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Typology of the Hydromorphic Soils-based Mixed Forest Formation in a Community Forest in the North-East of Congo-Kinshasa

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Abstract

The forests of the Democratic Republic of Congo (DRC) constitute one of the most complex terrestrial ecosystems in the world and are confronted with the erosion of the diversity they contain, with the concomitant loss of secondary metabolites with as yet unknown pharmaco-biological properties. Understanding their typology in order to facilitate their sustainable management is becoming a priority. The objective of the present study was to determine the structure and diversity of a heterogeneous forest stand in a few hydro-morphic sites of the Uma community forest (Tshopo, DRC). 281 individuals (representing 94 species) were recorded and grouped into 72 genus and 28 families. Plots 1 and 4 have more typical species (16 species and 13 species respectively). In all the plots inventoried, the species *Petersianthus macrocarpus* has a relative density of 6.4%, followed respectively by the species *Dichostemma glaucescens* (5.7%), *Heisteria parvifolia* and *Peudospondias microcarpa* (4.6% each), *Cola griseiflora* (4.3%) and *Guarea cedrata* and *Pancovia harmisiana* (3.2% each). The Euphorbiaceae family has a relative density of about 15.3%; followed by Fabaceae (13.97%); Meliaceae and Anacardiaceae (6.98%); Lecythidaceae and Myristicaceae (5.99% vs 6.65%. The species *Piptadeniastrum africanum* has a higher relative dominance (8.4%) than the species *Petersianthus macrocarpus* (6.9%); followed respectively by *Peudospondias microcarpa* (6.1%); *Alstonia boonei* (5.9%); *Pachyelasma tessmannii* (5.3%) and *Ricinodendron heudellotii* (5.1%) The Fabaceae family presents a relative dominance clearly superior to that of other families (36.7%). It is followed respectively by Euphorbiaceae (12.8%); Meliaceae (9.3%); Lecythidaceae (6.2%); Anacardiaceae (5.8%). Specific diversity was high in all the plots sampled: Simpson index (0.95-0.96); Shannon-w (3.35-3.42); equitability (0.91-0.96). The total basal area of this mixed forest formation is 26.7 m^2/ha. The size distribution shows an inverted "J" pattern that gives an indication of a dynamic equilibrium situation, with dominance in the plot of individuals of the 10 cm dbh class that constitutes almost double those of the 20 cm class. The study showed that the populations are scattered over the hydromorphic soils in the mixed forest (t=6, 9364, dof=3, P-Value=0.006144<0.05%) making it difficult to rank them.

Keywords

Floristic Survey, Diametric Structure, Biodiversity, Terrestrial Ecosystem, Democratic Republic of Congo

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1. Introduction

In tropical forests, the diversification of habitats (expression of geomorphological complexity within the forest cycle) and interactions between biological populations are two major elements that do not make it easy to understand their functioning [1]. However, perceiving the laws that govern the internal organization of their biological diversity is an imperative to facilitate the understanding of this functioning in order to lay the foundations for a sustainable and integrated management of these ecosystems [2, 3]. Furthermore, the characterization of forest stands based on general considerations dictated by the absence of the dominance of a species (mixed forest) provides information that masks in most cases the influence of internal geomorphological differentiations on the real floristic composition of forest stands and on their syngenetic dynamics. However, within each forest stand, preferential groupings of species according to the different biotopes are defined, leading to the spatial structuring of the stand [1]. As a result, vast areas of tropical forest are in reality complexes of plant communities at local and regional scales, particularly those of trees, and whose definition remains crucial for a better characterization of the environment. The floristic, structural and functional complexity observed there requires the development of strategies or methods that can lead to a simplification, which would lead to a hierarchy that could facilitate the understanding of the functioning of these forests and, moreover, the management work itself [4]. As ecological preferences are diverse within each forest complex, these strategies consist of defining floristic groupings and associating them with abiotic environmental constraints, based in particular on geomorphology, and then stratifying conservation efforts within each of them [5]. Thus, finding effective environmental indicators that will facilitate understanding of their influence on the spatial structuring of tree populations and stand syngenetic dynamics in tropical forests has applied interest beyond scientific interest [3, 4]. Furthermore, characterization of a forest entity or formation based on its floristic composition often provides general information that considers the entire forest mass. This approach generally provides very little internal information related to geomorphological variability about the actual floristic composition of the forest area under study. To remedy this situation, it is important that the results of floristic and structural descriptions are expressions of the induction of internal geomorphological variability on vegetation descriptions. Under these conditions, it is considered that a typological approach describing forest vegetation, taking into account the spatial variations of the environment, would provide information that would facilitate not only the understanding of the functioning of tropical forests, but also their sustainable management. Clearly, a typology of forest sites within each forest cycle, with a view to helping forest managers to establish a rapid diagnosis of the eco-floristic conditions existing on the different plots, is essential. Since tropical forest management is an ecological and economic issue that involves many scientific disciplines [2], such a diagnosis based on more detailed descriptions of forest stands makes it possible to adapt them to ecological conditions, reconciling the exploitation of biological diversity and respect for the environment in the current context of sustainable production [4]. The construction of a simple typology of the different specific groupings that may exist, without any formulation of a typological key that would make it possible to highlight the ecological preferences of the tree populations within each forest complex, is an obligation in the management of biodiversity in tropical forests. From the above, it is generally known that during rainy periods, many small accidental streams form within forest formations, and move around carrying diaspores of species from one site to another within the forest. Because this movement is internal, reciprocal transport of these diaspores occurs easily between different forest formations at the local scale [5]. In addition to this water connectivity, there is another mechanism related to the dynamics of forest stands. Stands established on hydro-morphic soils are very dynamic due to the importance of windthrow [6, 7]. Moreover, it is established that in tropical forest environments, the regional floristic pool constitutes a specific reservoir of forest formations that allow them not only to enrich their floristic cortèges but also to facilitate exchanges between these different formations. Indeed, it has been established that water connectivity (which causes the transport of diaspores) and floristic exchange between forest formations are two important mechanisms in tropical forests that lead to the local diversification of forest stands. In tropical forests, although the floristic complexity and the multiplicity of interactions are a hindrance to the understanding of their functioning, their dynamism, and the implementation of management strategies, efforts to quantify the biological expressions dictated by environmental variables are essential to provide the scientific basis for a reasoned and sustainable management of these biological systems. The objective of the present study was to determine the structure and diversity of a heterogeneous forest stand in a few hydro-morphic sites of the Uma community forest (Tshopo province) in the Democratic Republic of Congo (DRC).

