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Study of the Structures of *Brachystegia laurentii* (De Wild) (Fabaceae) Forest of Biaro in the Tshopo Province (D. R. Congo)

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Abstract. This research focused on the study of different structures of the *Brachystegia laurentii* forest on an area of 3 ha in Biaro in the Tshopo Province of the Democratic Republic of Congo. The density of trees is 353 individuals per hectare, the number of species inventoried is 91 grouped in 18 families. The structure of the forest corresponds to an inverse regression, the average total height is 20.6 m, the vertical stratification recognizes four strata of which the shrubby one, the lower arborescent one, the middle arborescent one and the upper arborescent one. The spatial distribution according to the nearest neighbor method or Clark and Evans Index for all trees with DBH ≥ 10 cm is random while that of *Brachystegia laurentii* species is aggregated or clustered.
Key words: Structures, Forest, *Brachystegia laurentii,* Spatial distribution, Biaro

Introduction

The Democratic Republic of Congo is a forestry country (Lokombe, 2004). It was a vast African country with more than half of its national territory covered by forest. It is one of the world's reservoirs of biodiversity (Lomba *et al.*, 2017; Okangola *et al.*, 2016; Asimonyo *et al.*, 2015). However, forest management requires structural studies in order to know which forest species can be exploited taking into account the logging standards set by the Congolese forestry administration (SPIAF, 2007).

At the beginning of the 21st century, the world's attention to its future is focused on the accelerated degradation of the environment and therefore of biodiversity, which seems to hasten the process of climate and habitat modification and amplify the unavailability of biological resources (Katuala, 2009). This biological diversity is both the result of the size of the massif, the second largest in the world after the Amazon, and the diversity of climates. The Democratic Republic of Congo alone is home to 60% of this massif (Kahindo, 2011).

In Africa's tropical forest ecosystems, due to global climate change and increasing deforestation linked to anthropogenic activities (Juo & Wilding, 1996; Querouil, 2001; Katuala, 2005). The need to study Congolese forests is all the greater because they constitute a natural heritage that deserves to be preserved. Thus, knowledge of the floristic richness of a *Brachystegia laurentii* forest or of a given ecosystem, the identification of its diametric and horizontal structure (spatial distribution) or, better still, the way in which its elements are arranged, are important elements for its sustainable management (Katusi *et al.*, 2021).

It is really important to understand the functioning of tropical forests to better manage and preserve them (Lomba, 2011; Mabiangana & Malaisse, 2020). Indeed, the forests are not sufficiently known (Musepena, 2009).

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The central question of this study is whether the *Brachystegia laurentii* forest is expanding or contracting. The *Brachystegia laurentii* forest is growing as many regenerating individuals are present at the edge of mature stands.

Materials and Methods

Description of the Study Area

The village of Biaro is located between kilometers points 41 and 48, in the Barbote group, in the Bakumu Mangongo community, in the Ubundu territory in the Tshopo Province of the Democratic Republic of Congo.

The site of our research being located at the periphery of Kisangani, it benefits from the general climate of Kisangani of the type AF of the Koppen classification (Bultot, 1950; Ifuta, 1993).

- ✓ The average temperature of the coldest month was above 18°C;
- ✓ The annual thermal amplitude is less than 0,5°C;
- ✓ The average precipitation of the driest month is around 60 mm;
- ✓ High average annual relative humidity of 82%.

The equatorial climate of Kisangani region, which includes our study site, has a long rainy season and two short sub-dry seasons in January and February and in July (Bultot, 1950).

The Biaro forest is part of the mesophilic evergreen forests (Lomba, 2012). These are replacement forests that succeed forest recursions with tolerant heliophic and deciduous species (White, 1986; Puig *et al.*, 1989).

These forests have a less dense cover and numerous openings. According to the Forestry Transformation Compagny (2005), these forests are made up of primary, secondary and fallow forests.

Amani (2011) defined two types of soils namely, clay dominated soils located in the areas crossed by streams and sandy dominated soils located on the plateaus.

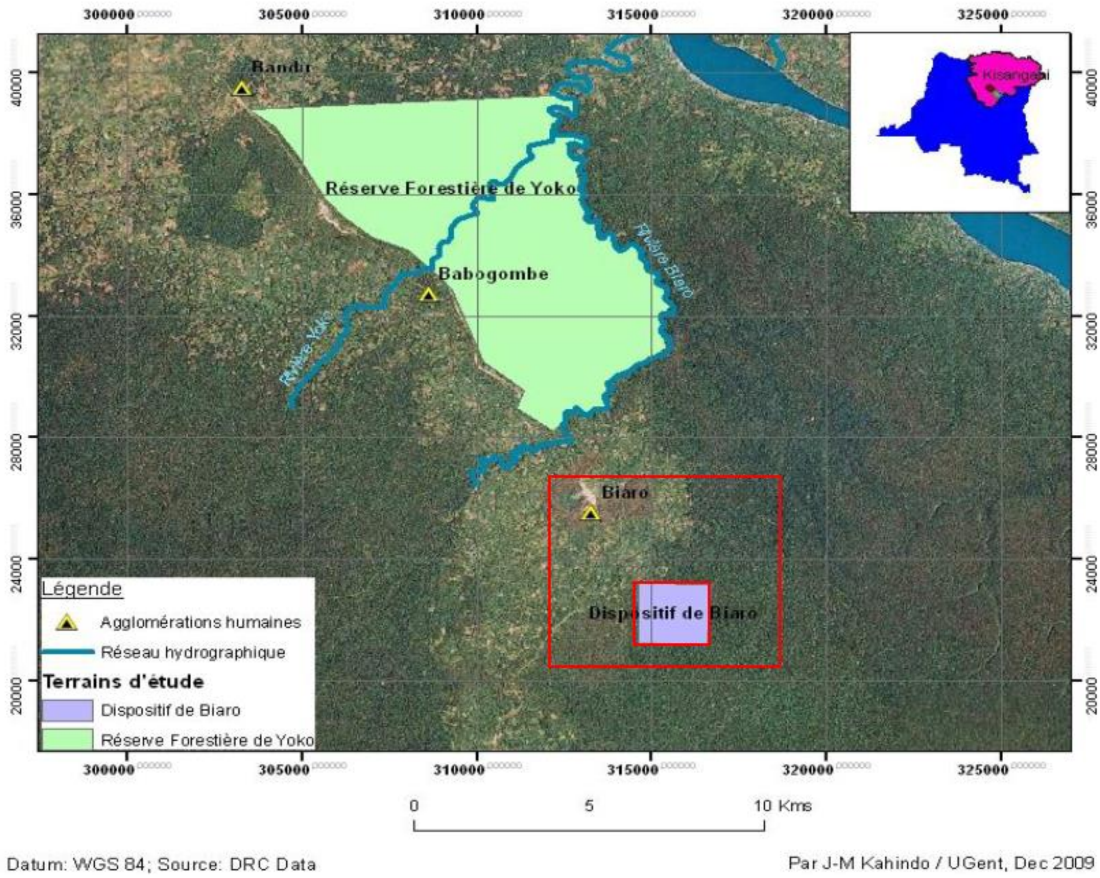


Figure 1: Biaro forest (Source: KAHINDO/UGent 2009)

Biological and Technical Equipment

The biological material used would refer to all woody species with DBH (Diameter at Breast Height) greater than or equal to 10 cm encountered in this *Brachystegia laurentii* forest.

Equipment used included: two *Bitterlich Relascopes* (broad band and narrow band) for measuring dendrometric parameters (DBH, tree heights); the compass (Topo chaix) and machetes (6) for layering; the pair of binoculars for observing the particular distinctive characteristics of the flowers and leaves of certain species whose identification by external morphological characters poses a problem; blood chalk (yellow and red) for numbering the trees to be inventoried and marking the level of the DBH on which to take the measurement; the dendrological manual for the identification of certain species; the GPS for taking geographical coordinates; and the different equipment used for the study of 91 woody species distributed in 1010 individuals scattered in three hectares of this forest with *Brachystegia laurentii*.

Methods

The reviews of the literature referring to previous studies on the structure of forest stands and the genus *Brachystegia* in the dismembered Eastern Province or in the vicinity of Kisangani was the first methodological step. It was followed by the reconnaissance survey allowing us to choose the experimental site. Finally; after having circumscribed the study area and after the main path had been opened, we divided the forest first into 6 plots of 25 m x 200 m along the main path (i.e. 3 ha of surface), then into other 6 sub-plots or sample plots of 10 m x 50 m (i.e. 0,3 ha) at the rate of a survey of 10% of the total surface, based each time on one of the sides of the path per plot.

