*Research in Plant Sciences, 2015, Vol. 3, No. 3, 49-60*
Available online at http://pubs.sciepub.com/plant/3/3/2

DOI:10.12691/plant-3-3-2

# Structure and Flora Tree Biodiversity in Congo Basin: Case of a Secondary Tropical Forest in Southwest of Congo-Brazzaville

**Félix KOUBOUANA[1,*], Suspense Averti IFO[2,*], Jean-Marie MOUTSAMBOTE[1], Robia Ridelle Farelle BANZOUZI[1], Adrienne AKOBE[1], Chimelle OPENGA IKAMA[1], Alima Brigitte MANTOTA[1], DZAI Saint[1], Mackline MBEMBA[1]**

[1]ENSAF, BP 69 Université Marien Ngouabi, Brazzaville, Congo
[2]ENS, BP 69 Université Marien Ngouabi, Brazzaville, Congo
*Corresponding author: koubouanafelix@gmail.com; ifo.suspense@hotmail.fr

**Abstract** The Boubissi forest exploitation unit is one of the forest management units assigned to logging. Knowledge of the existing floristic resource through a management inventory is a preliminary operation allowing the planning of the logging activity. In the Boubissi forest exploitation unit, floristic diversity was studied from the floristic surveys made along the inventory tracks on 0.5 ha contiguous plots. Altogether 35 ha of forest were inventoried allowing to count 5158 trees of DBH ≥ 20 cm belonging to 160 species spread within 38 botanical families. In qualitative terms, this forest consists mainly of species from the *Fabaceae* family in general and Fabaceae-Caesalpinioideae specifically, Meliaceae, Annonaceae, Sapotaceae, Euphorbiaceae, Olacaceae, Burseraceae, Guttifereae, Sapindaceae, Moraceae, Fabaceae-Mimosoideae and Irvingiaceae. Measurement of the phytogeographic spectra showed that the flora of the study area is essentially Guineo-Congolese. Calculation of the Shannon-Weaver index yielded high values indicating a high floristic diversity. Results from the calculation of the Jaccard and Sørensen similarity indices do not show a large floristic heterogeneity between inventory plots. The distribution of tree numbers within diameter classes showed that the forest studied consists of 66% crop trees, 14 % trees that are exploitable in the first cut and 20% will be at the second cut. The floristic composition of the study area is a reflection of an old secondary forest of the central Mayombe. Its operation must be done with the pace of growth of trees to not compromise its regeneration.

***Keywords:*** *Congo basin, secondary forest, floristic diversity, phytogeographical spectrum, diametric structure; Republic of the Congo*

**Cite This Article:** Félix KOUBOUANA, Suspense Averti IFO, Jean-Marie MOUTSAMBOTE, Robia Ridelle Farelle BANZOUZI, Adrienne AKOBE, Chimelle OPENGA IKAMA, Alima Brigitte MANTOTA, DZAI Saint, and Mackline MBEMBA, "Structure and Flora Tree Biodiversity in Congo Basin: Case of a Secondary Tropical Forest in Southwest of Congo-Brazzaville." *Research in Plant Sciences*, vol. 3, no. 3 (2015): 49-60. doi: 10.12691/plant-3-3-2.

## 1. Introduction

Tropical forests contain between half and two-thirds of terrestrial global biodiversity [4]. Rainforests are characterized by very high plant diversity and arouses great interest from the research community for their multiple roles both for the maintenance of the global equilibrium, environment preservation (role in mitigation and adaptation to climate change) and for the health and nutrition of the thousands of people who depend directly on them [8].They store 283 Gt of carbon in biomass, 38 Gt in deadwood and 317 Gt in soils (up to 30 cm in height) and litter. The total forest ecosystem carbon content was estimated at 638 Gt in 2005. To date these forests continue to sequester significant carbon stocks [17]. Forests are one of the most biodiversity-rich habitats on Earth. For example, about 60% of all higher plants are located in tropical forests.

Diversity, structure and functioning of tropical rainforests are particularly complex and insufficiently known. This lack of knowledge is an obstacle to the definition of rules for sustainable management [1]. Biodiversity is a key determining factor for forests to provide effectively for ecosystem services, particularly carbon sequestration, and at the same time to maintain their resilience to disturbance, such as climate change. In the Republic of the Congo, for more than fifty years botanists have contributed to knowledge on the flora of the Congo. These studies were conducted in the forests of Northern Congo [10,16] gallery forests and on dry land in the Niari Valley [12] the Batéké plateaux [3,7], and also important work in the natural forests of Mayombe [2,3,7,15]. In spite of these efforts, much remains to be done to arrive at a good understanding of the flora of Congo Brazzaville. These Congolese forests occupy almost 65% of the National territory, extend to almost 22 million ha and are divided into three areas: the forests of Northern Congo, the forests of the Chaillu Massif and the Mayombe forest. For a better management of these forests, they are divided into zones of different importance called forest management unit (FMU). They are attributed to loggers for purposes of value creation by the forestry administration and subsequently become forest concessions. In the southern part of the country, the FMU are subdivided into forest exploitation unit (FEU). Each FEU becomes a forest concession after allocation to theloggers. It obliges each company awarded a FMU or a FEU to develop a plan for the concession.

In the context of the REDD + process occurring in Republic of Congo, a better assessment of the efforts to preserve the floristic richness also requires better management of the national flora database. Logging is an activity that violates the original integrity of the forest, and measuring its impact requires comparison of inventories before and after logging.

This study takes place in the area of the Mayombe that has been the subject of some botanical studies [2,11,15]. The different surveys conducted to date reveal a North-South and East-West regional floristic gradient. These different studies have revealed that the Mayombe forest are dominated by Fabaceae-Caesalpinioideae on the sea front as well as on the Mayombe front towards Dolisie. These studies have showed a few local differences.

This study aims to (i) contribute to the knowledge of the forest flora of the Mayombe, (ii) the characterisation of the flora of the locality of Boubissi, (iii) Study the alpha and Beta biodiversity index along the transects and studying the vertical structure of forest in the aim to planify its exploitation. More specifically, this work highlights the floristic composition in the surveyed area and plans the logging operation.

