

Systematic and structural analysis of woody species of forest relics in the Korhogo region (northern Côte d'Ivoire)

Dramane Soro¹⁻³, Adama Pagadjovongo Silue¹, Doudjo Noufou Ouattara²⁻³, and Mamidou Witabouna Koné²⁻³

¹UFR Sciences Biologiques, Université Pelefero Gon Coulibaly, BP 1328 Korhogo, Côte d'Ivoire

²UFR Sciences de la Nature, Université NANGUI ABROGOUA, 02 BP 801 Abidjan 02, Côte d'Ivoire

³Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), 01 BP 1303 Abidjan 01, Côte d'Ivoire

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ABSTRACT: Vegetation in northern Côte d'Ivoire is facing strong pressure of human activities and climate change. The aim of this study is to analyze floristic diversity, woody vegetation structure and conservation value of village forest relics in Korhogo department. For this purpose, a surface inventory has been carried out in plots of 625 m² (25 x 25 m²). The relative importance of flora has been assessed through Indices Value Importance (IVI) and Rare Species and Families. Vegetation structure was studied through woody density, burrow surface and diametric structure. A total of 107 species divided into 80 genera, which include 30 families was obtained. The most important families are Fabaceae, Rubiaceae and Combretaceae. Flora of these forests relics is also characterized by the presence of species of special status, including one endemic to West African forest block. Eight species are ecological importance (*Daniellia oliveri* (IVI = 26.90), *Piliostigma thonningii* (IVI = 19.24), *Pericopsis laxiflora* (IVI = 18.33), *Vitellaria paradoxa* (IVI = 18.87), *Anogeissus leiocarpus* (IVI = 16.69), *Terminalia glaucescens* (IVI = 13.26), *Detarium microcarpum* (IVI = 12.48) and *Parkia biglobosa* (IVI = 10.32)). Density of 884 plantes/ha and basal area mean (12.82 m²/ha) are indicators of good level of conservation of forested formations of these relics. The diametric structure of the vegetation has an «inverted J» shows a predominance of small diameter individuals. Efforts to conserve endemic, rare and endangered species and to manage these village forests sustainably must be a priority for local populations and local authorities.

KEYWORDS: Floral diversity, woody plants, forest relics, vegetation structure, Korhogo.

1 INTRODUCTION

Tropical forest ecosystems are important as sources of wood, providers of environmental services such as carbon sequestration and soil erosion protection, reservoirs of biodiversity and local sources of useful plants [1]. However, climate change and human-induced actions such as deforestation, over-exploitation of natural resources, agriculture, overgrazing and bushfires are currently contributing to loss many critically important native plants [2].

In Côte d'Ivoire, forest area, estimated at more than 15 million hectares in 1960, was less than half in 2000 [3] deforestation rate of 1.1% to 2.9% per year [4]. Plant formations in the northern regions, dominated by Sudanian savannah, seem to be among those ecosystems most affected by these transformations. This is the case in Korhogo region, where plant formations are full of many woody and non-woody forest products, which constitute genuine food, medicinal, energy and fodder resources of great importance to local population [5]; [6]. Although the pressure on natural resources is increasing, accurate data on the structure of woody vegetation and the loss of biodiversity in some forest formations are still lacking in this part of the country [7]. However, this information on structure and diversity provides indicators for analyzing trends in qualitative and quantitative evolution of vegetation [8]. In addition, there is now talk of better management of vegetation cover, with a view to carbon sequestration [9].

It is in view of this problem that this study was conducted in the Korhogo region. The objective of this study is to evaluate the floristic potential of wood and its structural characteristics in order to provide baseline data for their sustainable management. In particular, it will be necessary to determine floristic diversity of woody species of plant formations and to analyze their ecological and dendrometric characteristics in wooded areas of Korhogo.

2 MATERIAL AND METHODS

2.1 STUDY SITE

This study was done in Korhogo department. Located in northern Ivory Coast, more than 600 km from the economic capital. The department of Korhogo is the administrative center of the Poro region and the district of Savannah. The department has sixteen sub-prefectures [10]. It is limited to the north, by M'Bengué and Ouangolodougou department, to the north-east by Sinématiali and Ferkéédougou department, to the south-east by Niakaramadougou department, to the south by Dikodougou department and to the west by Boundiali and Dianra department.