The main parameters taken into account to obtain field data in this part of the *Brachystegia laurentii* forest in Biaro are: the Diameter at Breast Height corresponding to measurements at 1,30 m from the ground (DBH) to characterize the diametric structure; the different heights (Bole Height and Total Height) for the height structure and finally; X, Y coordinates to determine the spatial distribution of the trees (RS) of the species.

The transformations of the raw measurements obtained with the Bitterlich Relascope were carried out in the following way:

$$\text{Diameter } (d) = 2\ \mu\ a$$

Where: d = diameter (cm)
μ = number of relascopic units
a = horizontal distance in m between the shalf and the operator for height.

$$\text{Height } (H) = Ls - Li$$

Where: H = height (m)
Ls = top reading (taken from the top of the tree)
Li = low reading (30 cm from the ground)

This height is obtained from the measurement scales. There are then for the relascope with narrow bands, three scales: that of 20 m, of 25 m and of 30 m.

When the operator places himself at any horizontal distance not corresponding to those of the scales, we will obtain in this case a false height after transformation of the data by the formula H' = Ls– Li and the true height will be obtained by the relation:

$$H = \frac{H'L'}{L}$$

Where: H = true height (m)
L'= the horizontal distance between the shaft and the operator (m)
L = the measuring scale used.

For the relationship between diameter and density

Linear model: $y = a + bx$
Logarithmic model: $y = a + b \ln x$
Power model: $y = a\,x^b$
Exponential model: $y = a.e^{bx}$
Quadratic model: $y = a + bx + cx^2$
Inverse model: $y = a + b/x$

For wealth indices

- Relative Frequency (FR)

$$FR = \frac{\text{Frequency of a species}}{\text{Total frequencies of all species}} \text{ X } 100$$

- Relative Density (DER)

$$DER = \frac{\text{Number of individuals of a family or species}}{\text{Total number of individuals in the sample}} \text{ X } 100$$

- Relative Dominance (DOR)

$$DOR = \frac{\text{ST of a family or species}}{\text{Total ST of the sample}} \text{ X } 100$$

- Importance Index

$$\text{Importance Index} = DER + DOR + FR$$

The frequency of a species is the number of sample units containing that species and for each of the first three parameters mentioned above, the values can theoretically vary between 0 and 100. The importance index of a species or family is the sum of its density, dominance and relative frequency. The range of values for the importance index of a species or family varies between 0 and 300 (Cottan & Curtis, 1956).

For characterization of spatial distribution according to the Clark and Evans Index

Population Density (ρ)

$$\rho = \frac{\text{Number of individuals in the study area}}{\text{Survey area}}$$

The average distance observed to the nearest neighbor

$$r_O = \sum \frac{ri}{n}$$

Where: r_i: distance to the nearest neighbor for individual i;
n: Number of measured distances.

The expected distance to the nearest neighbor (r_E)

$$r_E = \frac{1}{2}\sqrt{D}$$

The distance measure of the observed distance from the random distance (R)

$$R = \frac{rO}{rE}$$

The standard error of the exp (S_r)

$$S_r = \frac{0{,}26136}{\sqrt{\text{n x p}}}$$

The normal standard deviation (Z) /

$$Z = \frac{\text{rO} - \text{rE}}{\text{Sr}}$$

Criteria: R=1 Random distribution; R is close to 0 the distribution is aggregated; R is ± 2.15 the distribution is uniform.

Statistical Data Processing

In addition to the data processing software listed above, the rest of the statistical analyses were performed using R software version 2.10.0 (R Development Core Team, 2009). The analyses performed were as follows:

a. Comparison of means test

The analysis of variance, which is a parametric test, was used to compare the means, including densities and land areas between the three forest stands under study. Where the ANOVA was significant, the Tukey multiple comparison post hoc test was used to detect these differences.

b. Comparison of proportions

To perform comparisons of proportions, especially between diameter classes, we used the chi-square compliance test:

$$\chi 2 \text{ (chi-square)} = \sum_{i=1}^{k} \frac{(ni-ti)2}{ti}$$

Where ni = number of observed individuals in class i; ti = number of theoretical individuals in class i; k = number of classes in the qualitative variable (k ≥ 2); and i = class number in the qualitative variable (1 ≤ i ≤ k).

Chi-square should always be applied on raw observed values, never on transformed values (Harvey, 2002; Nshimba, 2008). The other essential condition required to ensure the validity of the chi-square test results is the fulfillment of the Cochran rule (Millot, 2011) setting a minimum number of classes: in each class the theoretical frequencies must be greater than or equal to 5, but the possibility of having some classes with theoretical frequencies between 1 and 5% is likely if a minimum of 80% of the total classes have at least 5 theoretical numbers. When the Cochran rule was not followed, Fisher's exact test was used either in place of the Chi-square test or concurrently to validate the Chi-square results.

c. Normality test

The analysis of variance is performed on variables obeying the normal distribution. To do this, the test of verification of the normality of the variables, done before this test, was that of Shapiro-Wilk.

d. Significance of a test

To decide the significance of a test, we referred to the value of the statistic (p-value) provided by the R software at the end of each analysis:

if p-value ≥ 5 %: non-significant difference;

if p-value < 5%, < 1% and < 0.1%: significant, very significant and highly significant difference respectively.

Results

Diameter Structure

Diameter at breast height (DBH)

DBH is the most widely used parameter in tropical forest inventory (Lokombe, 1996). It provides information on the minimum usable diameter (MUD) which is of particular interest to loggers (Figure 2).

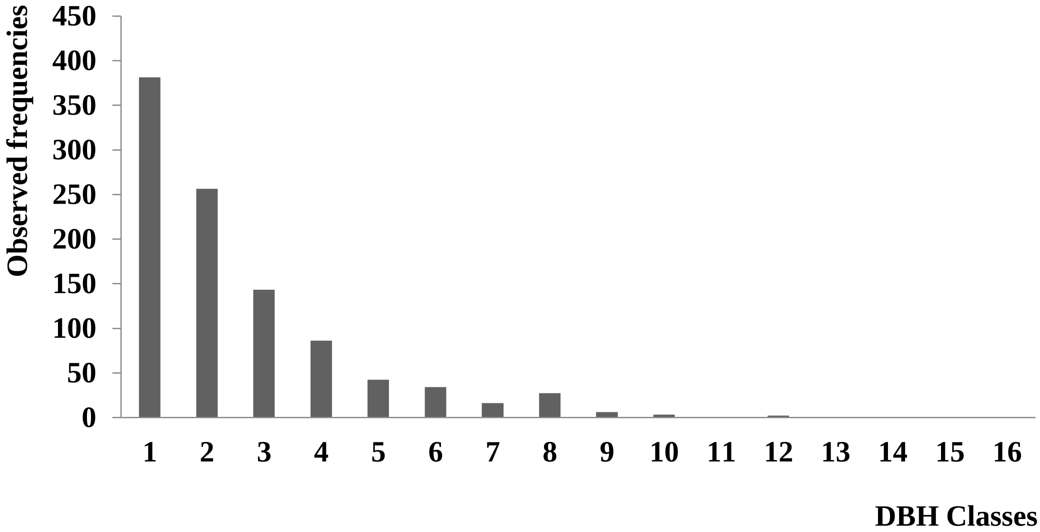


Figure 2: Distribution according to DBH (3 ha)

According to Terrea's classification (2006), this curve presents an i-shaped structure denoting a constant regeneration over time. The peak is made up of trees with a DBH lower than 20 cm and the low level by those of 110 cm and more.

Relationship between DBH and density

Six regression models were tested, of which only four passed the calculations because power and exponential could not be estimated due to missing DBH classes (Table 1).

Table 1: Relationship between DBH and density

N°	Regression factor	Linear regression	Logarithmic regression	Inverse regression	Quadratic regression
1	a	73,68	229,31	-18,48	136,18
2	b	- 0,58	-48,28	2255,33	-2,46
3	c	-	-	-	0,01
4	r	- 0,76	-0,92	0,98	0,94
5	r^2	0,57	0,84	0,97	0,89

This table illustrates that the inverse, quadratic and logarithmic equations gave acceptable r² (greater than or equal to 0.800). However, we retain the inverse regression because of its clearly high r² and especially because it gives frequency values that approach the reality of the field data by replacing the DBH in the equation.