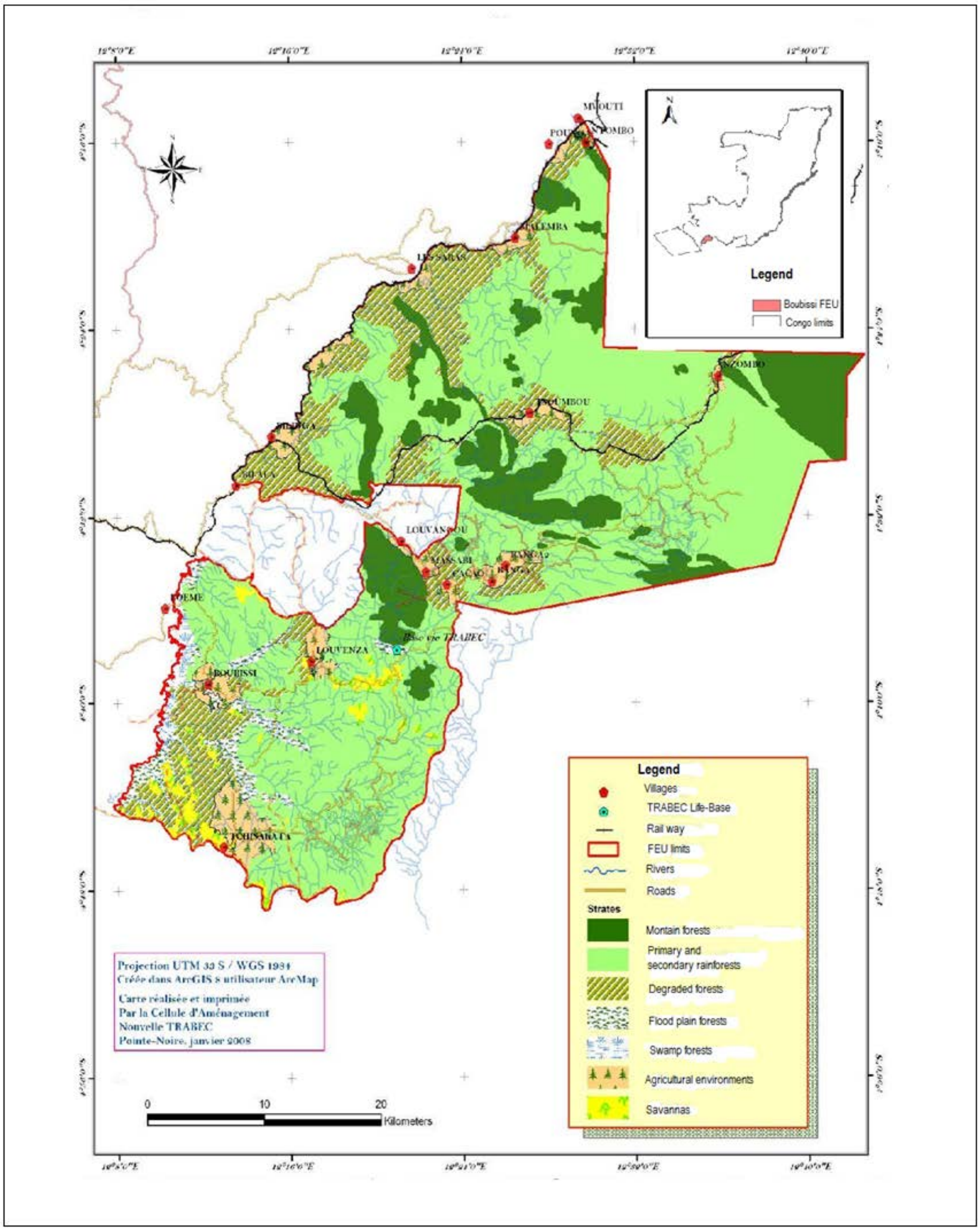


**Figure 1.** vegetation map of the study area

# 2. Methods

## 2.1. Study Area

The Boubissi Forest Exploitation Unit (FEU) is located in the Congolese Mayombe (12° 12'0 "E to 12° 42'0"E; 4° 12'0" S to 4° 54'0"S) Southwest of the Republic of the Congo (Figure 1). It has an area of approximately 140,024 ha and borders with the province of Cabinda (People's Republic of Angola). The climate of the area is characterized by an average rainfall of 1600 mm per year. The dry season lasts four months from June to September while the longer rainy season extends from October to May. The soils identified in the study area are recent alluvial soils from very contracted grained silt and rocks are MICA schists, sandstones, and quartzites [9] of the Guena series [18]. The zone is characterized by two types of vegetation, namely forest and savannah. Primary forest clusters remain concentrated in difficult to access mountainous areas (Figure 1). The areas of old secondary forest are where most of the logging activity is carried out. The study area is located in the northern part and consists of forest. It is a lowland Guineo-Congolese rainforest.

## 2.2. Vegetation of the Study Area

The management inventory of the study area was conducted on plots of 200 m x 25 m of dimension, i.e. 0.5 ha, delineated in a contiguous manner along the counting transect opened in the FEU (Figure 2). Transect are equidistant from each other by 2 km, with a South-North orientation. In each plot, all species were identified and all trees with a diameter greater than or equal to 20 cm taken at human breast height (≥20 cm DBH) counted.

The survey area is crossed by a base transect, the longest, from which other secondary transects start every 2km, of varying lengths depending on their proximity either to the border of the FEU, or the border of the inventoried area. In total nine transects with a total length of 14.2 km comprising 71 plots with a total area of 35.5 ha (Table 1) were opened.

**Table 1. Length of the different inventory transects**

| Transect number | Transect length (m) | Transect length(km) | Number of plots | Area (ha) |
|---|---|---|---|---|
| $L_B$ | 6,200 | 6.2 | 31 | 15.5 |
| $L_{19}$ | 600 | 0.6 | 3 | 1.5 |
| $L_{20}$ | 2,000 | 2.0 | 10 | 5.0 |
| $L_{25}$ | 400 | 0.4 | 2 | 1.0 |
| $L_{26}$ | 2,200 | 2.2 | 11 | 5.5 |
| $L_{30}$ | 800 | 0.8 | 4 | 2.0 |
| $L_{31}$ | 400 | 0.4 | 2 | 1.0 |
| $L_{34}$ | 1,200 | 1.2 | 6 | 3.0 |
| $L_{35}$ | 400 | 0.4 | 2 | 1.0 |
| **Total** | **14,200** | **14.2** | **71** | **35.5** |

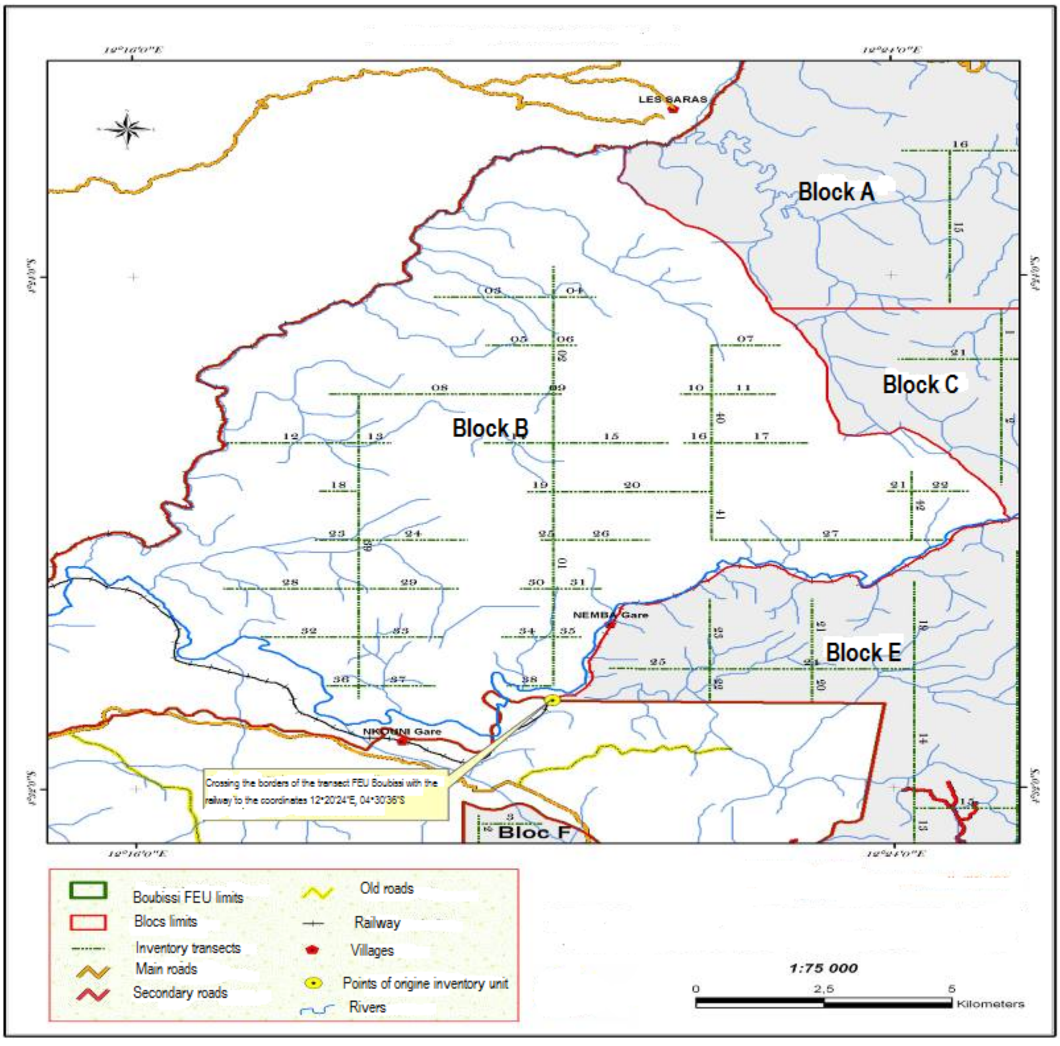


**Figure 2**. Schematic plan of transect in the study area

## 2.3. Data Analysis

### 2.3.1. Frequency

The frequencies and specific contributions of each plant family were calculated using the following formulae:

$$Fsi = \frac{ni}{N} \times 100 \quad (1)$$

Where "N" is the number of sample units or the total number of individuals, "ni" the number of units where the "i" species is present.