2.2 DATA COLLECTION

The surface survey method was used for this study. We have first prospected the area concerned using existing tracks on each 200 meters to ensure that environment was not disturbed. 26 plots (200 m x 50 m) were laid. Each plot was subdivided into 16 plots of 25 m x 25 m, or 625 m². Four plots (25 m x 25) were inventoried per plot (200 m x 50 m). These plots were distributed on both sides of 200 m median line [11]. They were laid in village forest relics of Korhogo department. Individuals of plants species with DBH greater than or equal to 10 cm were considered in this study.

2.3 DATA ANALYSIS

2.3.1 RICHNESS AND FLORISTIC COMPOSITION

For this study, qualitative diversity was first determined. It takes into account the floristic richness (number of species, genera and families), the floristic composition (biological types, chorological affinities) and species with special status. The objective was to identify Ivorian endemic species (GCI), endemic forests of Upper Guinea (HG), or the West African forest block (GCW), using the basis lists of plants species prepared by [12], [13], [14]. To endemic plants species has been added list of rare or endangered species of Ivorian flora according to [15].

2.3.2 QUANTITATIVE DIVERSITY

The quantitative diversity of plants species was evaluated through several ecological parameters.

Importance Value Index (IVI) for each species; it provides information on a number of individuals, their distribution and their importance on burial area. This index helps to highlight the most important species. It is the sum of three factors representative of quantitative biometric values of hectare survey.

The relative dominance that is the ratio of basal area of the species and the sum of basal areas of all species;

The relative density that is the ratio of a number of individuals of plants species in a family and the total number of individuals of all species;

The relative frequency that is the ratio between a number of plots in which the species is found and the total number of plots. Frequency is a number of plots in which the species is found.

$$IVI = \text{Relative Dominance} + \text{Relative Density} + \text{Relative Frequency}$$

Family Importance Value (IVF): it provides information on floristic importance of each family by giving a number of individuals in a family, a number of species representing the family and the quantitative importance of families through their basal areas. It is the sum of three factors representative of the quantitative biometric values of hectare survey.

The relative dominance that is the ratio between the sum of the basal areas of individuals in a family and the sum of all basal areas of individuals in all families;

The relative density that is the ratio of a number of individuals in a family and a total number of individuals;

The relative diversity that is the ratio between a number of species in a family and a total number of species.

$$IVF = \text{Relative Dominance} + \text{Relative Density} + \text{Relative Diversity}$$

The diversity (H') indices of Shannon (1948) and the equity (E) indices of [16]. These two indices were calculated using the following mathematical formulas:

$$H = - \sum \left(\frac{ni}{N} \times \ln \frac{ni}{N} \right)$$

H' is Shannon index, ni a number of individuals of a specie i , and N a total number of individuals of all species.

$$E = \frac{H}{\ln S}$$

E is the equity index; H Shannon diversity index and S a total number of species.

2.3.3 DEMOGRAPHIC STRUCTURE

The density and basal area of individuals surveyed were calculated in order to take into account a demographic structure of forest relics. The distribution of individuals by diameter class was subsequently performed.

Density is defined as a number of individuals per unit area. It reflects the occupation of land by species. This parameter was calculated for each plot using the mathematical formula below:

$$d = \frac{n}{S}$$

In this formula n represents a number of stems identified and S a total area of observations assessed in hectares.

The basal area better reflects a horizontal occupation of soil by plant species. To estimate this, we first transformed the circumference values into diameter. The values obtained were then used for basal area calculation using following formula:

$$S = \sum \frac{\pi D^2}{4}$$

3 RESULTS

3.1 FLORISTIC RICHNESS AND COMPOSITION

In this study, 107 woody plants species were identified. There were distributed in 80 genera and 30 families. *Pericopsis* (9.42%), *Piliostigma* (8.81%), *Daniellia* (8%), *Detarium* (6.11%), *Terminalia* (5.58%), *Anogeissus* (5.08%), *Cassia* (4%), *Combretum* (4%), *Ficus* (4%), *Lannea* (3%) and *Terminalia* (3%) are the genera that colonize better in terms of individuals (Fig. 1). The most abundant families in Korhogo department are *Fabaceae* with 26 species, *Rubiaceae* (9 species), *Combretaceae* (8 species), *Euphorbiaceae* (7 species) and *Apocynaceae* (7 species) (Fig. 2).