Presentation of the Inverse Regression Curve

Figure 3 illustrates the inverse regression curve retained after the calculations.

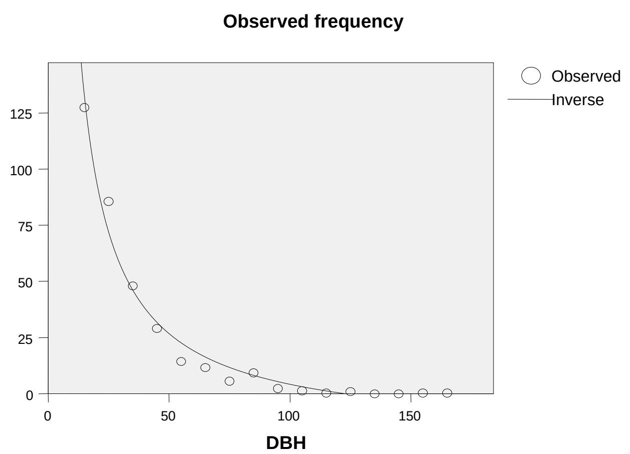
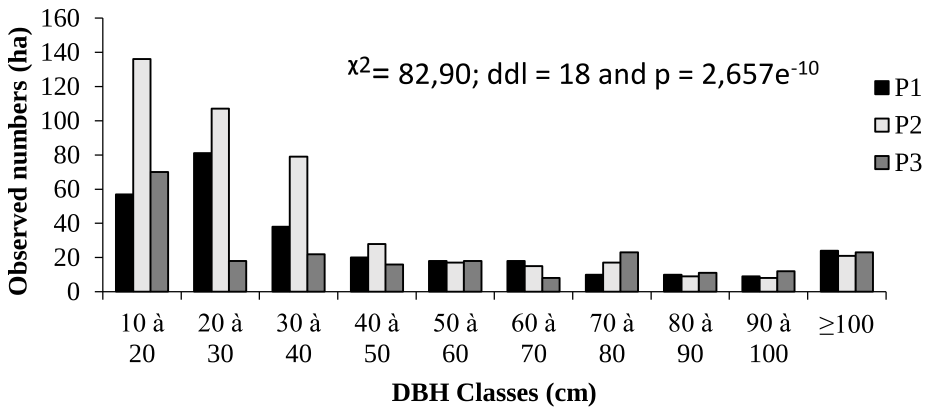


Figure 3: Presentation of the inverse regression curve

Density and Basal Area



X-squared = 82.8947, ddl = 18, p-value = 2.657e-10

Figure 4: Relationship between density and basal area

Two to Two Comparison

P1 and P2

X-squared = 23.0841, ddl = 9, p-value = 0.00601, the difference is highly significant.

P1 and P3

X-squared = 48.275, ddl = 9, p-value = 2.269e-07, the difference is not significant.

P2 and P3

X-squared = 59.6239, ddl = 9, p-value = 1.584e-09, the difference is not as significant.

Height Structure

Total height (Ht)

Figure 5 shows the graphical representation of the distribution of stem frequencies by total height classes.

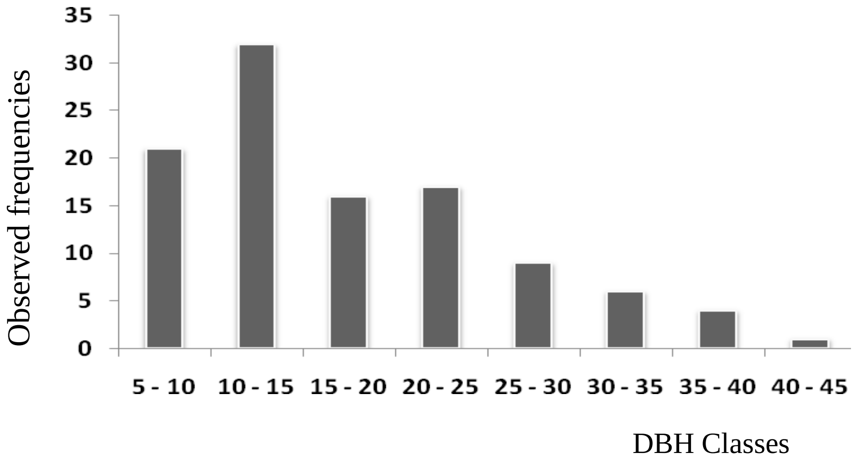


Figure 5: Distribution of stems according to total height Ht

Reading this graph shows that most of the trees in the study forest are between 5 and 25 m in total height, with a high relative frequency in the 10 - 15 m class. This bell curve shows that the tallest tree is between 40 and 45 m in height and that trees between 10 and 15 m in height are the most numerous.

Stratification

The following Table 2 illustrates the different strata estimated in the *Brachystegia laurentii* forest of Biaro.

Table 2: Distribution of stems according to their spatial occupancy by total height

Classes of Ht	Class Index (Xi)	Observed frequencies (ni) 0,3 ha	Relative frequencies (ni') %	Observed frequencies accumulated	Observed frequencies (ni) 1 ha
1 - 5	3	9	8,49	9	30
5 -15	10	44	41,51	53	147
15 -25	20	33	31,13	86	110
25 -35	30	15	14,15	101	50
35 - 45	40	5	4,72	106	17
TOTAL		**106**	**100**		**353**
Average height (m)	**20,6**				
Standard deviation	**14,89**				
Variation coefficient %	**72,29**				

From this table we can see that the lower tree stratum (class 5 - 15) occupies a greater number of stems than all the other strata (41,51% of observed frequencies) followed by the middle tree stratum (15 - 25).

Relative Density, Relative Dominance, Relative Frequency and Importance Indices

Table 3 presents the relative density, relative dominance, relative frequency and importance index of the ten most represented species in the *Brachystegia laurentii* forest.

Table 3: Relative density, relative dominance, relative frequency and importance indexes of the ten most represented species in the study forest

N°	Species	Number of individuals 3 ha	Number of individuals 1 ha	DER	DOR	FR	Index of importance
1	*Gilbertiodendron dewevrei*	215	72	7,1	35,00	21,26	63,36
2	*Brachystegia laurentii*	179	60	5,91	20,00	17,70	43,61
3	*Cola griseiflora*	84	28	2,77	4,60	8,30	15,68
4	*Cleistanthus mildbraedi*	50	17	1,65	2,90	4,94	9,49
5	*Dialium corbisieri*	28	9	0,92	1,90	2,77	5,59
6	*Polyalhia suaveolens*	27	9	0,89	1,40	2,67	4,96
7	*Drypetes louisii*	26	9	0,89	1,20	2,57	4,63
8	*Julbernardia serettii*	26	9	0,89	1,70	2,72	5,13
9	*Aphanocalyx cynometroides*	23	8	0,76	1,00	2,27	4,03
10	*Baikiaea insignis*	15	5	0,5	0,90	1,48	2,87
Total for 10 species		**673**	**224**	**22,21**	**70,60**	**66,56**	**159,37**
81 remaining species		**337**	**112**	**77,79**	**29,40**	**33,43**	**140,62**
General total		**1010**	**337**	**100**	**100,00**	**100**	**300,00**

The above table shows that the relative density, relative dominance and relative frequency, give values that vary between 0 and 100 and the index of importance is 300.

Floristic Structure

Specific richness

The intermediate stand has the highest number of species (33, consisting of 23 species in the DBH ≥ 10 cm category and 10 species in the DBH ≥ 50 cm category), followed by the low density stand of *Brachystegia laurentii* (30 species, consisting of 21 species in the DBH ≥ 10 cm categories and 9 species in DBH ≥ 50 cm) and the *Brachystegia laurentii* stand (28 species, 19 et 9 species in the first and second categories); 91 species (i.e., 63 in the DBH ≥ 10 cm category and 28 species in the DBH ≥ 50 cm category) were inventoried across all three stands (Table 4).

Table 4: Floristic structure

0	P1	P2	P3
Species	33	28	30
Individuals	385	437	226
Families	21	17	23
Simpson_1-D	0,9131	0,9519	0,8164
Shannon_H	3,095	3,507	2,562
Fisher_alpha	18,02	12,2	19,88

Spatial Structure

Positioning of all species per plot

The figures below show the positioning (X, Y) of all trees in the sample plots over an area of 0,3 ha.