### 2.3.1 Species Richness

The floristic richness (number of families, genera and species) is evaluated on all surveys in each sampled station.

### 2.3.2. SHANNON and WEEVER Diversity Index:

$$H' = -\sum_{i=0}^{n} PiLog_2 Pi \quad (2)$$

PI = specific contribution; The Shannon index is expressed in bit and typically varies between 0 and 5.

### 2.3.3. Index of Regularity (fairness)

$$E = \frac{H'}{Log_2 S}$$

Where 'S' is the total number of species inventoried.

### 2.3.3. The Similarity Coefficients of Jaccard and Sørensen

The similarity coefficients of Jaccard and Sørensen are distinguishable by the fact that the first gives the same rating to presence and absence, whilst the second grants a double benefit to the presence. In this latter case, the presence is more informative than the absence (Legendre and Legendre 1984).

$$Jaccard\ S(\%) = \frac{C}{A+B-C} \times 100 \quad (3)$$

$$Sorensen\ K(\%) = \frac{2C}{A+B} \times 100 \quad (4)$$

Where A = number of species of the 1st census, B = number of species of the 2nd census, C = number of species common to both censuses).

### 2.3.4. Calculation of Phytogeographic Spectrum

The phytogeographic distribution of each species was determined from the existing literature, which allowed to present the phytogeographical spectrum of the study area.

The phytogeographic distribution of the listed species was prepared on the basis of large chorologic subdivisions of Africa (White, 1983), depending on their phytogeographical distribution (Figure 7).

We also used the Excel 2013 spreadsheet for processing the data and the Biostat GV software for comparative analyses of average biodiversity indices.

## 3. Results

### 3.1. Analysis of the FLORISTIC DIVERSITY

The result of the forests' floristic inventory of the Boubissi FMU (Table 2) shows 41 families for 150 species. 14 out of the 41 families of the study area represent 72% of the entire species population. In qualitative terms, the inventory of the entire block reveals a dominance of Fabaceae-Caesalpinioideae with 13.25%, followed by the Meliaceae with 5.95%, and Annonaceae, Euphorbiaceae and Sapotaceae with 5.30% each (Figure 3).