2. Materials and Methods

2.1. Study Area

The present study was conducted in the Uma community forest, a forest ecosystem located nearly 92 Km from the city of Kisangani in North-East direction, between 0° 34´ N and 25 52 S, in the Bakumu-Kilinga community, Ubundu Territory, Tshopo Province. It is surrounded by a series of other forest formations including the Okapi Wildlife Reserve to the north and the Maiko Reserve Forest to the south.

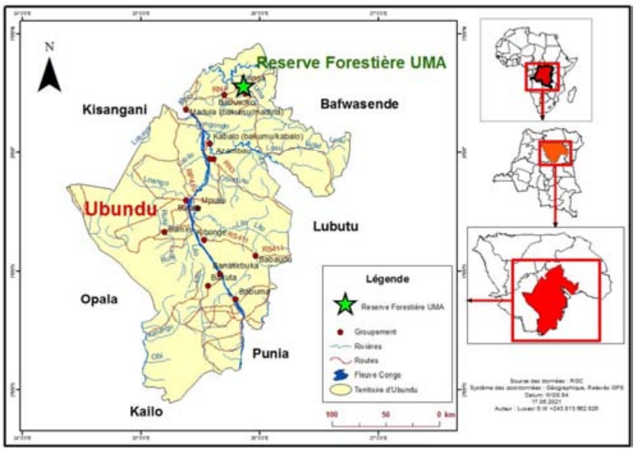

Figure 1. Location of the Uma Community Forest.

2.2. Methods

2.2.1. Installation of Sampling Devices and Tree Inventory

To carry out our study, the first work was to locate the hydromorphic soils inside the mixed forest where we subsequently installed our devices in an alternating manner, following the meander of a stream called "OLEKO". In total, four (04) plots of 50 m X 50 m each or 1 ha were installed where all individuals with dbh ≥ 10 cm in diameter at 1.30 m from the ground were inventoried.

2.2.2. Data Analysis

In this work, we used two parameters: floristic and structur*al.* Regarding the floristic parameters, we calculated the species richness, abundances and dominances of species and families for each plot. And finally, the diversity indices (Shannon-Weaver, Simpson, Piélou Equitability and Similarity) were calculated using Past software package version 1.94b [8]. As for structural parameters, we calculated basal area and determined total diametric structures as previously described in our previous work [9-11]. Student's t test was used to compare sample means while chi-square test was used to compare tree size distribution. Factorial correspondence analysis was used to group surveys with similar floristic profiles (floristic affinities between species or patches in a forest sample). Discriminant analyses for floristic partitioning of plots were performed using R software package.

3. Results and Discussion

3.1. Floristic Parameters

3.1.1. Taxonomic Richness and Floristic Typification of the Stand

281 individuals representing 94 species were counted and grouped into 72 genera and 28 families. The specific typification of the plots shows that plots 1 and 4 have more typical species (16 species and 12 species respectively) than plots 2 and 3 which have only 8 typical species each (Figure 2). The statistical test reveals a significant difference between these plots at the 0.05 probability threshold (t= 5.6997, dof = 3, p-value = 0.01071).

Table 1. Typical species of the plots inventoried.

Plot A		**Plot B**		**Plot C**		**Plot D**	
Typical species	**Ni**	**Typical species**	**Ni**	**Typical species**	**Ni**	**Typical species**	**Ni**
Aidia micrantha	1	*Celtis tessmannii*	1	*Chytrantu smacrobotrys*	1	*Angylocalyx pynaertii*	1
Albizia gummifera	2	*Funtumia africana*	2	*Diospiros boala*	2	*Anopyxix klaineana*	1
Anthrocaryon nannanii	1	*Julbernadia seretii*	1	*Millettia laurentii*	1	*Chrysophyllum africanum*	1
Bellucia axinanthera	1	*Nauclea vanderguchtii*	1	*Ricinodendron heudelotii*	1	*Dialium excelsum*	1
Canarium schweinfurthii	1	*Sorindeia africana*	2	*Strombosia pustulata*	1	*Diogoa zenkeri*	1
Chlarnydocola chlamydantha	1	*Synphonia globulifera*	1	*Synsepalum subcordatum*	1	*Eriocoelum microspermum*	1
Cynometra sessiliflora	2	*Tessmannia africana*	1	*Torinea thouarsii*	1	*Musanga cecropioides*	3
Enantia lebrunii	2	*Trichilia rubescens*	1	*Trichilia gilletii*	1	*Tessmannia anomala*	1
Greenwayodendron suaveaolens	1	-	-	-	-	*Tetrorchidium didymostemon*	1
Hexalobus crispiflorus	1	-	-	-	-	*Xylopia acutiflora*	1
Omphalocarpum mortehanii	2	-	-	-	-	*Xylopia gilbertii*	1
Pachystela excelsa	2	-	-	-	-	*Xylopia rubescens*	1
Panda oleosa	1	-	-	-	-	-	-
Tabernaemontana crassa	2	-	-	-	-	-	-
Trichilia welwitschii	1	-	-	-	-	-	-
Uapaca heudolotii	1	-	-	-	-	-	-