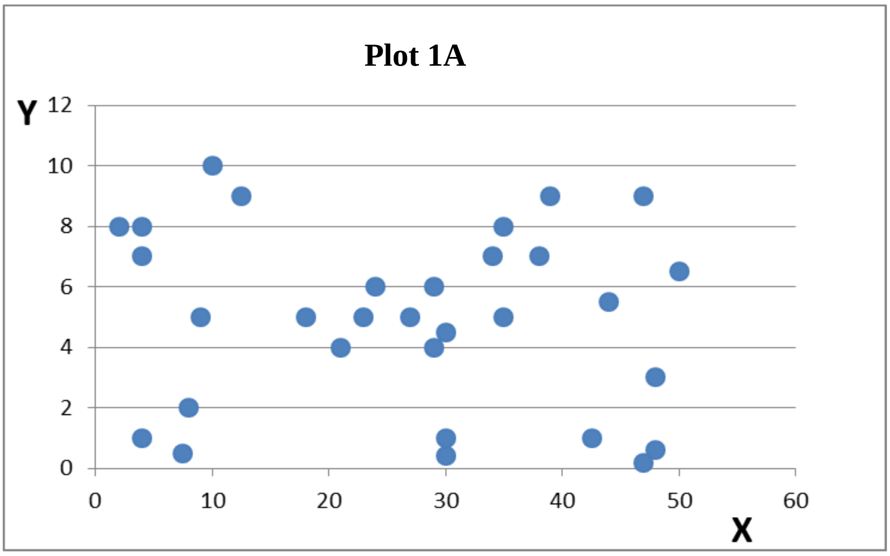


Figure 6: Positioning of trees in plot 1A

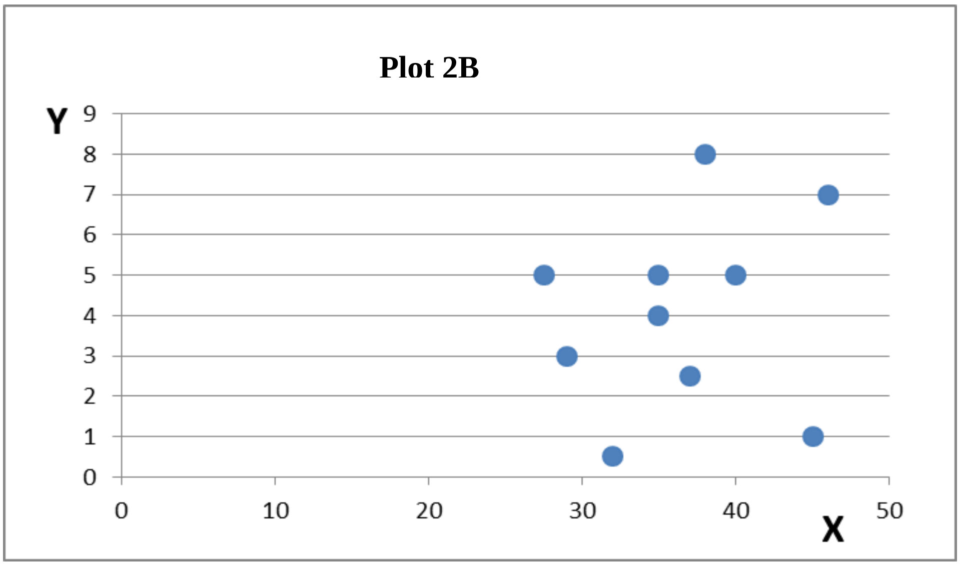


Figure 7: Positioning of trees in plot 2B

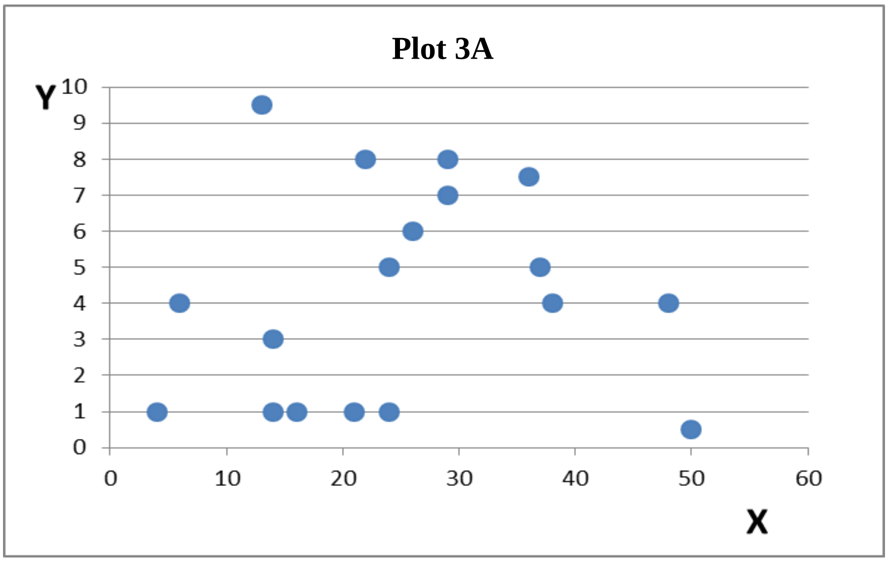


Figure 8: Positioning of trees in plot 3A

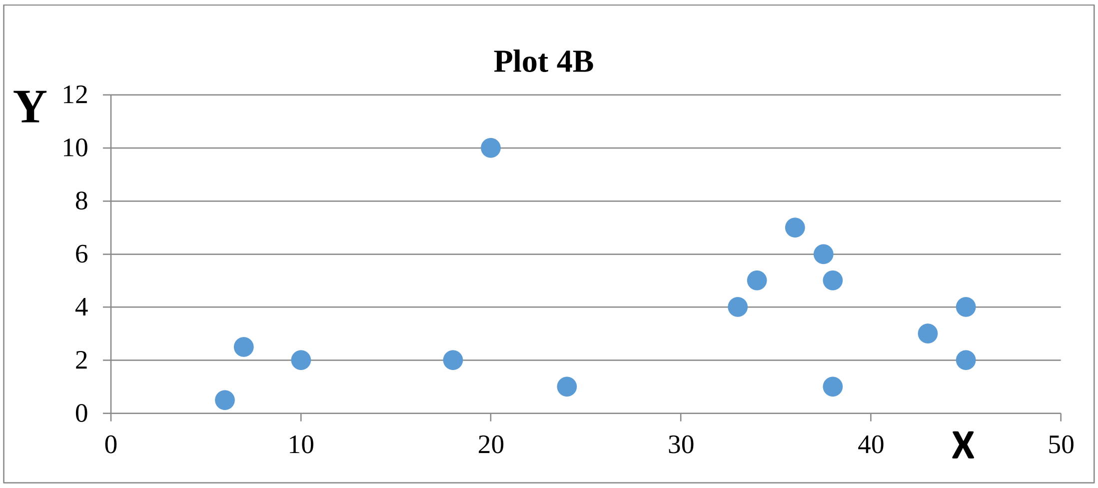


Figure 9: Positioning of trees in plot 4B

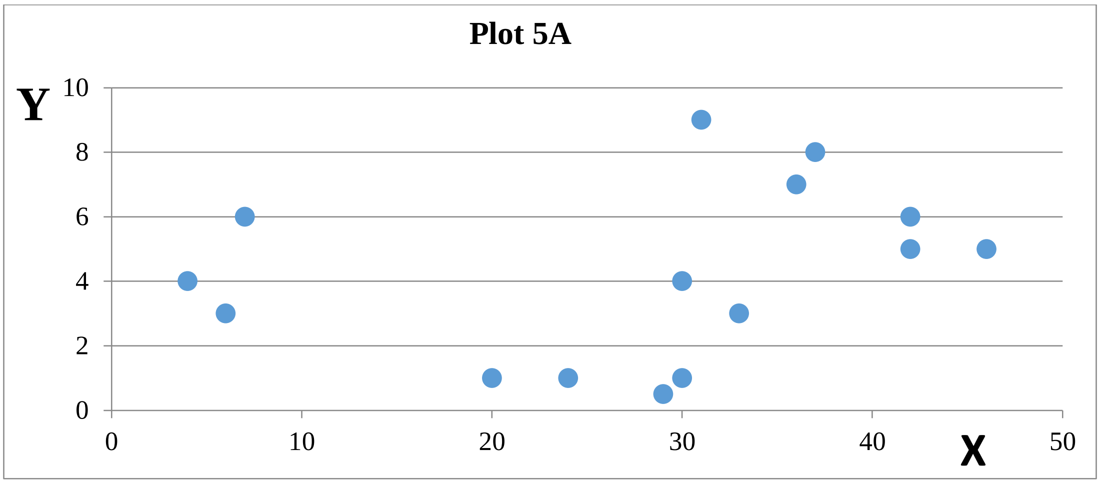


Figure 10: Positioning of trees in plot 5A

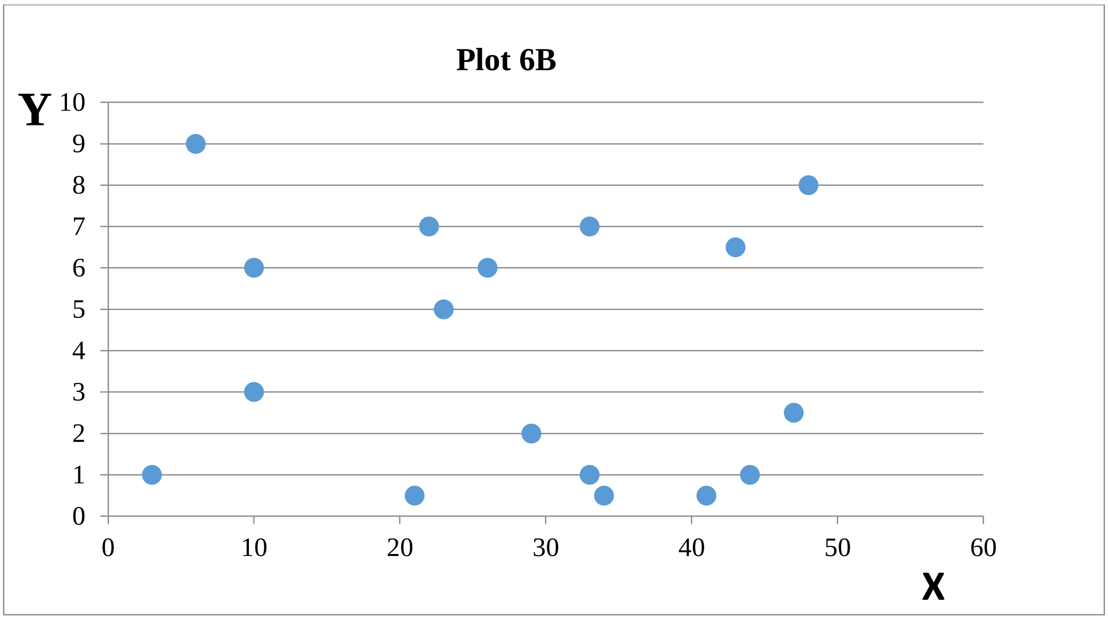


Figure 11: Positioning of trees in plot 6B

Positioning of the species Brachystegia laurentii by plot

The following figures show the positioning of *Brachystegia laurentii* on an area of 0.3 ha.