**Table 2. List of flora species in the area of study**

| Familles | Espèces | phytogeographic spectrum | Number of species | Number of trees | Gross frequency | weighted frequency |
|---|---|---|---|---|---|---|
| Anacardiaceae | *Antrocaryon klalneanum* Pierre | CG | 4 | 39 | 2,67 | 0,77 |
| | *Antrocaryon* micraster A. Chev. & Guillaumin | CG | | | | |
| | *Trichoscypha acuminata* Engl. | GC | | | | |
| | *Trichoscypha ferruginea* Engl. | At | | | | |
| Anisophylleaceae | *Anisophyllea polyneura* Floret | CG | 1 | 1 | 0,67 | 0,02 |
| Annonaceae | *Anonidium mannii* (Oilv.) Engl. & Diels | CG | 8 | 448 | 5,33 | 8,83 |
| | *Cleistopholis patens* (Benth.) Engl. & Diels | GC | | | | |
| | *Annickia chlorantha* (Oliv.) Setten & Maas | GC | | | | |
| | *Hexalobus crispiflorus* A. Rich. | GC | | | | |
| | *Greenwayodendron suaveolens* (Engl. & Diels.) Verdc. | GC | | | | |
| | *Xylopia aethiopica* (Dunal) A. Rich. | At | | | | |
| | *Xylopia staudtii* Engl. & Diels | CG | | | | |
| Apocynaceae | *Funtumia elastica* (P. Preuss) Stapf. | GC | 5 | 88 | 3,33 | 1,73 |
| | *Pleiocarpa mutica* Benth. | GC | | | | |
| | *Tridesmostemon omphalocarpoides* | CG | | | | |
| | *Voacanga chalotii* | AM | | | | |
| | *Voacanga thouarsii* Roem. & Schult | AM | | | | |
| Balanitaceae | *Balanites wilsoniana* Dawe & Sprague | GC | 1 | 1 | 0,67 | 0,02 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Burseraceae | *Canarium schweinfurthii* Engl. | CG | 6 | 234 | 4,00 | 4,61 |
| | *Dacryodes edulis* (G. Don.) H. J. Lam. | CG | | | | |
| | *Dacryodes igaganga* Aubrév. & Pellegr. | CG | | | | |
| | *Dacryodes klaineana* (Pierre) H. J. Lam. | CG | | | | |
| | *Dacyodes pubescens* (Vermoesen) H.J. Lam. | GC | | | | |
| | *Santiria trimera* (Oliv.) Aubrév. | GC | | | | |
| Cannabaceae | *Celtis mildbraedii* Engl. | GC | 2 | 9 | 1,33 | 0,18 |
| | Celtis tessmannii Rendle | GC | | | | |
| Cecropiaceae | *Musanga cecropioides* R. Br. | GC | 1 | 59 | 0,67 | 1,16 |
| Chrysobalanaceae | *Parinari excelsa* Sabine | GC | 1 | 1 | 0,67 | 0,02 |
| Combretaceae | *Terminalia superba* Engl. | GC | 1 | 1 | 0,67 | 0,02 |
| Ebenaceae | *Diospyros canaliculata* De Wild. | GC | 3 | 236 | 2,00 | 4,65 |
| | *Diospyros crassiflora* H. Perrier | GC | | | | |
| | *Diospyros dendo* Hiern | GC | | | | |
| | *Diospyros hoyleana* F. White | GC | | | | |
| Euphorbiaceae | *Antidesma venosum* Mey. Ex Tul. | GC | 8 | 211 | 5,33 | 4,16 |
| | *Discoglypremna caloneura* (Pax) Prain | GC | | | | |
| | *Macaranga barteri Müll.* Arg. | GC | | | | |
| | *Macaranga spinosa* Müll. Arg. | GC | | | | |
| | Mbambala | GC | | | | |
| | *Plagiostyles africana* (Müll. Arg.) Prain | GC | | | | |
| | *Ricinodendron heudelotii* (Baill.) Pierreex Heckel | GC | | | | |
| | *Scottelia coriacea* | GC | | | | |
| Fabaceae-Caesalpinioideae | *Afzelia bipindensis* Harms | CG | 20 | 997 | 13,33 | 19,64 |
| | *Amphimas ferrugineus* Pierre ex Pellegr. | GC | | | | |
| | *Anthonotha fragrans* (Baker f.) Exell & Hillc. | GC | | | | |
| | *Berlinia bracteosa* Benth. | GC | | | | |
| | *Berlinia grandiflora* (Vahl) Hutch. & Dalziel | GC | | | | |
| | *Bobgunnia fistuloides* (Harms) J.H. Kirkbr. & Wiersema | GC | | | | |
| | *Cynometra sp* | CG | | | | |
| | *Daniellia spp.* | GC | | | | |
| | *Dialium dinklagei* Harms | GC | | | | |
| | *Dialium pachyphyllum* Harms | GC | | | | |
| | *Erythrophleum ivorense* A. Chev. | GC | | | | |
| | *Gilbertiodendron dewevrei* (De Wild.) J. Léonard | CG | | | | |
| | *Gilletiodendron pierreanum* (Harms) J. Léonard | GC | | | | |
| | *Guibourtia arnoldianum* (De Wild. & T. Durand) J. Léonard | CG | | | | |
| | *Hylodendron gabunense* Taub. | GC | | | | |
| | *Hymenostegia sp* | CG | | | | |
| | *Prioria balsamifera* (Vermoesen) Breteler | CG | | | | |
| | *Prioria oxyphylla* (Harms) Breteler | GC | | | | |
| | *Scorodoploeus zenkeri* Harms | CG | | | | |
| | *Tessmannia africana* Harms | GC | | | | |
| Fabaceae-Fabioideae | *Angylocalyx pynaertii* De Wild. | GC | 2 | 7 | 1,33 | 0,14 |
| | *Pterocarpus soyauxii* Taub. | CG | | | | |
| Fabaceae-Mimosoideae | *Albizia ferruginea* (Guill. & Perr.) Benth. | GC | 6 | 188 | 4,00 | 3,70 |
| | *Fillaeopsis discophora* Harms | GC | | | | |
| | *Parkia bicolor* A. Chev. | GC | | | | |
| | *Pentaclethra eetveldeana* De Wild. & T. Durand | GC | | | | |
| | *Pentaclethra macrophylla* Benth. | GC | | | | |
| | *Piptadeniastrum africanum* (Hook. F.) Brenan | G-SZ | | | | |
| Gentianaceae | *Anthocleistha schweinfurthii* Gilg | G-SZ | 1 | 2 | 0,67 | 0,04 |
| Guttifereae | *Allanblackia floribunda* Oliv. | GC | 6 | 319 | 4,00 | 6,28 |
| | *Allanblackia staneriana* Exell & Mendonça | CG | | | | |
| | *Garcinia epunctata* Stapf. | GC | | | | |
| | *Mammea africana* Sabine | GC | | | | |
| | *Pentadesma butyracea* Sabine | GC | | | | |
| | *Symphonia globulifera* L. | AM | | | | |
| Huaceae | *Afrostyrax lepidophyllus* Mildbr. | GC | 1 | 9 | 0,67 | 0,18 |
| Hypericaceae | *Harungana madagascariensis* Lam. Ex Poir. | AM | 1 | 1 | 0,67 | 0,02 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Irvingiaceae | *Irvingia excelsa* Mildbr. | CG | 5 | 30 | 3,33 | 0,59 |
| | *Irvingia gabonensis* (Aubry-LeComte ex. O'Rorke) Baill. | CG | | | | |
| | *Irvingia grandifolia* (Engl.) Engl. | CG | | | | |
| | *Irvingia sp* | CG | | | | |
| | *Klainedoxa gabonensis* Pierre ex. Engl. | GC | | | | |
| Lauraceae | *Beilschmiedia obscura* (Stapf.) Engl. Ex. A. Chev. | GC | 1 | 1 | 0,67 | 0,02 |
| Lecythidaceae | *Pertersianthus macrocarpus* (P. Beauv.) Liben | GC | 1 | 42 | 0,67 | 0,83 |
| Malvaceae-Steculioideae | *Cola acuminata* (P. Beauv.) Schott. & Endl. | GC | 5 | 121 | 3,33 | 2,38 |
| | *Cola lateritia* K. Schum. | GC | | | | |
| | *Nesogordonia kabingensis* (K. Schum.) Capuron ex; Germ. | GC | | | | |
| | *Pterygota bequaertii* De Wild. | GC | | | | |
| | *Pterygota spp.* | CG | | | | |
| Malvaceae-Tiliacoideae | *Duboscia macrocarpa* Bocq. | GC | 3 | 90 | 2,00 | 1,77 |
| | *Duboscia viridiflora* (K. Schum.) Mildbr. | GC | | | | |
| | *Grewia coriacea* Mast | GC | | | | |
| Meliaceae | *Carapa procera* C. DC. | AA | 9 | 105 | 6,00 | 2,07 |
| | *Entandophragma angolense* (Welw.) C. DC. | GC | | | | |
| | *Entandophragma candollei* Harms | GC | | | | |
| | *Guarea cedrata* (A. Chev.) Pellegr. | GC | | | | |
| | *Guarea thompsonii* Sprague & Hutch. | CG | | | | |
| | *Khaya grandifoliola* C. DC. | GC | | | | |
| | *Lovoa trichilioides* Harms | GC | | | | |
| | *Trichilia lanata* A. Chev. | GC | | | | |
| | *Trichilia rubescens* Oliv. | GC | | | | |
| Moraceae | *Antiaris toxicaria var. welwitschii* (Engl.) C.C. Berg. | GC | 6 | 94 | 4,00 | 1,85 |
| | *Ficus exasperata* Vahl | At | | | | |
| | *Myrianthus arboreus* P. Beauv. | GC | | | | |
| | *Pseudospondias microcarpa* (A. Rich.) Engl. | GC | | | | |
| | *Treculia africana* Decne | At | | | | |
| | *Treculia obovoidea* N. E. Br. | CG | | | | |
| Myristicaeae | *Pycnanthus angolensis* (Welw.) Warb. | GC | 3 | 235 | 2,00 | 4,63 |
| | Coelocaryon preussii Warb. | | | | | |
| | *Staudtia kamerunensis var gabonensis* (Warb.) Fouilloy | CG | | | | |
| Myrtaceae | *Syzygium rowlandii* Sprague | GC | 1 | 1 | 0,67 | 0,02 |
| Olacaceae | *Coula edulis* Baill. | CG | 7 | 842 | 4,67 | 16,59 |
| | *Diogoa zenkeri* (Engl.) Exell & Mendoça | GC | | | | |
| | *Heisteria parvifolia* Sm. | GC | | | | |
| | *Ongokea gore* (Hua) Pierre | GC | | | | |
| | *Strombosia grandifolia* Hook. F. | GC | | | | |
| | *Strombosia pustulata* Oliv. | GC | | | | |
| | *Strombosiopsis tetrandra* Engl. | GC | | | | |
| Pandanaceae | *Panda oleosa* Pierre | GC | 1 | 10 | 0,67 | 0,20 |
| Passifloraceae | *Barteria fistulosa* Mast. | At | 1 | 1 | 0,67 | 0,02 |
| Phyllanthaceae | *Uapaca guineensis* Müll-Arg. | GC | 2 | 21 | 1,33 | 0,41 |
| | *Bridelia spp.* | GC | | | | |
| Putranjivaceae | *Drypetes gossweileri* S. Moore | GC | 2 | 139 | 1,33 | 2,74 |
| | *Drypetes obanensis* S. Moore | GC | | | | |
| Rhamnaceae | *Maesopsis eminii* Egl. | GC | 1 | 19 | 0,67 | 0,37 |
| Rubiaceae | *Hallea stipulosa* (Aubrév. & Pellegr.) LeRoy | GC | 3 | 169 | 2,00 | 3,33 |
| | *Nauclea diderrichii* (De Wild. Et T. Durand) Merr | GC | | | | |
| | *Corynanthe macroceras* K. Schum | GC | | | | |
| Rutaceae | *Zanthoxylum heitzii* (Aubrév.& Pellegr.) PG Waterman | GC | 2 | 41 | 1,33 | 0,81 |
| | *Zanthoxylum gilletii* (De Wild.)PG Waterman | CG | | | | |
| Samydaceae | *Homalium aubrevillei* Keay. | GC | 3 | 67 | 2,00 | 1,32 |
| | *Homalium letestui* Pellegr. | CG | | | | |
| | *Homalium sp* | CG | | | | |
| Sapindaceae | *Blighia sp* | GC | 5 | 94 | 3,33 | 1,85 |
| | *Eriocoelum microcarpa* Gilg. Ex Radlk. | GC | | | | |
| | *Ganophyllum giganteum* (A. Chev.) Hauman | GC | | | | |
| | *Lecaniodiscus cupanioides* Planch. | GC | | | | |
| | *Pancovia spp* | GC | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sapotaceae | *Aningeria robusta* (A. Chev.) Aubrév.& Pellegr. | GC | 8 | 78 | 5,33 | 1,54 |
| | *Breviea leptosperma* (Baehini) Heine | GC | | | | |
| | *Chrysophyllum africanum* A. DC. | CG | | | | |
| | *Chrysophyllum beguei* Aubrév. & Pellegr. | GC | | | | |
| | *Letestua durissima* (A. Chev.) Lecomte | CG | | | | |
| | Omphalocarpum elatum Miers | GC | | | | |
| | *Synsepalum dulcificum* (Schumach. & Thonn.) Daniel. | GC | | | | |
| | *Tieghemella africana* Pierre | GC | | | | |
| Simaroubaceae | *Odyendya gabonensis* | CG | 1 | 1 | 0,67 | 0,02 |
| Verbenaceae | *Vitex cf doniana* Sweet | GC | 2 | 24 | 1,33 | 0,47 |
| | *Vitex ferrugineus* Bojet ex. Schau. | GC | | | | |
| TOTAL | | | 150 | 5076 | 100,00 | 100,00 |