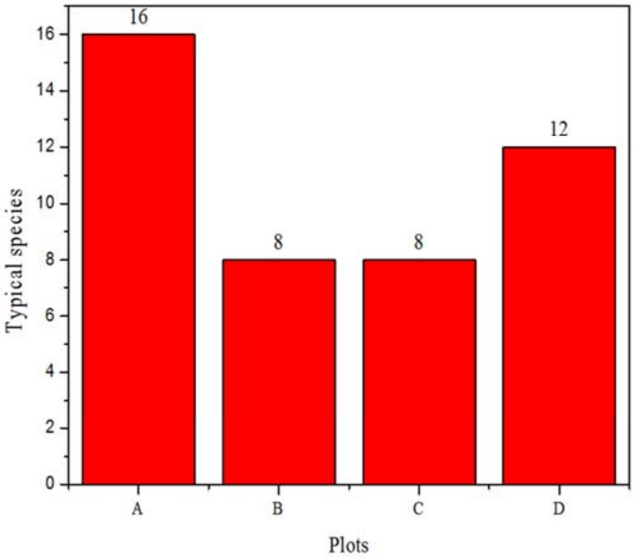

Figure 2. Distribution of typical species in the different plots.

3.1.2. Abundance of Taxa

Figure 3 shows the relative density of dominant species for the entire plot in this forest.

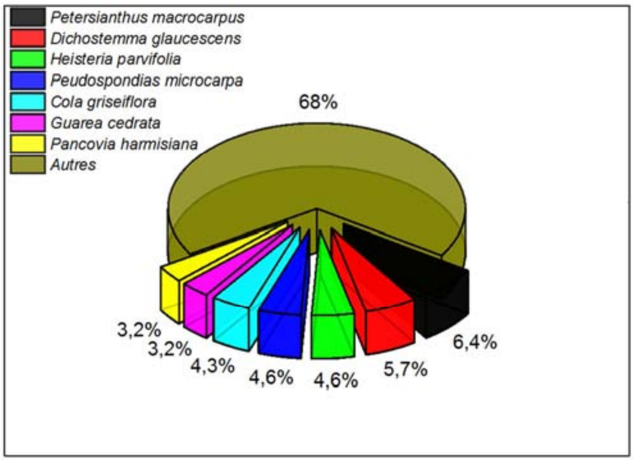

Figure 3. Relative density of species.

From this figure, it appears that on all the plots, the *Petersianthus macrocarpus* specie has a relative density of 6.4%, followed respectively by the species *Dichostemma glaucescens* (5.7%), *Heisteria parvifolia* and *Peudospondias microcarpa* (4.6% each), *Cola griseiflora* (4.3%) and *Guarea cedrata* and *Pancovia harmisiana* (3.2% each). The remaining species represent 68%.

Figure 4 shows the relative density of families.

Of all the families recorded, the Euphorbiaceae has a relative density of about 15.3%, followed by Fabaceae (13.97%), Meliaceae and Anacardiaceae (6.98%), Lecythidaceae and Myristicaceae with 5.99% and 6.65% respectively.

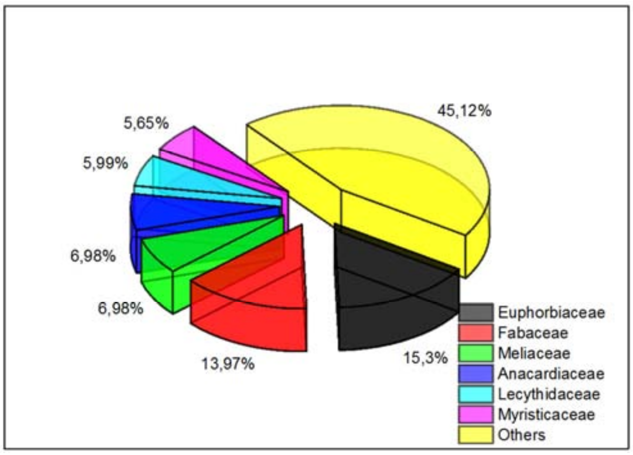

Figure 4. Relative density of botanical families.

3.1.3. Dominance of Taxa

Figure 5 shows the relative dominance of species.

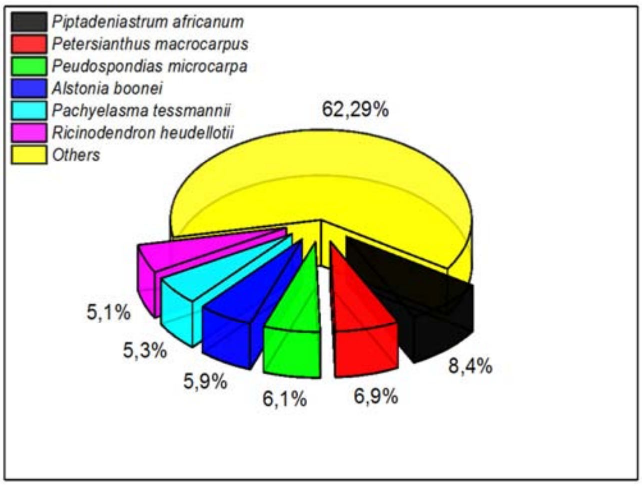

Figure 5. Relative dominance of plot species.