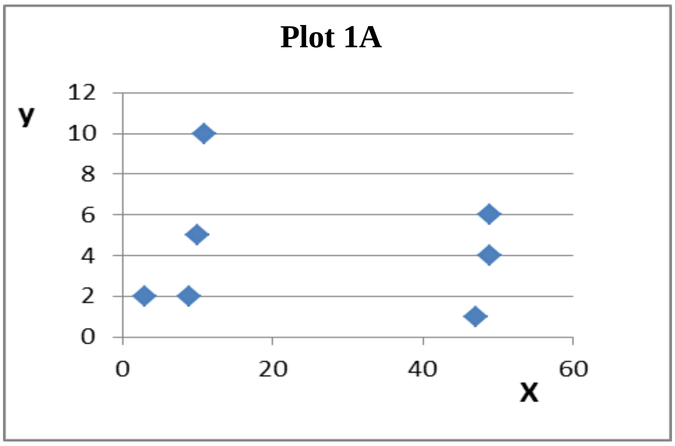


Figure 12: Positioning of *Brachystegia laurentii* in the plot 1A

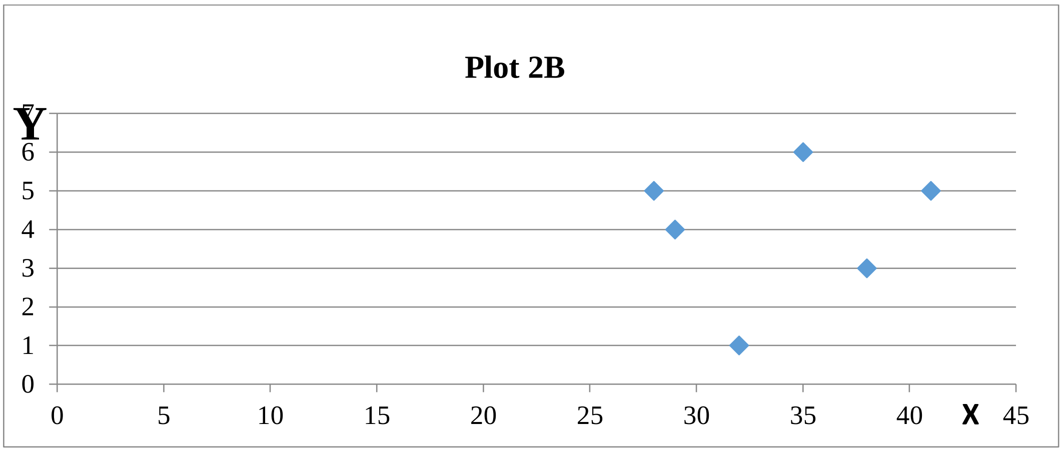


Figure 13: Positioning of *Brachystegia laurentii* in the plot 2B

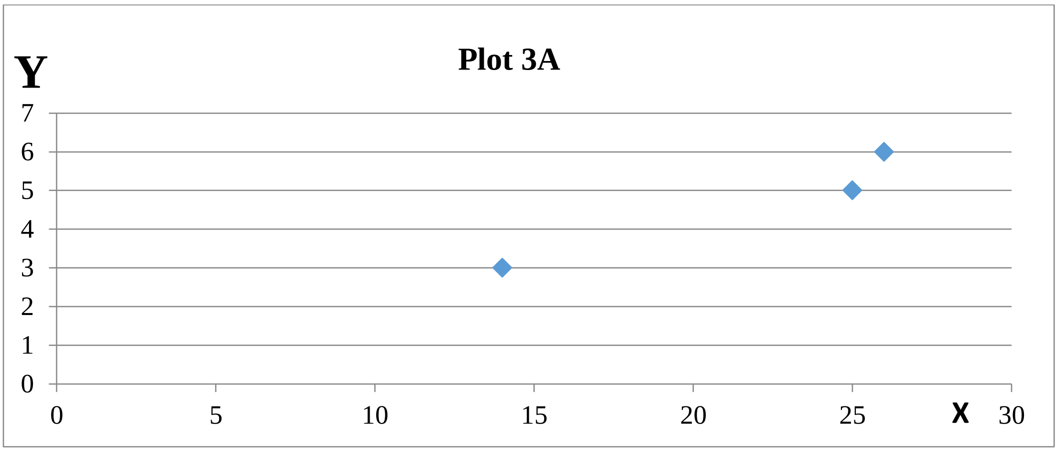


Figure 14: Positioning of *Brachystegia laurentii* in the plot 3A

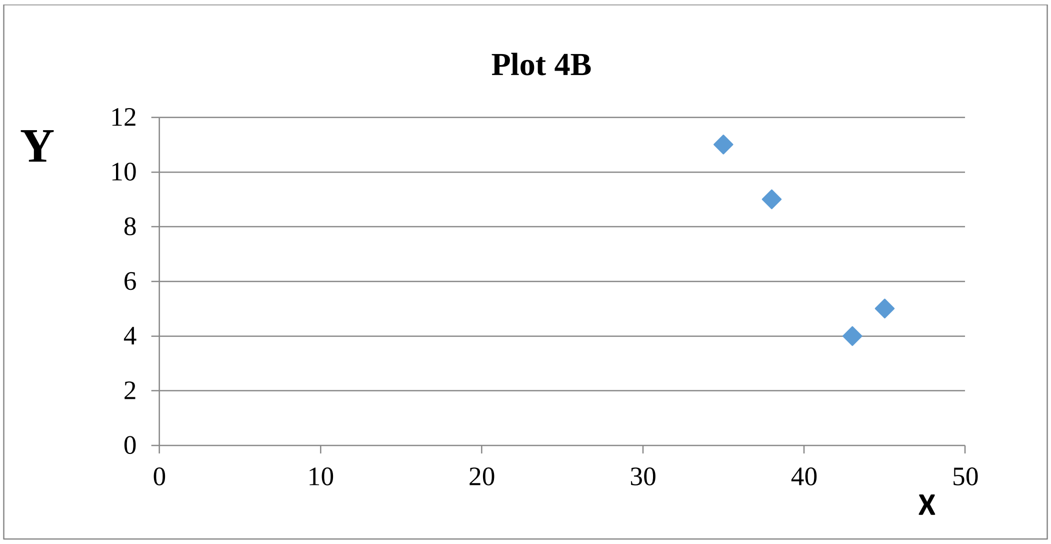


Figure 15: Positioning of *Brachystegia laurentii* in the plot 4B

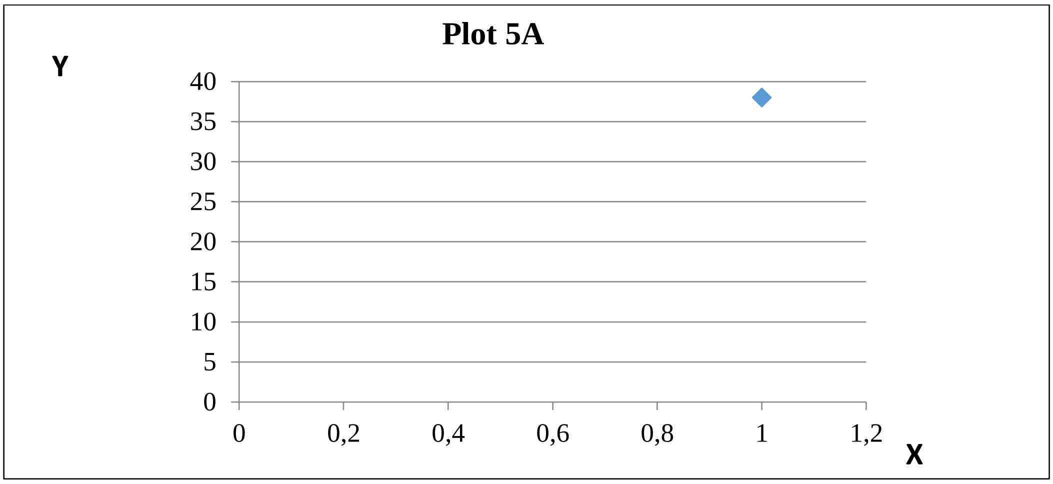


Figure 16: Positioning of *Brachystegia laurentii* in the plot 5A

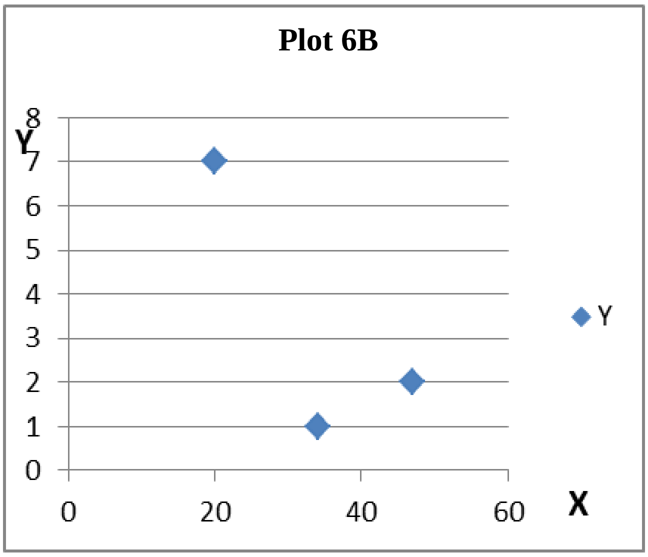


Figure 17: Positioning of *Brachystegia laurentii* in the plot 6B

Characterization of Spatial Distribution

The CLARK and EVANS index or nearest neighbor method was used to analyze the spatial structure of *Brachystegia laurentii* and all species in this *Brachystegia laurentii* forest of Biaro.

Calculations of spatial distribution parameters for all species:

a) ρ = 106/ 3750 = 0,0282
b) r_O= 336,5/99 = 3,3989
c) r_E = 1/ 2√0,0282 = 2,9739
d) R = 3,3989/2,9739 = 1,1429
e) S_r = 0,26136/ √24 x 0,0282 = 0,8980
f) Z = 3,3989- 2,9739/ 0,8980 = 0,4732

Calculation of the parameters of the spatial distribution for the species *Brachystegia laurentii:*

a) ρ = 23/ 3750 = 0,0061
b) r_O= 88/17 = 5,1764
c) r_E = 1/ 2√0,0061 = 6,3844
d) R = 5,1764/6,3844 = 0,8107
e) S_r = 0,26136/ √23 x 0,0061 = 7,1855
f) Z = 5,1764- 6,3844 / 7,1855 = 0,1681

Table 5: Presentation of the results of the spatial distribution

Calculated Parameters	All species	*Brachystegia laurentii*
n	106	24
ρ	0,0282	0,0061
r_i min (m)	0,5	1
r_i max (m)	15	14
r_O (m)	3,3989	5,1764
r_E (m)	2,9739	6,3844
R	1,1429	0,8107
S_r	0,8980	7,1855
Z	0,4732	0,1681