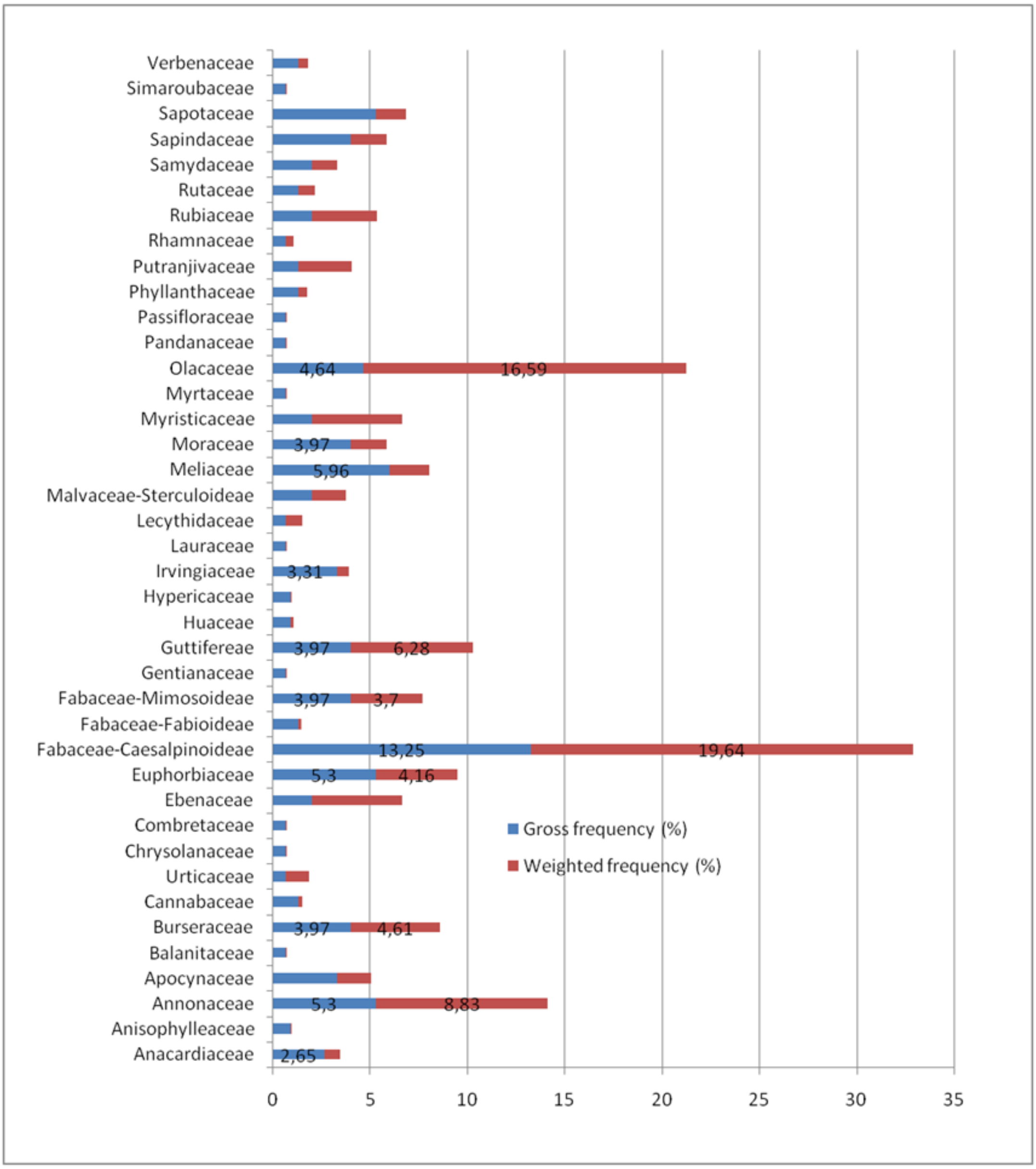


**Figure 3.** Specific contribution of different families

However in quantitative terms, the family of Fabaceae-Caesalpinioideae (19.64%) is followed by the Olacaceae (16.29%) families, the Annoncaeae (8.83%) of the Guttifereae (6.28%), of the Ebenaceae (4.65%), of the Myristicaceae (4.63%) and of the Burseraceae (4.61%). On the

In quantitative terms,–5076 trees of diameter ≥20 cm were surveyed. On the first 40 species, the most abundant are *Strombosia grandifolia* (Olacaceae) and *Dialium dinklagei* (Fabaceae-Caesalpinioideae with respective abundances of 9.85% and 9.23%. These two species are followed by *Anonidium mannii* (Annonaceae) and *Allanblackia staneriana* (Guttifereae) with frequencies of 5.62% and 5.31%. Other species have an abundance lesser than 5%. Species with only a single individual among them were also surveyed including *Voacanga thouarsii*, *Parinari excelsa*, *Odyendya gabonensis*, and *Syzygium rowlandii* (Figure 4).