It appears from figure 5 that the *Piptadeniastrum africanum* specie has a higher relative dominance (8.4%) than the species Petersianthus macrocarpus (6.9%); followed respectively by Peudospondias microcarpa (6.1%); Alstonia boonei (5.9%); Pachyelasma tessmannii (5.3%) and Ricinodendron heudellotii (5.1%). The other species represent 62.29%.

Figure 6 shows the relative dominance of the families.

The figure 6 shows that the Fabaceae family has a relative dominance clearly superior to that of other families (36.7%). It is followed respectively by Euphorbiaceae (12.8%); Meliaceae (9.3%); Lecythidaceae (6.2%); Anacardiaceae (5.8%). The high value of dominance observed in the family of Fabaceae is justified by the presence of large trees that make up the tropical forests, most of which belong to this family (Flores, 2005).

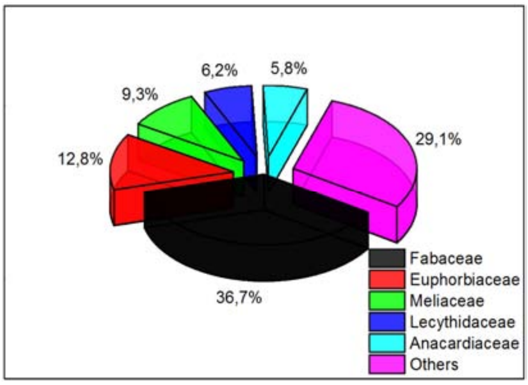

Figure 6. Relative dominance of families.

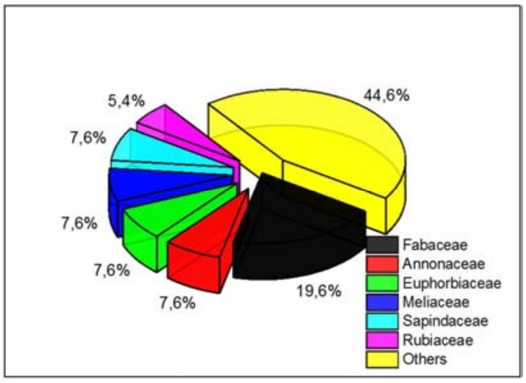

Figure 7. Relative diversity of families.

3.1.4. Diversity

Figure 7 shows the relative diversity of the families.

It appears from this figure that in the studied stand, the Fabaceae family is the most diversified (19.6%); followed by Annonaceae, Euphorbiaceae, Meliaceae and Sapindaceae (with 7.61% each) and the Rubiaceae (5.43%). The others represent 44.6%.

Table 2 gives the values of different diversity indices of the forest formation (50 m x 50 m plot).

Table 2. Diversity indices calculated by plot.

Index of biodiversity	**Plot**			
	A	**B**	**C**	**D**
Simpson	0,95	0,96	0,95	0,96
Shannon – w	3,42	3,40	3,37	3,35
Equitability/ Equity	0,91	0,96	0,94	0,93

From this table, it can be seen that the specific diversity is high in all the sampled plots: Simpson's index (0.95-0.96); Shannon-w (3.35-3.42); equitability (0.91-0.96).

The figures below show the floristic similarity of plots (Figure 8) and the distribution of plots on the factor map (Figure 9).