This table reveals that for all species, the observed distance is 14% larger than expected and for *Brachystegia laurentii*, the distance is 19% smaller than expected. This indicates a random distribution for all species and aggregated for *Brachystegia laurentii*. Normal standard deviations indicate that the spatial distributions obtained are not significantly different from a random distribution for all species on the one hand and an aggregated distribution for *Brachystegia laurentii* on the other hand because the Z values do not exceed the threshold for $\alpha = 0.05$.

Floristic Similarity between the Six Studied Stands

The six forest stands studied do not constitute the same plant community in terms of floristic composition. Analysis of the Morisita Similarity Index results between these stands (Table 6) indicates that Stands IV and V are very close floristically (MHC =0.81 > 0.50), while Stands VI and IV, VI and V are similar (MHC = 0.54 and 0, 55) and II and I constitute two distinct plant communities (MHC = 0.48 < 0.50). These results support the analysis that stand VI is a transition zone, as it has similarities with the other two stands that are otherwise distinct from each other. The analysis of similarity between the plots inventoried discriminates in turn, in a separate group, the plots installed in the *Brachystegia laurentii* stand (MHC between the plots of this group and those of two others < 0.50, except for plots VI and V-IV of the intermediate stand which are close to them). Figure 18 again shows that the records from Stand I-II and IV-V are clustered together, but approach those from Stand VI through the first plot of that stand, which appears to be rather close floristically.