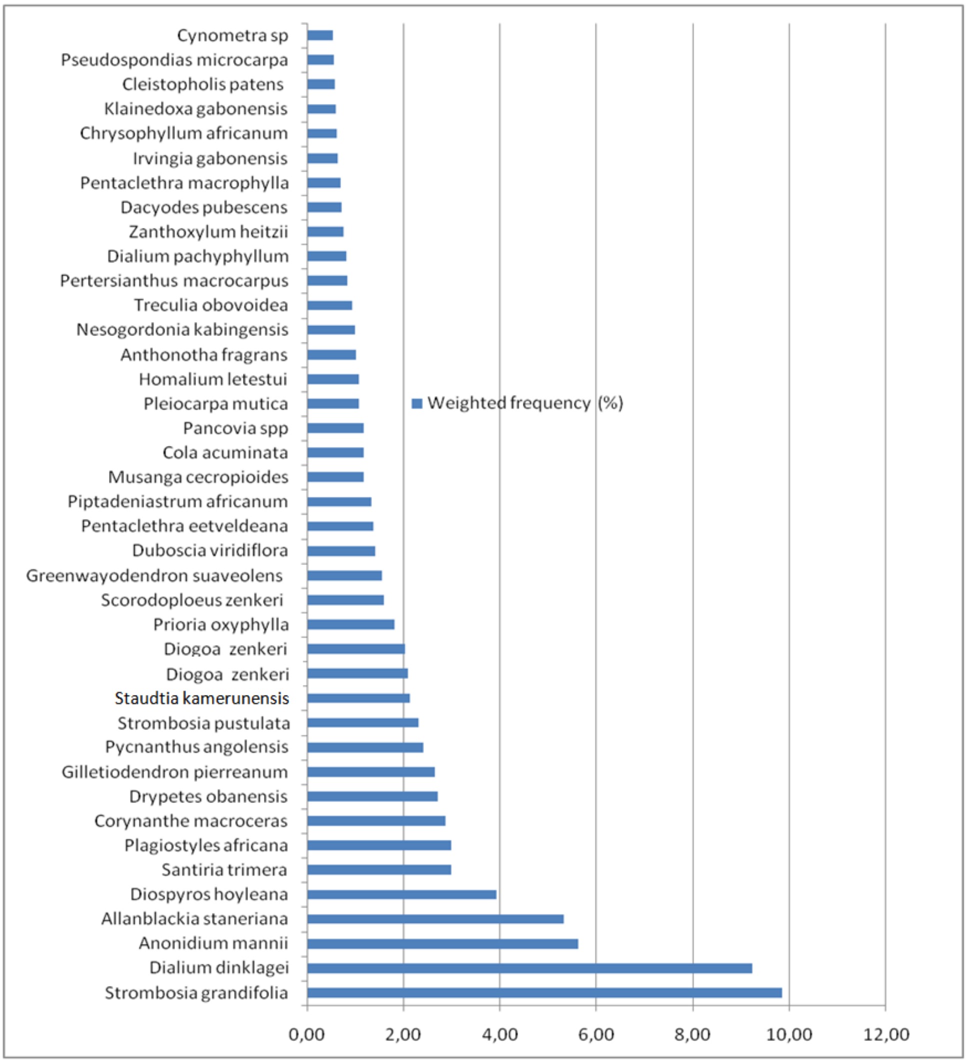


**Figure 4.** Weight Contribution of different species

## 3.2. Analysis of Similarity Coefficients

For this analysis, transects with very high numbers surveyed were considered, i.e.transects 01, 020 and 025. The similarity coefficients of Jaccard and Sørensen were applied in this study by considering the longest transects of the study area, but also transects with the largest floristic inventory. The Jaccard similarity coefficient ranged from 49% regarding transects L01 and L025 to 58% (L020 and L025), whereas the Sørensen coefficient varies for shrubs from 66% for L01 and L025 to 74% for transects L020 and L025 (Figure 5).

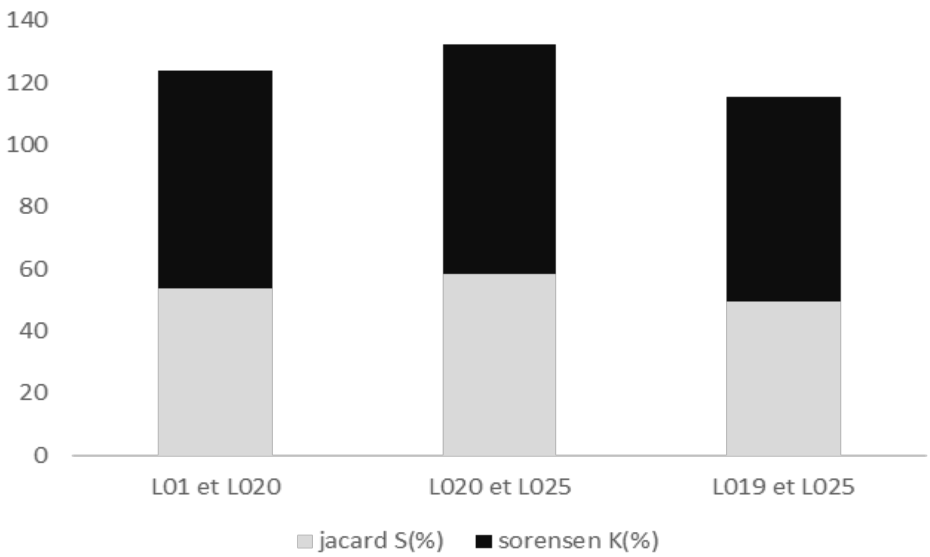


**Figure 5.** Variation of the Jaccard and Sørensen coefficients

### 3.3. Variation of the Shannon Index

The biodiversity analysis is made also by considering the Shannon index. We have considered in this study the analysis of biodiversity between transects. This analysis shows that the number of families by transect varies from one transect to another. The highest Shannon index observed was in transect L030 (4.16 bit) while the lowest was observed in transect 038 (3.08 bit). It is important to note that this index is greater than 3 in transects of this forest block of the Boubissi forest (Figure 6).

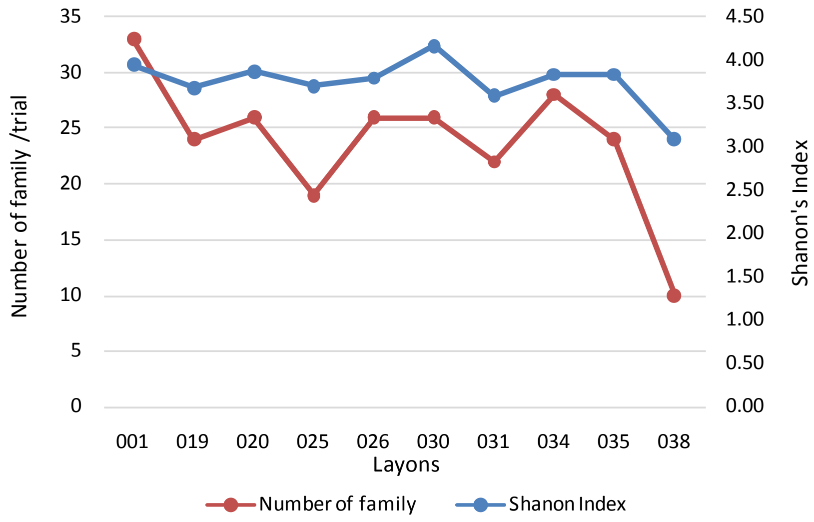


**Figure 6.** Variation of the Shannon biodiversity index between transects

### 3.4. Phytogeographic Spectrum

The phytogeographic spectrum of the forest of the study area is represented in Figure 7. This figure shows the Guineo-Congolese species as the most numerous, representing 93% of the total species surveyed. They are: 27% of Centro-Guinean species represented by *Prioria balsamifera*, *Cannarium schweinfurthii*, etc.; Guinean species have a high percentage of 66%, represented for instance by *Khaya anthotheca*, *Entandrophragma angolense*, etc.

The afro-tropical liaison species (*Treculia africana*, *Barteria fistulosa*, etc.) and sudano-zambezian (*Anthocleistha schweinfurthii*, *Ficus mucoso*) represent only 3% and 1% respectively.

Species with a wide geographic spread are poorly represented in our inventory with a percentage of 1%, which is the case for Afro-American (*Carapa procera*) and 2% for the Afro-Malagasy (*Symphonia globulifera*).

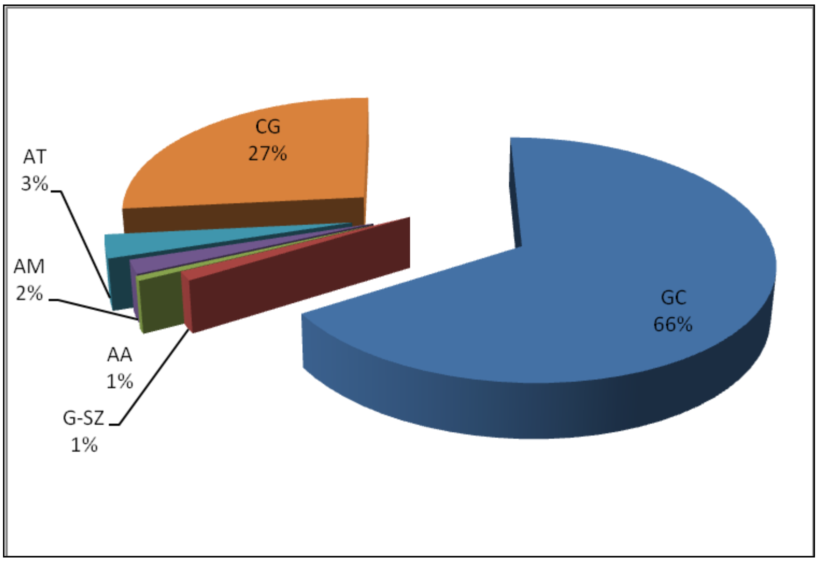


**Figure 7.** Phytogeographic spectrum of the study forest

### 3.5. Vegetation Structure

On the entire block studied, identified trees were divided into measured diameter classes (Figure 8). This figure shows classes 2, 3 4 and 5 representing crop trees including 86% of trees surveyed. Harvestable trees of DBH ≥ 60 cm represent 14% of trees surveyed in the study area. Note the absence of individuals from CL11, CL13, CL14, CL15, CL16 and CL17 classes. CL18 class is represented by only one individual *Klainedoxa gabonensis* Pierre ex Engl. Similarly CL12 class contains 4 individuals belonging to 4 different species *Dacryodes pubescens* (Verm.) Lam, *Ganophyllum giganteum* (Chev.) Hauman, *Piptadeniastrum africanum* (Hook.F.) Bren,, and

