This is mainly due to human action as farmers harvest the average diameter (≤ 40 dbh) of species for commercial interests.

Quantitative analysis of the floral data revealed that the global basal areas for the Masako *G. dewevrei* monodominant forest is 29.5 m².ha⁻¹ and 24.2 m².ha⁻¹ for *G. dewevrei* individuals. For the Yoko forest, Masiala (2009) calculated these as 24.4 m².ha⁻¹ and 22.7 m².ha⁻¹, respectively. This allows us to hypothesise that the forest at Yoko is still evolving and that this is no longer the case for the forest at Masako, which also has a much more disturbed character.

By comparing the species abundance in the *G. dewevrei* mono-dominant forest at Masako with the work of other researchers, the current study indicates that the dominant species at Masako are: *Gilbertiodendron dewevrei*, *Musanga cecropioides*, *Anonidium mannii*, *Trilepisium madagascariensis*, *Funtumia africana*, *Klainedoxa gabonensis*, *Petersianthus macrocarpus* and *Panda oleosa*. At Yoko, Masiala (2009) found the dominant species to be: *Gilbertiodendron dewevrei* followed by *Scorodophloeus zenkeri*, *Julbernardia seretii*, *Gilbertiodendron kisantuensis* and *Grossera* sp. In the forest of Uma, Katembo (2013) found that the dominant species are: *Gilbertiodendron dewevrei* (29%), followed by *Cola griseiflora* (8%), *Diospiros* sp (6%) and other species. The species composition varies from site to site.

In the three sites (Masako, Yoko and Uma) the same trend in abundance of *Gilbertiodendron dewevrei* was encountered. However, in the two following locations, this was not the case. Indeed, in Mbiye Island, Kambale (2009) found that *Coelocaryon botryoides* was the most abundant species, followed by *Gilbertiodendron dewevrei*, *Diospiros boala*, *Pycnanthus angolensis* and *Cleistanthus mildbraedii*.

The diameter distribution of all species combined (total structure) is one of the stand's characteristics reflecting an equilibrium constant, which is the existence wherever moist evergreen forests are in their original state (Fournier *et al.* 1983). To highlight the disturbed state of forest plant community proposed a structural analysis for the species that account for the unbalanced or balanced state of the forest.

Nshimba (2008) indicated that *Gilbertiodendron dewevrei* forest at Uma and the mixed forest on the Mbiye Island have the form of a "mirrored J" for the stems with dbh ≥ 30 cm, whereby the class size 30–39.9 cm accounts for the highest number of trees and subsequent diametric classes all have lower values. These forests have the typical diametric structure of natural forests, which is contrary to the Masako *Gilbertiodendron dewevrei*.

Forest showing that the histogram has the form of a "mirrored J with a bulbous tail". The diametric classes between 40 and 70 cm dbh contain much higher numbers of trees, which indicate that the Masako forest is unbalanced and this is due to human action. Farmers harvest the average diameter of species for commercial interests.

CONCLUSION

The current study has focused on the forest structure of a *Gilbertiodendron dewevrei* monodominant forest based on tree species in the Masako Forest Reserve. An inventory of the mature trees (dbh ≥ 30 cm) was made on a 3 ha area, which was composed of 12 plots of 50 \times 50 m each, where all trees meeting this condition were surveyed.

- In the 3 ha sample area, 259 meeting the dbh condition were registered. The number of trees is 259 for the forest *G. dewevrei* in 3 ha. Trees belonging to the Fabaceae family were found to be the most commonly occurring group (85% of species).
- The results showed that the overall tree density is 83.3 stems/ha and 63.3 stems/ha for *G. dewevrei*.
- In the forest, the overall basal area is 29.5 m².ha⁻¹ and for *G. dewevrei* this is 24.2 m².ha⁻¹.
- The vegetation was classified in eight diameter classes: 30–39.9 cm; 40–49.9 cm; 50–59.9 cm; 60–69.9 cm; 70–79.9 cm; 80–89.9 cm; 90–99.9 cm and ≥ 100 cm.
- As illustrated by the high values for the variance coefficient (exceeding 30%), the diametric distribution is heterogeneous for both the overall sample and *G. dewevrei* alone.

Regarding the distribution of the number of trees over the sampled plots, the variation coefficient has values between 15 and 30 %, indicating that the forest is relatively homogeneous. Additional research is needed to find ways to stop the decrease and to determine measures enabling to prevent the forest overexploitation.

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