Table 6: Analysis of the results of the Morisita Similarity Index

Plots	I	II	III	IV	V	VI
I	1					
II	0,48	1				
III	0,32	0,43	1			
IV	0,71	0,16	0,51	1		
V	0,75	0,22	0,05	0,81	1	
VI	0,57	0,27	0,24	0,54	0,55	1

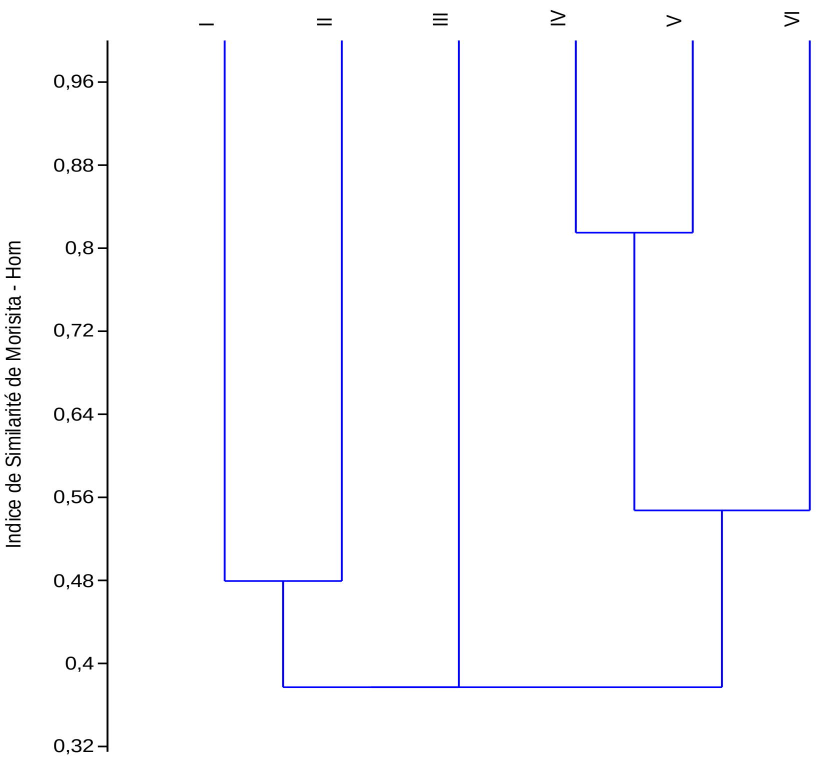


Figure 18: Dendrogram grouping plots according to their floristic similarity in terms of their abundance in the study stands

Discussion

We inventoried a total of 1010 trees grouped into 91 species and 18 different families for all individuals with DBH ≥ 10 cm and over an area of 3 ha.

The results with respect to diameter structure, height structure and stratification, floristic richness structure and spatial structure of species are compared in this section to other results obtained in other forests already studied and having the minimum DBH of 10 cm in common; i.e. DPH ≥ 10 cm.

Diameter Structure

Table 7 compares the regression models selected for the *Brachystegia laurentii* forest studied, with those of other forests in order to evaluate the relationship between diameter and stand density.

Table 7: Presentation of some mathematical models for distinguishing stems by DBH classes

Types of Forests	Location	Mathematical models		References
Brachystegia laurenti forest	Biaro	$y = -18{,}46 + 2255{,}33/DHP$	$R^2{=}0{,}97$	Present study
	Biaro	$y = 136{,}18 - 2{,}46\ DHP + 0{,}010\ DHP^2$	$R^2{=}0{,}89$	Present study
Mixed forest	Yoko	$y = 446{,}14\ e\ 0{,}62\ DHP$	$R^2{=}0{,}91$	Ebuy, 2006
	Yoko	$y = 3157076 DHP^{-3{,}22}$	$R^2{=}0{,}80$	Ebuy, 2006
Scorodophleus zenkeri forest	Loweo	$y = 352{,}95e^{-0{,}05DHP}$	$R^2{=}0{,}93$	Assumani, 2006
	Loweo	$y = 300{,}35 - 65{,}64\ DHP$	$R^2{=}0{,}92$	Assumani, 2006
	Loweo	$y = 3157076\ DHP^{-9057}\ DHP$	$R^2{=}0{,}99$	Solia, 2007
	Loweo	$y = 145{,}66 + 1466{,}50\ DHP$	$R^2{=}0{,}96$	Solia, 2007
Gilbertiodendron dewevrei forest	Abou	$y = 104{,}36 – 22{,}45 \log DHP$	$R^2{=}0{,}96$	Lokombe, 1996
	Abou	$y = 146{,}23e^{0,\ 048}\ DHP$	$R^2{=}0{,}92$	Lokombe, 1996
	Azolo	$y = 69096{,}3DHP – 2315$	$R^2{=}0{,}92$	Lokombe, 1996
	Azolo	$y = 48{,}04e^{-0{,}032}\ DHP$	$R^2{=}0{,}88$	Lokombe, 1996
	Bawombi	$y = 107539{,}1DHP^{-2{,}362}$	$R^2{=}0{,}81$	Lokombe, 1996
	Bawombi	$y = 74{,}34e^{-0{,}034}\ DHP$	$R^2{=}0{,}91$	Lokombe, 1996

The inverse, quadratic, and logarithmic regression models gave acceptable coefficients of determination $R^2 \geq 0.80$. However, we retain the inverse model due to the fact that it gives estimated stem frequencies that approach the reality of the field.

Height Structure and Stratification

Height structure (Ht)

Table 8 below compares the average total heights obtained with those of the other forests already studied.

Table 8: Comparison of the average heights (Ht) of the *Brachystegia laurentii* forest in Biaro with those of other forests in the sub-region

Types of forests	Location	Total height average (m)	References
R.D. CONGO			
Brachystegia laurentii forest	Biaro	20,6	Present research
Scorodophloeus zenkeri forest	Loweo	19,60	Assumani, 2006
Gilbertiodendron dewevrei forest	Abou	24	Lokombe, 1996
Gilbertiodendron dewevrei forest	Azolo	25,60	Lokombe, 1996
Gilbertiodendron dewevrei forest	Bawombi	17,40	Lokombe, 1996
GABON			
Mixed forest	Boussala	22,10	Reistma, 1988
Mixed forest	Ekobakoba	25	Reistma, 1988
Mixed forest	Lope	23,50	Reistma, 1988
Mixed forest	Oveng	24,20	Reistma, 1988

It appears here that the average total height observed in the *Brachystegia laurentii* forest is 20.6 m. This forest is thus comparable to the *Scorodophleus zenkeri* forest of Loweo and the *Gilbertiodendron dewevrei* forest of Bawombi, which have total heights of 19.60 and 17.4.

Vertical stratification

We identified five strata in the *Brachystegia laurentii* forest: shrub stratum; lower tree stratum; middle tree stratum; upper tree stratum and the emergent stage. These different strata were also observed by several other authors who studied dense formations. This is the case of Ebuy (2006) in Yoko; Ewango (1994) in Loweo and Solia (2007) in Loweo.

Spatial Distribution of Species

Table 9 compares the spatial distribution of species in the different forest types of the Democratic Republic of Congo.

Table 9: Comparison of spatial distribution of DRC species

Species	Types of forests	Location	Types of distributions	References
Brachystegia laurentii	*Brachystegia laurentii* forest	Biaro	Grouped	Present study
Scorodophloeus zenkeri	*Scorodophloeus zenkeri* forest	Loweo	Isolated	Assumani, 2006
Olax gambecola	*Scorodophloeus zenkeri* forest	Loweo	Isolated	Assumani, 2006
Pancova harmsiana	*Scorodophloeus zenkeri* forest	Loweo	Isolated	Assumani, 2006
Dialium pachyphyllum	*Scorodophloeus zenkeri* forest	Loweo	Grouped	Assumani, 2006
Polyalthia suaveolens	*Scorodophloeus zenkeri* forest	Loweo	Grouped	Assumani, 2006
Xylopia quintasii	*Scorodophloeus zenkeri* forest	Loweo	Grouped	Assumani, 2006
Scorodophloeus zenkeri	*Scorodophloeus zenkeri* forest	Loweo	Random	Solia, 2007
Olax gambecola	*Scorodophloeus zenkeri* forest	Loweo	Random	Solia, 2007
Staudtia gabonensis	*Scorodophloeus zenkeri* forest	Loweo	Random	Solia, 2007
Coelocaryon bostryoïdes	Flooded forest of Mbiye Island	Mbiye Island	Random	Nshimba, 2005
Gilbertiodendron dewevrei	Flooded forest of Mbiye Island	Mbiye Island	Random	Nshimba, 2005
Funtumia africana	Mixed forest	Yoko	Random	Ebuy, 2006
Celtis mildbraedii	Mixed forest	Yoko	Random	Ebuy, 2006
Gilletiodendron kisantuensis	Mixed forest	Yoko	Grouped	Ebuy, 2006
Olax gambecola	Mixed forest	Yoko	Grouped	Ebuy, 2006

The spatial distribution of the species *Brachystegia laurentii* in the study forest, resembles those of the species *Dialium pachyphyllum*, *Polyalthia suaveolens* and *Xylopia quintasii* in the *Scorodophloeus zenkeri* forest in Loweo and those of the species *Gilletiodendron kisantuensis* and *Olax gambecola* in the Yoko mixed forest.