*Prioria oxyphylla* (Harms) Brettler. CL2 class that has the largest number of trees is composed of individuals belonging to four different species, *Piptadeniastrum africanum* (Hook.F.) Bren, *Ganophyllum giganteum* (Chev.) Hauman, *Prioria balsamifera* (Verm.) Brettler and *Dacryodes pubescens* (Verm.) Lam. Harvestable species (DBH ≥ 60cm) belong to 30 species of which the most abundant are *Dialium dinklagei* Harms & Engl, , *Strombosia grandifolia* HooK. F., *S. pustulata* Oliv, *Treculia africana* Decne, *Dialium pachyphyllum* Harms. *Dacryodes pubescens* (Verm.) Lam

*Gilletiodendron pierreanum* Léonard, *Allanblaickia staneriana* Excell et Mend., *Guarea thompsonii* Sprague et Hutch., *Khaya grandifolia* C. DC., *Prioria oxyphylla* (Harms) Brettler, *Hallea stipulosa* (DC.) Leroy, *Entandrophragma candollei* Harms, *Entandrophragma angolense* (Welw.) C. DC., *Pterygota bequaertii* De Wild., *Terminalia superba* Engl. Et Diels, *Stautia kamerunensis* Warb. *var. gabonensis* Fouilloy etc.

It should be noted that the *Olacaceae* and *Annonaceae* are much more represented by trees not exceeding 30 m in height outside *Ongokea gore* (Olacaceae) and *Greenwayodendron suaveolens* (Engl. & Diels) Verdc. (Annonaceae) that sometimes exceed this height. They are trees of the middle stratum. In terms of dominance, the part of the Boubissi FEU forest studied is dominated by *Fabaceae-Caesalpinioideae* (*Dialium dinklagei* Harms, *Gilletiodendron pierreanum* (Harms) J. Léonard, *Daniellia soyauxii* (Harms) Rolfe, *Prioria oxyphylla* (Harms) Brettler, Guttifereae (*Allznblackia staneriana* Exell & Mendonça, *Allanbliackia floribunda* Oliv. or *Symphonia globulifera* L.), the Burseraceae (*Dacryodes pubescens* (Verm) Lam., *Santiria trimera* (Oliv.) Aubr., *Canarium schweinfurthii* Engl.), the Myristicaceae with *Staudtia kamerunensis* Warb. Var. *gabonensis* Fouilloy and Irvingiaceae (*Klainedoxa gabonensis* Pierre ex Engl., *Irvingia grandifolia* (Engl) Engl.).

This diameter structure of the forest allows to schedule the cutting of logs in the surveyed part. The numbers of trees (DBH ≥ 60 cm) which will be harvested at the first cut of logs represent 14% and those of the second cut approximately 20% of the number of trees surveyed. Crop trees represent 66%.

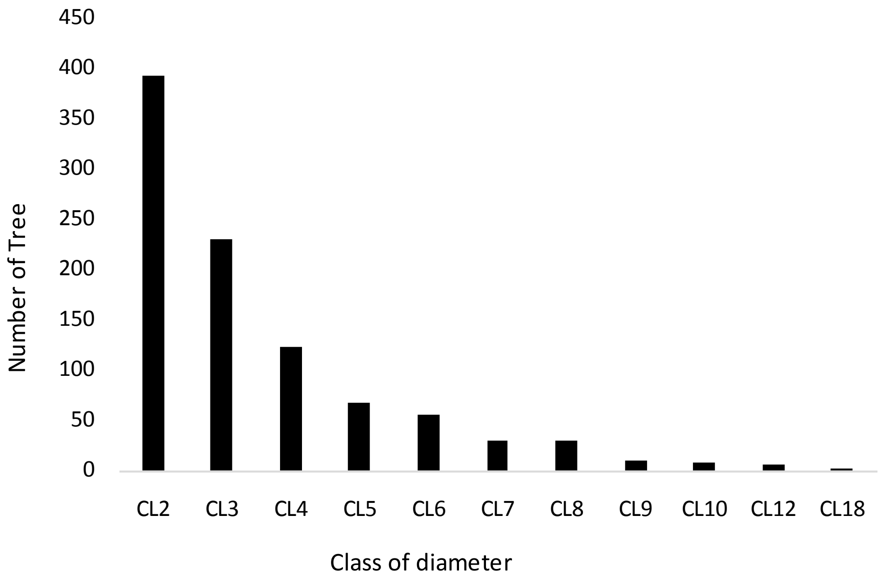


**Figure 8.** Distribution of trees by diameter class

# 4. Discussion

Forest management inventory in block B of the Boubissi forestry exploitation unit showed a great diversity of plant species of trees of DBH ≥20 cm. High species richness is a hallmark of many tropical forests [4,6].

In total 160 species were inventoried in 35 ha along the inventory transects. These species are distributed within 38 botanical families. This study is a contribution to the knowledge of the still little known flora of the Congo [2]. The result of this inventory presents a greater richness than that obtained by [10] in the Okoumé forests of the Congolese coast, at the Youbi site, located at about 90 km North of the town of Pointe Noire. In their inventory of 1186 trees with DBH≥ 10 cm representing 71 forest species had been inventoried. Other inventories Kimpouni, [10] conducted in the Cataracts plateau had allowed the identification of 153 species distributed within 116 genera and grouped, according to APG II (2003), within 42 families.

This high biodiversity in our study area is confirmed by the fact that Shannon-Weaver indices for each transect are very high. Shannon's biological diversity indices do not allow to discriminate between forests transects for their floristic composition.

Moreover, similarity coefficients of Sevan and Sørensen give a very good idea of the presence or absence of the species in the different transects of the inventory.

The range of this coefficient is between 0 and 1. Interpretation of the CSJ values: 1: both survey sites have only common species. 0: both survey sites have only singular species', 1/2: the two survey sites have as many common species as the sum of singular species at each survey site, [0, 1/2]: the similarity in terms of species diversity between both survey sites is rather low, [1/2.0]: the similarity in terms of species diversity between both survey sites is rather high.

In our case, it ranges from 49 to 58 per cent, in the three longest transects of the study area. This suggests that there is a species group that is present in the different surveys at the three transects L01, L020, and L025. This could also reveal floristic affinities. The high floristic biodiversity of the study area is also reflected in species found in only one or few transects of the study area.

In this study the Sørensen coefficient varies for shrubs between 66% for transect L01 and 74% for transect L025.

In qualitative terms, it is species from the *Fabaceae* family in general that are the most abundantly represented, and more specifically the Fabaceae-Caesalpinioideae followed by the Meliaceae, Annonaceae, Euphorbiaceae, Sapotaceae, Olacaceae, Burseraceae, Fabaceae-Mimosoideae, Guttifereae, Moraceae, Sapindaceae, Apocynaceae, Irvingiaceae, Anacardiaceae Ebenaceae and Malvaceae-Sterculioideae. Although the species of Fabaceae are also present, the presence of dominant trees of the Mahogany family Meliaceae (*Entandrophragma angolense* (Welw.) C. DC., *E. cylindricum* (Sprague) Sprague, *Guarea cedrata* (A. Chev.) Pellegr., *G. thompsonii* Sprague & Hutc.), Rubiaceae (*Nauclea diderrichii* (De Wild. & th. Dur.) Merrill), Sapotaceae (*Chrysophyllum spp.*, *Aningeria altissima* (A. Chev.) Aubr. & Pellegr.), Moraceae (*Milicia excelsa* (Welw.) Berg.), Burseraceae (*Dacryodes pubescens* (Verm) Lam., *Canarium schweinfurthii* Engl., *Santiria trimera* (Oliv.) Aubr.), Euphorbiaceae (*Ricinodendron heudelotii* (Baill.) Pierre ex Pax) allows, according to Cusset [2] to relate the forest area inventoried to the 'mixed moist semi-evegreen guineo-congolese rainforest» of [18] The phytogeographic spectrum of the surveyed area confirms this point of view with a 93% presence of Guineo-Congolese species in the area (Figure 7).