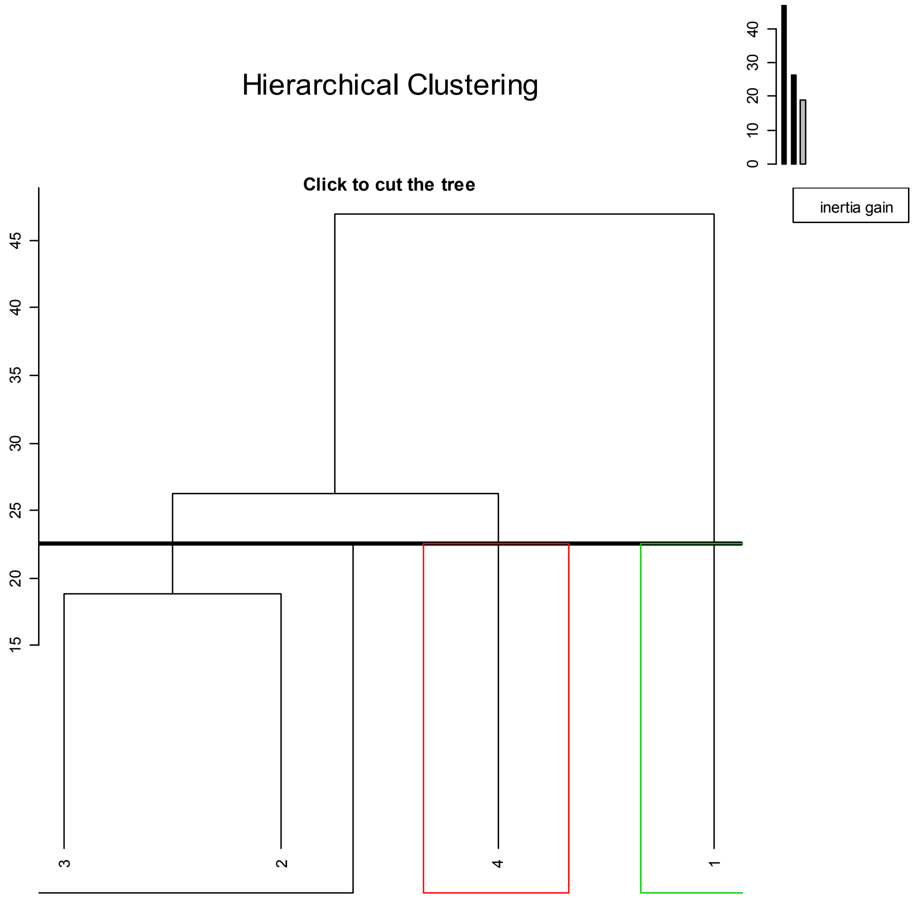

Figure 8. Similarity between plots.

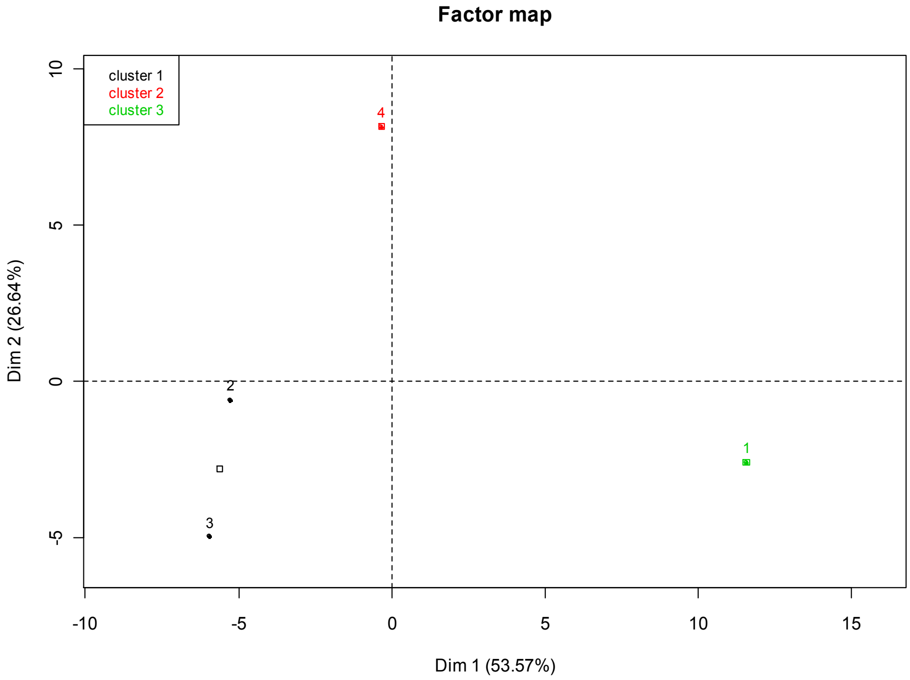

Figure 9. Plot distribution on the factor map.

From the point of view of the floristic similarity of the plots, Figure 8 shows that on the hydromorphic substrate of this forest formation, plot 1 stands out from the other plots (B, C and D). This indicates that from a floristic point of view, plots 2 and 3 are closer to plot 4 than to plot 1, which is clearly individualized. The visualization of these relationships in the factorial map shows a marked distance between plots 1 and 4 (Figure 9).

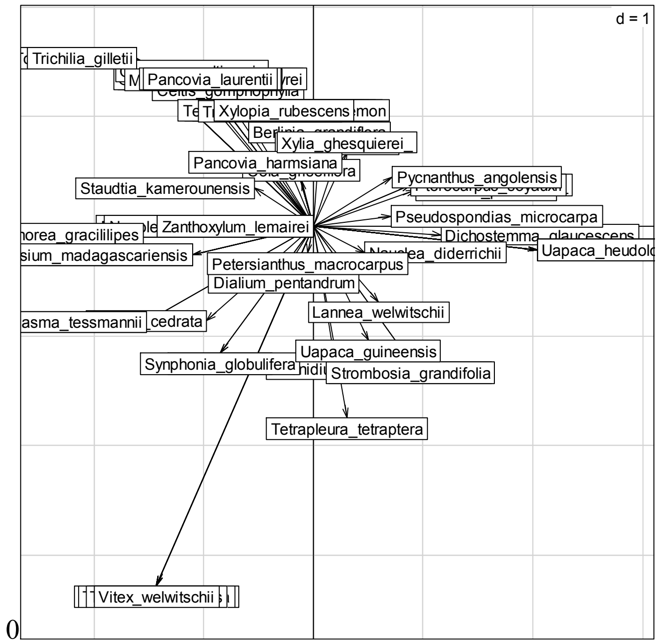

Figure 10. Spatial patterning (structuring) of populations.

Figure 9 shows the spatial clustering of populations established on the colonizable substrate in this mixed forest formation.

The figure 10 shows that species do not show spatial groupings. This can be considered as the consequence of a certain spatial homogeneity of the influence of the luminous intensity which reaches the ground by the opening of the canopy. Since light intensity is not a major constraint in hydro-morphic environments [3, 7], species distribution is often random [12].