Conclusion

The present study focused on the structure of a *Brachystegia laurentii* forest in the Biaro sector on the Ubundu road, 41 km from Kisangani in the Tshopo Province of the Democratic Republic of Congo.

The data collection was based on a systematic inventory and covered a total area of 3 ha where all trees of at least 10 cm DBH were considered. The density of trees was 353 individuals per hectare, and the number of species inventoried was 91, divided into 18 families. This shows that the forest studied is floristically diverse.

According to their relative frequencies, the species *Gilbertidendron dewevrei* 21,26% and *Brachystegia laurentii* 17,7% are the most represented next to *Cola griseiflora* 8,3%; *Cleistanthus mildbraedi* 4,9%; *Dialium corbisieri* 2,7%; *Polyalthia suaveolens* 2,6%; *Drypetes louissii* 2,5%; *Julbernadia serettii* 2,5% and *Aphanocalyx cynometroides* 2,2%.

The structure of the forest corresponds to an inverse regression, the average total height is 20.6 m, the vertical stratification recognizes five strata of which the shrubby, the lower arborescent, the middle arborescent, the upper arborescent and the emergent. The species *Brachystegia laurentii* and *Gilbertiodendron dewevrei* occupy all strata. They dominate in the middle and upper tree strata and are the only species occupying the emergent class.

The spatial distribution according to the "nearest neighbor method" or Clark and Evans Index for all trees with DBH $\geq$ 10 cm is random while that of *Brachystegia laurentii* species is aggregated or clustered.

References

Amani, A. C. (2011). *Vegetation patterns and role of subtrate heterogeneity on plant communication in semi-deciduous forests from the Congo basin*. Thesis, Brussels Libra University, Belgium, 215p.

Asimonyio, J.A., Kambale, K., Shutsha, E., Bongo, G.N., Tshibangu, D.S.T., Mpiana, P.T., & Ngbolua, K.N. (2015). Phytoecological Study of Uma Forest (Kisangani City, Democratic Republic Of The Congo). *Journal of Advanced Botany and Zoology, 3*(2). DOI: 10.15297/JABZ.V3I2.01.

Assumani, A. (2006). *Contribution à l'étude structurale de la forêt à Scorodophloeus zenkeri de la réserve de Loweo, Yangambi*. Mémoire inédit, FSA, UNIKIS, 66p.

Bultot, F. (1950). *Carte des régions climatiques du Congo belge.* Etablie d'après les critères de koppen. Imiac publication, Bureau climatologique, communication 2, 5p.

Cottam, G., & Curtis, J. T. (1956). The Use of Distance Measurements in Phytosociological Sampling. *Ecology, 37*, 451-460.

Ewango, C. (1994). *Contribution à l'étude structurale de la forêt Monodominante à Gilbertiodendron de la Reserve de Faune à Okapi*. Mémoire inédit, Fac des Sc, UNIKIS.

Ebuy, J. (2006). *Contribution à l'étude structurale de la forêt mixte de la réserve forestière de Yoko.* RD Congo/Kisangani-Ubundu 25 km, Mémoire inédit, FSA-UNIKIS, 68p.

Ifuta, N. B. (1993). *Ecological and hormonal parameters during the growth and reproduction of Epongs franqueti (Mammalia Chiroptèra) from the Masako equatorial rainforest (Kisangani - Zaire).* Unpublished doctoral dissertation, K U L. 142p.

Juo, A.S.R. & Wilding, L.P. (1996). Soils of the lowland forests of West and Central Africa. *Proc. R. Soc. Edinburgh, 104B*, 15-29.

Kahindo, M. (2011). *Potential for non-timber forest products in the forest formations of the Kisangani region. Case of Eremospatha haullevilleana de Weld. and Laccosperma secundiflorum (P. Beauv) Küntze rattans in the Yoko Forest Reserve (Province Orientale, DR Congo).* Unpublished thesis, Faculty of Science, UNIKIS, 269p.

Katuala, G.B., Hart, J.A., Hutterer, R., Leirs, H. & Dudu, A. (2005). Biodiversity and ecology of small mammals (Rodents and Shrews) of the "Réserve de Faune à Okapi", Democratic Republic of the Congo. *Belgian Journal of Zoology*, *135*, 191-196.

Katuala, G.B. (2009). *Biodiversity and biogeography of Myomorph and Sciuromorph rodents (Rodentia: Mammalia) of some forest blocks of the Kisangani region (R D Congo).* Unpublished PhD thesis, Faculty of Sciences, Unikis,

Katusi, L.R., Mangambu, M. JDD, Aruna, S. J. & Nshimba, S.M.H. (2021). Phenological studies and fruit dispersal of Guarea cedrata and Guarea thompsonii (Meliaceae) in the semi-caducified forests of the Kisangani forest massif (Democratic Republic of Congo). *Journal Geo-Eco-Trop.*, *45*(1), 145-159.

Lokombe, D. (1996). *Etude dendrométrique de la forêt à Gilbertiodendrondewevrei dans la collectivité de Bamanga*. DES unpublished, IFA-Ybi, 124p.

Lokombe, D. (2004). *Dendrometric characteristics and management strategy of the Gilbertiodendrondewevrei forest in the Bengamisa region*. Unpublished doctoral thesis, IFA-Ybi, 222p.

Lomba, B.C., Ndjele, M.B.L., Jean Lejoly, Asimonyio Justin A., & Koto-te-Nyiwa Ngbolua, (2017). Etude comparative de la structure diamétrique de Pterocarpus soyauxii Taub. (Fabaceae) in permanent plots in Yoko Forest Reserve and Biaro Forest (Ubundu, Democratic Republic of Congo), *International Journal of Innovation and Scientific Research*, *33*(2), 177-185.

Lomba, B.C. (2012). *System of aggregation and diametric structures according to temperaments of some species in the permanent devices of Yoko and Biaro (Ubundu. Province Orientale RD Congo).* PhD thesis, F.S.-UNIKIS, 239p.

Miabangana, E.S. & Malaisse, F. (2020). Structure, composition and floristic diversity of the Loufézou forest island in the Cataract Plateau (Republic of Congo). *Journal Geo-Eco-Trop.*, *44*(2), 205-220.

Millot, G. (2011). *Understanding and performing statistical tests using R. Handbook of biostatistics* (2nd ed.). Deboeck, Brussels. 767 p.

Musepena, M. (2009). *Studies of monodominant forests with Gilbertiodendron dewevrei. Dewild on patches along the Yoko River*. Unpublished thesis of D.E.S. Faculty of Science, University of Kisangani. 59p.

Ndjele, M.B.L. (1988). *Les éléments phytogéographiques, endémiques dans la flore vasculaire du Zaïre.* Thèse de doctorat inédit, Facultés des Sciences, ULB.

Nshimba, H.S.M. (2008). *Etude floristique, écologique et phytosociologique des forêts de l'île Mbiye à Kisangani, RDCongo*. PhD thesis. Université Libre de Bruxelles. 271p.

Okangola, E., Solomo, E., Lituka, Y., Tchatchambe, W.B., Mate, M., Upoki, A., Dudu, A., Asimonyio, J.A., Mpiana, P.T. & Ngbolua, K.N. (2016). Ethnobotanical and floristic study of some host plants of edible caterpillars for medicinal use in the Bakumu-Mangongo area (Ubundu Territory, Tshopo Province, DR C). *International Journal of Innovation and Scientific Research, 26*(1), 161-168.

Reitsma, G. (1988). *Végétation forestière du Gabon: Forêts et végétations du Gabon*. Technical seris, The Tropendos Foundation, 64p.

Solia, S. (2007). *Contribution à l'application des mesures en carré aux espèces Scorodophloeus zenkeri, Olax gambecola et Staudtia gabonensis dans la cuvette centrale congolaise*. *Cas de la forêt à Scorodophloeus zenkeri HARMS de la Réserve de Loweo à Yangambi RDC*. DEA, UNIKIS, Faculté des Sciences, 64p.

Terrea (2006). "Inventaire d'Aménagement" Module 5, Formation des forestiers Aménagistes et des gestionnaires forestiers. Ecole Nationale des Eaux et Forêt du Cap, Esterias, Libreville Gabon. 44p.

Querouil, S. (2001). *Interest and limits of the molecular approach to biography and speciation: the example of some tropical African mammals*. PhD thesis, University of Rennes, 1310p.