By considering the number of inventoried trees, Fabaceae are the most represented followed by Olacaceae, Annonaceae, Euphorbiaceae, Guttifereae, Ebenaceae, Burseraceae, Myristicaceae and Rubiaceae. This fact confirms the observation made by [2] that among the primary features of the Yombé forest, we note the presence of Olacaceae (*Diogoa zenkeri* (Egnl.) Excell & Mendosa, *Ongokea gore* (Hua) Pierre, *Strombosia grandifolia* HooK. F., *S. pustulata* Oliv.), Annonaceae (*Greenwayodendron suaveolens* (Engl. & Diels) Verdc.), Euphorbiaceae (*Uapaca guineensis* (Mull-Arg.) Prain, *Drypetes gossweileri* S. Moore, *Antidesma venosum* Auct., *Plagiostyles Africana* (Müll-Arg) Prain), Guttifereae (*Mammea Africana* Sabine, *Allanblackia floribunda* Oliv., *Symphonia globulifera* L.). In areas of shallow water along the rivers, there is the presence of large trees in swampy areas belonging to the Rubiaceae family (*Hallea cilata*, Ledermannii (K. Krausse) Verdc., *Hallea stiypulosa* (DC.)) Leroy). There is also the presence of undergrowth from this family, which according to Schnell (1970) is common in the understory of dense forests of the old and new world.

The distribution of tree numbers shows a L-shaped structure. The highest numbers of trees occur in small diameter classes, which show a good regeneration of the Boubissi FEU forest. There are only 379 trees of DBH ≥ 40 cm on 35 ha of inventoried forest. This low number of large trees is explained by the fact that the Yombe forest massif is the first that has been logging in Congo. The surveyed area has experienced several cuts from the 1930s until now. It is a secondary forest in full regeneration.

## 5. Conclusion

The secondary forests of Boubissi represented by a dense semi-deciduous forest is composed mainly of *Fabaceae–Caesalpinioideae* species encountered indominant as well as average strata. Among the dominant species, those belonging to the *Burseraceae*, *Meliaceae*, *Sapotaceae* and *Irvingiaceae* families are also present. The phytogeographic spectrum showed that though being located in the South of the Congo and with the border with Angola, the Boubissi FEU forest belongs to the great Guineo-Congolese phytochorion, dominating with 66% of species; followed by Congolo-Guinean species (27%). The other phytochoria are very poorly represented, the Guineo-Sudano-Zambezian and the Afrotropicals represent only about 4% of species and 3% for the Afro-Malagasy and Afro-American. The dominance of the Guineo-Congolese phytochorion was also observed in forest bits of the Niari's Valley, which is mostly a savannah area, between the Mayombe forest and the Chaillu by Koubouana (1993) as well as in the massif of the Northern Congo.

The diametric 'L' structure shows that the Boubissi FEU forest is in full recovery with low numbers of large trees resulting from previous logging activities. The commissioning of this forest should take into account its history because it has already suffered cuts in the 1960s and 1980s. Logging exploitation of trees must be done following of growth of trees to not compromise regeneration.

## Abbreviations

CRF: Cedar Research Forest; EBG: Ecological-Botanical Gardens; DBH: Diameter at Breast Height; DOY: Day of the year; LAI: Leaf area index; FEU: Forest Exploitation Unit.

## Conflict of Interests

The authors declare that they have no competing interests.

## Authors' Contributions

Félix Koubouana, Suspense Averti Ifo and Jean-Marie Moutsamboté are the principals' authors, who contributed in the processing of the data, and writing of this article.

Robia Tailboard Farelle Kesavakumar, Adrienne Akobé and Helen Openga POOJA contributed with Félix Koubouana in the collect of field data.

## Authors' Information

This article was prepared after field work inventory in UFE Boubissi located in the south west of the Republic of Congo.

## Acknowledgments

Authors thanks very sincerely TRABEC which enabled us to work in their forest concession. Also the authors thank Charlotte Jourdain for her contribution to the English version of this article.

## References

[1] Blanc, P. (2002) Être plante à l'ombre des forêts tropicales. Paris, France, Nathan, 428 p.

[2] Cusset G. (1989) La flore et la végétation du Mayombe congolais: état des connaissances. Rév. des connaissances sur le Mayombe. Paris, PNUD/UNESCO, pp: 103-136.

[3] Ekoungoulou R., Liu, X., Loumeto J., Ifo, S., Bocko Y., Koula F. & Niu S. (2014). Tree Allometry in Tropical Forest of Congo for Carbon Stocks Estimation in Above- Ground Biomass. *Open Journal of Forestry*, 4, 481-491.

[4] Gardner TA, Barlow J, Sodhi NS, Peres CA. (2010) A multi-region assessment of tropical forest biodiversity in a human-modified world. Biol. Conserv. 143, 2293-2300.

[5] Gentry AH (1988) Changes in plant community diversity and floristic composition on environmental and geographical gradients. Annals of the Missouri Botanical Garden 75: 1-34.

[6] Givnish TJ (1999) On the causes of gradients in tropical tree diversity. Journal of Ecology 87: 193-210.

[7] Ifo S.A., Koubouana F., Jourdain C., & Nganga D. (2015). Stock and Flow of Carbon in Plant Woody Debris in Two Different Types of Natural Forests in Bateke Plateau, Central Africa. *Open Journal of Forestry* Vol.5 No.1 (January), 2015.

[8] IPPC. (2014). Cinquième rapport du GIEC.

[9] Jamet R. (1976). Pédogénèse sur roches cristallophylliennes et argileuses en milieu équatorial congolais. Brazzaville, ORSTOM, 7 fascicules, 480p.

[10] Kimpouni V., Apani E. & Motom, M. (2013) Analyse phytoécologique de la flore ligneuse de la Haute Sangha (République du Congo). *Adansonia*, sér. 3, 35 (1): 107-134.

[11] Koechlin J., (1956) Notes sur une tournée dans la région de Pointe en Octobre 1956. IRSC, Brazzaville: 13 p.

[12] Koubouana F. (1993) Analyses floristique et quantitatives des forêts de la Vallée du Niari. Thèse de Doct. d'Univ. Pierre et Marie Curie, Paris, France, 265p.

[13] Legendre L, Legendre P. (1984) *Écologie Numérique, tome 1 : Traitement Multiple des Données Écologiques* (2e édn). Masson: Paris.

[14] Makany J. (1976) Végétation des plateaux téké. Travaux Universitaires Brazzaville.

[15] Moutsamboté J-M. (1985) Dynamique de reconstitution de la forêt Yombe (Dimonika, R.P. du Congo). These 3e cycle Univ. Bordeaux III, Bordeau : 301 p.

[16] Moutsamboté J-M. (2012) Etude écologique, phytogéographique et phytosociologique du Congo septentrional (Plateaux, Cuvettes, Likouala et Sangha), République du Congo, Brazzaville. Fac; Sciences, Univ. Marien Ngouabi, Thèse de Doctorat d'Etat, 632p.

[17] Phillips, L.O., Reitsma, J.M., White, L., Comiskey, J.A., Djuikouo, K.M.N.,Ewango, C.E. N., Feldpausch, T.R., Hamilton, A.C., Gloor, M., Hart, T., Hladik, A., Lloyd, J., Lovett, J. C., Makana, J.R., Malhil, Y., Mbago, F.M., Ndangalasi, H.J., Peacock, J., Peh1, K.S-H., Sheil1, D., Sunderland, T,. Swaine, M. D, Taplin, J., Taylor, D., Thomas, S.C., Votere, R ., Woll, H. (2009). Increasing carbon storage in intact African tropical forests. Nature. Vol 457: 1003-1006. pp 301.

[18] Vicat J-P. & Gioan P. (1989) La chaîne précambrienne du Mayombe en République Populaire du Congo : Géologie, Métallogénie, perspectives de développement. Rév. Des connaissances sur le Mayombe, Paris, PNUD/UNESCO, pp : 17-44.

[19] White F., (1983) The vegetation of Africa, Paris, UNESCO Press, 356p.