3.2. Structural Parameters

3.2.1. Spatial Structuring of Densities

Figure 11 shows the spatial variation of densities by plot.

This figure shows that plots P1 and P4 have more individuals (89 and 84 individuals respectively) than plots P2 (45 individuals) and P3 (63 individuals). Statistical analysis reveals that there is a significant difference between plots (t=6.9367, ddl=3, p-value=0.006144<0.05). It has been reported in the literature that densities vary between 450 and 750 trees/ha (for a minimum diameter of 10 cm) in dense tropical rainforests. For forests with no particular constraints, the average is 600 trees/ha. Density also varies within the same forest according to local conditions (steep slopes, lowlands, drainage, exposure, silvigenetic stage, etc.). It is therefore a good yardstick (criteria) for assessing forest dynamics and the local potential of the formation [13].

3.2.2. Basal Area

Figure 12 shows the basal area per plot sampled in this mixed forest formation (total basal area is 26.7 m^2/ha)

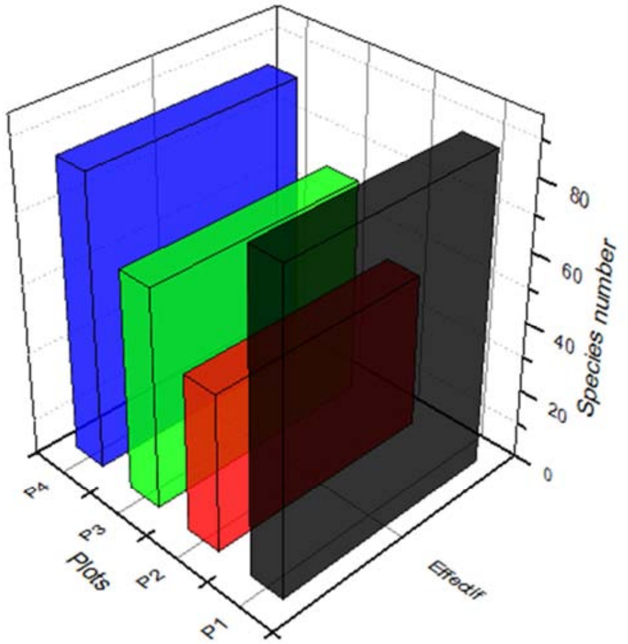

Figure 11. Spatial patterning (structuring) of densities by plot.

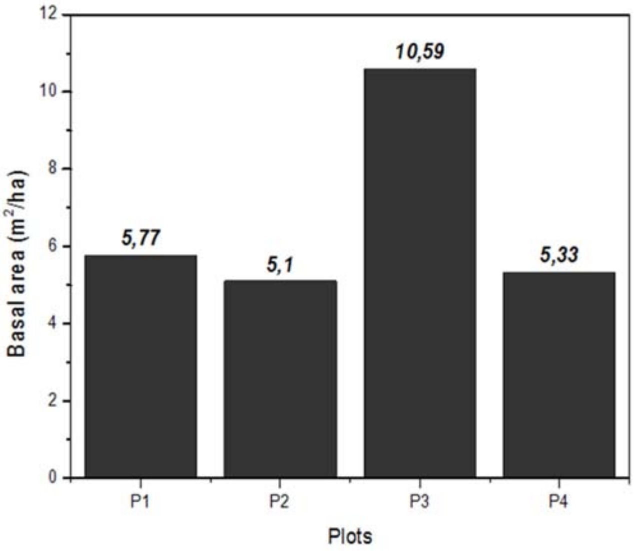

Figure 12. Basal area of different plots.

This figure shows that plot P3 has the highest basal area value (10.59 m^2/ha). This can be explained by the fact that plot P3 has large-diameter individuals despite their reduced number in terms of density. The statistical test reveals a significant difference between plots (t = 5.1325, dof = 3, p-value = 0.01433< 0.05).

The basal area is the sum of the horizontal sections of the trunks, taken by convention at 1.30 m from the ground. It can therefore be calculated for the whole stand, by species or by groups of species. However, many trees have buttresses that rise well above 1.30 m. Diameter is then conventionally measured above the buttresses. Also, many species have non-circular cross-sections, making diameter measurements imprecise. Calculated values for dense tropical rainforests generally range from 25 to 50 m^2/ha, with Asian and African forests averaging higher values than those in the Amazon [13].

3.2.3. Total Diameter Structure

Figure 13 shows the evolution of the number of individuals according to different diameter classes.

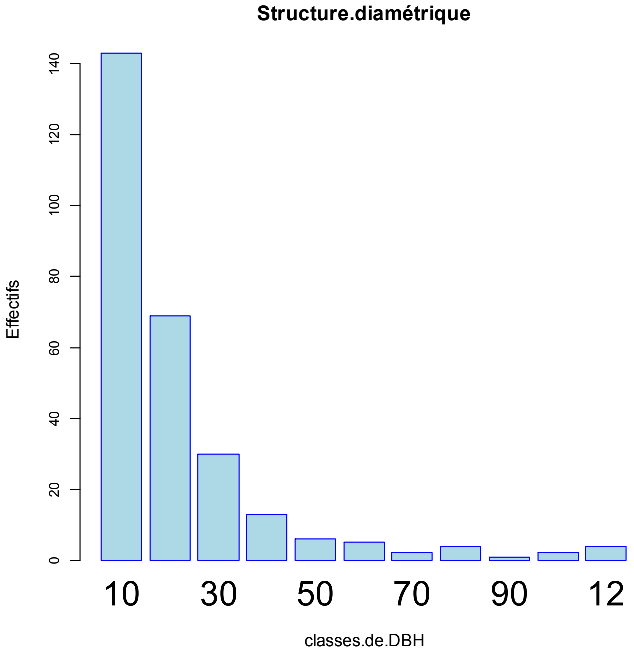

Figure 13. Total diameter structure of the plot.