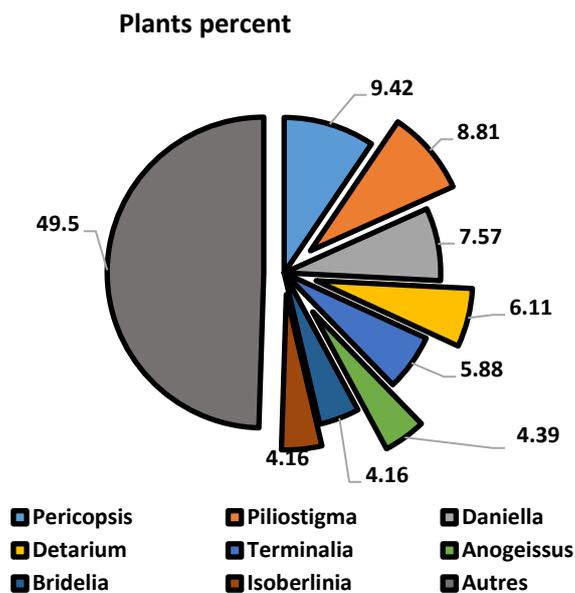


Fig. 1. Spectrum of most representative genera of study area

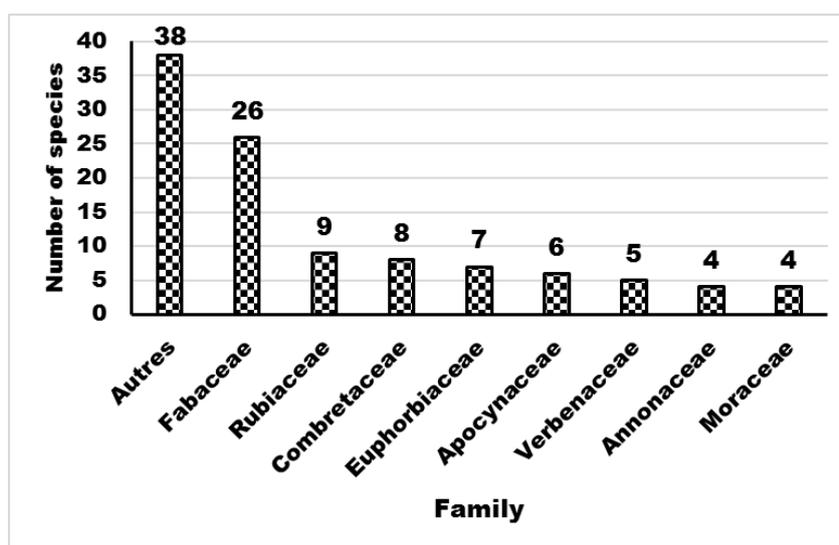


Fig. 2. Spectrum of most representative families of study area

Botanical inventory identified 4 biological types. These are microphanerophytes (mp) with 75% of species, nanophanerophytes (np) with 13%, mesocrophanerophytes (mP) with 10% and megaphanerophytes (MP) with 2% species inventoried (Fig. 3).

For entire study area, 4 types of chorological affinities were identified, Soudano-Zambezi (SZ) species were the most numerous with 49% (Fig. 4). They are followed by species of Guinean-Congolese Soudano-Zambezi (GC-SZ) zone with 41%. Species in West African Forest Block (WCG) are poorly represented with 1% of species.