From this figure 13, it can be seen that the size distribution shows an inverted "J" pattern that indicates a situation of dynamic equilibrium, with dominance in the plot of individuals of the 10 cm dbh class that is almost double that of the 20 cm class. It is well established that in dense tropical rainforests, the diameter classes for the whole stand are distributed according to a decreasing exponential function showing that there are many small diameters and few large ones [13]. According to the same author, such a decreasing exponential distribution (or a regular decrease) of the number of trees with the diameter classes is characteristic of sciaphilous species, tolerant of shade. It can be found both in species that spend their entire cycle in the understory (maximum diameters are then not very large) and in those that begin their development in the understory and end it in the canopy (thus reaching large diameters). Thus, the distribution of diameter classes provides information on the dynamic state of the stand as a whole (young/adult ratio), the temperaments of the species (sciaphilous, heliophilous), etc.

Figures 14, 15, 16 and 17 show the diametric structure of the four plots inventoried, the total of which is shown in Figure 13 above.

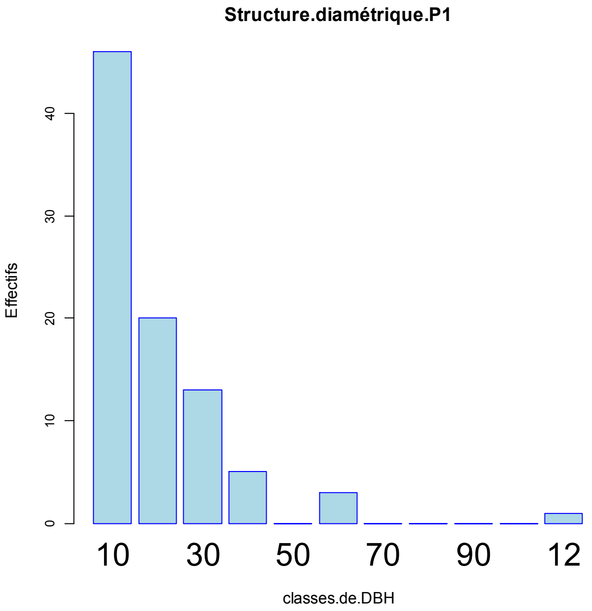

Figure 14. Diametrical structures of plot 1(A).

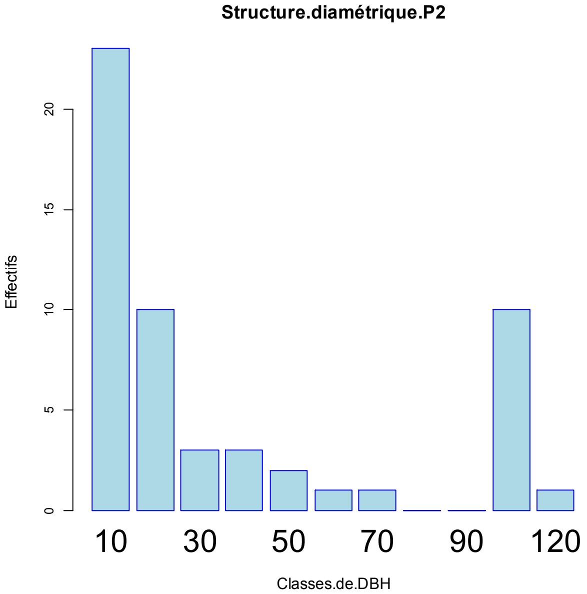

Figure 15. Diametrical structures of plot 2 (B).

It is well known that in tropical forests, the hydromorphic environments are, due to the intensity of windfalls encountered, generally very dynamic areas, dominated by the presence of species that are generally heliophilic and whose luminosity is not a limiting factor for their regeneration or growth [3, 7]. If it is established that the dominance of heliophiles is a fundamental characteristic of hydromorphic environments, their dynamism suggests that these environments are also the least ecologically balanced. However, by observing the different graphs of the size distributions (Figures 14-17), we can see that even on a small surface scale, all display an inverted "J" shape. This reasonably suggests that despite the dominance of heliophiles in these environments, equilibrium is established at each unit area within the forest cycle regardless of the geomorphological configuration and colonizable substrate to maintain the general forest equilibrium grid. Statistical analysis reveals that there is no significant difference between the different diametric distributions (chi-square = 6.5154, dof = 6, p-value = 0.368>0.05). Stand density and tree distribution patterns vary with topography, soil, exposure, silvigenetic stages, etc., while at the species level, spatial distribution may reflect species ecological preferences (soil type, drainage, moisture, light supply, etc.) [13]. In general, it is classically accepted that the floristic composition of forest stands is the result of the combined action of stochastic effects that allow a random installation of populations and deterministic effects more related to the action of environmental filtering [12].

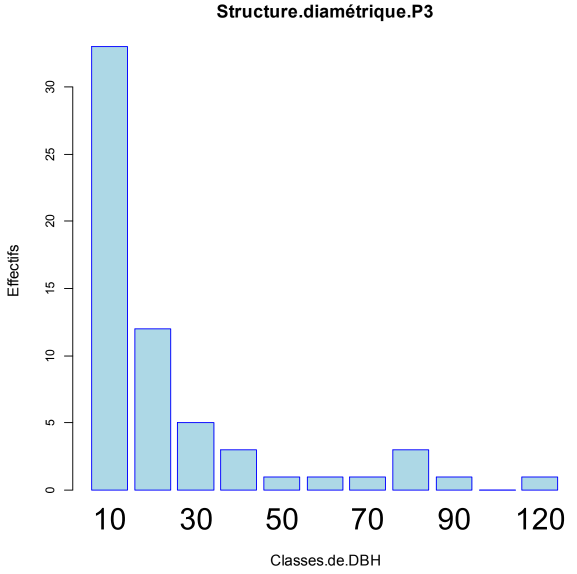

Figure 16. Diametrical structures of plot 3 (C).

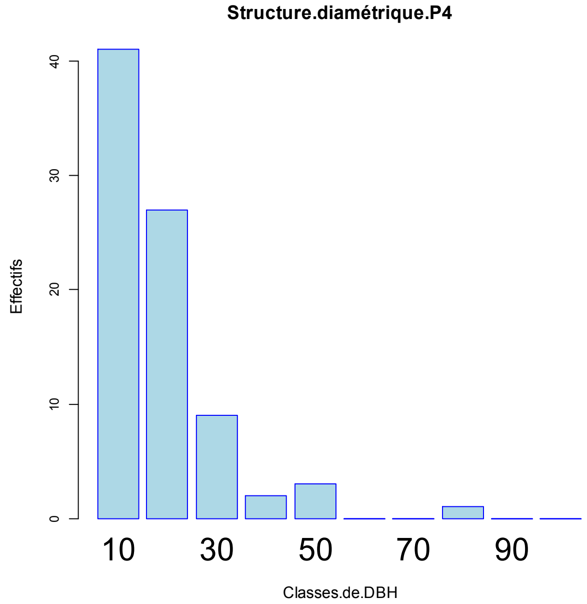

Figure 17. Diametrical structures of plot 4 (D).

Although the geomorphology of a site plays a major role in the floristic partitioning of a forest area and within a forest cycle [14], this partitioning is more marked and perceptible on a small scale than on large surfaces. This shows that a better floristic definition of the sites gives a better idea of the syngenetic relationships between them in order to understand their dynamism. Another explanation for the discrimination between these forest stands may be the edaphic difference under these stands, namely the clay content, the proportion of the sandy fraction of the soil, the degree of wetting and the proportion of plant-available phosphorus [4].

The observed demarcations indicate that all of these plots constitute syngenetically individualized ecological groups, although individualization is more pronounced in this one [5]. Although it is difficult to evaluate it objectively on the whole stand, given the physiographic and edaphic variations that dictate the distribution of species and the grouping of their individuals [2], its assessment on the scale of the sampled areas gives an idea of the floridity of the stand. Recent findings revealed that the distribution of abundances in any ecological system constitutes a quantitative variable that expresses the impact of variations in environmental factors on biological populations [6]. To appreciate the implication of soil hydromorphy on this variable, we found it appropriate to consider abundances in terms of actual stand density. The comparative density values obtained by the different authors are higher on hydromorphic soils in the Uma forest than those recorded in other study areas. At Ile Mbiye for example, Nshimba [15] recorded 251 individuals; at Masako, Toke [16] recorded 109 individuals; at Uma, Katembo [17] recorded 333 individuals while Yalanga [6] identified 668 individuals there. For the present work, 281 individuals were recorded in the mixed forest. Although it is difficult to evaluate objectively on the whole stand given the physiographic and edaphic variations that dictate the distribution of species and the grouping of their individuals [2], its assessment at the scale of the sampled areas allows us to have an idea on the floras of the stand.

4. Conclusion and Suggestions

The present study is a contribution to the knowledge of the ecology of communities' forest, more particularly those linked to hydro-morphic soils in tropical environments. It appears from this study that 281 individuals (representing 94 species) were recorded and grouped into 72 genus and 28 families. The *Petersianthus macrocarpus* specie has a high relative density followed respectively by the species *Dichostemma glaucescens, Heisteria parvifolia* and *Peudospondias microcarpa*, *Cola griseiflora* and *Guarea cedrata* and *Pancovia harmisiana*. The Euphorbiaceae family has a high relative density; followed by Fabaceae; Meliaceae and Anacardiaceae; Lecythidaceae and Myristicaceae. The species Piptadeniastrum africanum has a higher relative dominance than the species *Petersianthus macrocarpus*; followed respectively by *Peudospondias microcarpa*; *Alstonia boonei*; *Pachyelasma tessmannii* and *Ricinodendron heudellotii*. The Fabaceae family shows a relative dominance clearly superior to that of other families. It is followed respectively by Euphorbiaceae, Meliaceae, Lecythidaceae and Anacardiaceae. Specific diversity is high in all the plots sampled: Simpson's index (0.95-0.96); Shannon-w (3.35-3.42); equitability (0.91-0.96). The total basal area of this mixed forest formation is 26.7 m2/ha. The size distribution shows an inverted "J" pattern. The study showed that populations are sparsely distributed on hydromorphic soils in the mixed forest. It is desirable that similar studies be conducted at other forest sites over sufficiently large areas to allow correlations to be made between forest groupings and thus provide data for a good definition of forests established on hydromorphic soils in tropical forest environments.

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