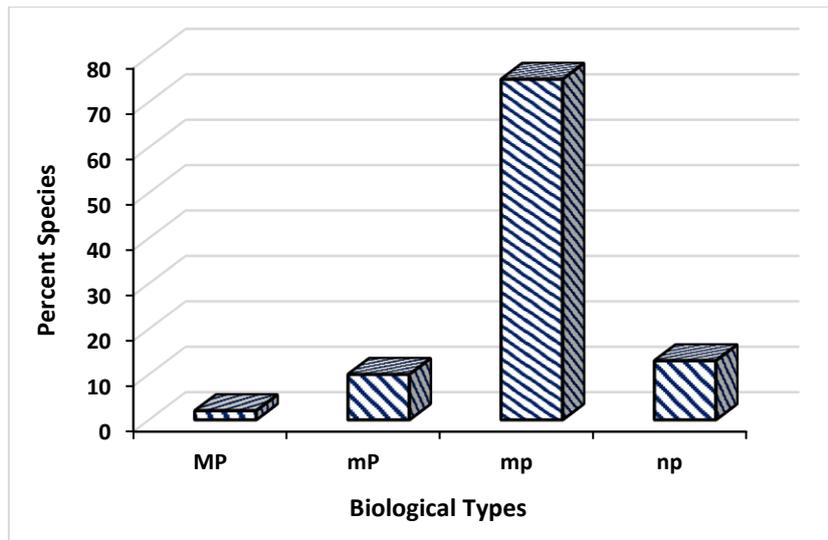


Fig. 3. Biological types Spectrum of study area

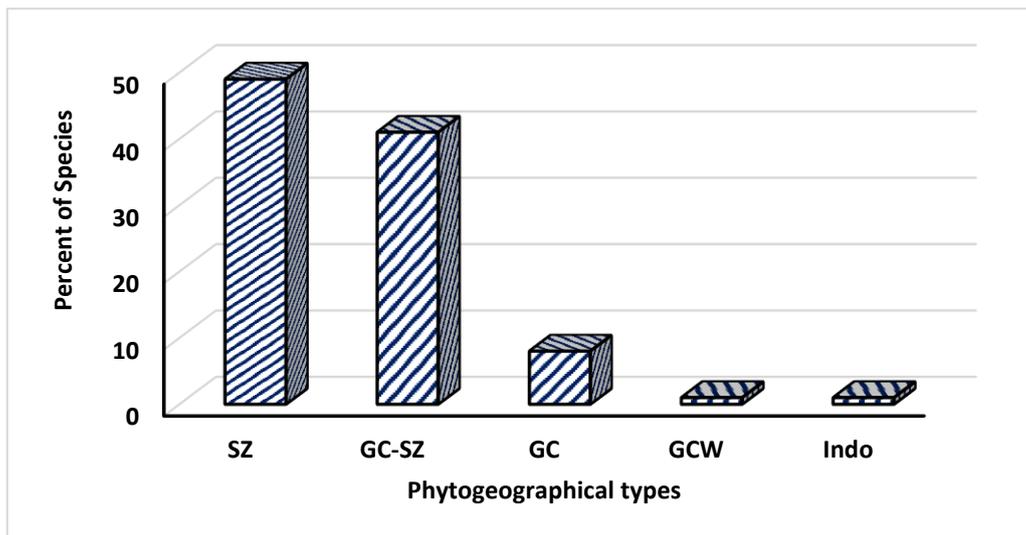


Fig. 4. Chorological types Spectrum of study area

3.2 SPECIAL STATUS SPECIES

A total of nine (09) species of special status were identified in village forest relics (Table I). One species is endemic to West African Forest Block (GWC). This is *Diospyros mespiliformis*. One species, *Syzygium guineense* var. *macrocarpum*, is considered threatened with extinction according to a list of [14]. The study identified seven (07) rare and threatened species according to [15]. These are two (02) species of minor concern (*Detarium microcarpum* and *Isobertinia doka*), four (04) vulnerable species (*Azizelia africana*, *Detarium senegalense*, *Khaya senegalensis* and *Vitellaria paradoxa*) and one (01) endangered species (*Pterocarpus erinaceus*).

Table 1. List of species with special status in forest relics

N°	Species	GCW	GCI	Aké Assi List	UICN Red List
1	<i>Azelia africana</i> .	-	-	-	Vulnerable
2	<i>Detarium microcarpum</i>				LC
3	<i>Detarium senegalense</i>				Vulnerable
4	<i>Diospyros mespiliformis</i>	+	-	-	-
5	<i>Isobertinia doka</i>				LC
6	<i>Khaya senegalensis</i>	-	-	-	Vulnerable
7	<i>Pterocarpus erinaceus</i>	-	-	-	EN
8	<i>Syzygium guineense</i>			+	
9	<i>Vitellaria paradoxa</i>	-	-		Vulnerable
	Total	1		1	7

LC: Minor Concern Species; EN: Endangered Species; Vu: Vulnerables Species. GCI: Endemics Species of Côte d'Ivoire; GCW: Endemics Species of West Africa

3.3 QUANTITATIVE DIVERSITY OF STUDY AREA

3.3.1 ABUNDANCE OF SPECIES AND FAMILIES

For entire area surveyed, eight (8) woody species have an Importance Value Index (IVI) superior than 10. *Daniellia oliveri* (IVI = 26.90) is a most abundant species. It is followed by *Piliostigma thonningii* (IVI = 19.24), *Pericopsis laxiflora* (IVI = 18.33), *Vitellaria paradoxa* (IVI = 18.87), *Anogeissus leiocarpus* (IVI = 16.69), *Terminalia glaucescens* (IVI = 13.26), *Detarium microcarpum* (IVI = 12.48) and *Parkia biglobosa* (IVI = 10.32) (Table II).

For Family Importance Value (FIV), families considered abundant are those with FIV superior than 10. These are Fabaceae (FIV = 97.48), Combretaceae (FIV = 26.53), Rubiaceae (FIV = 21.83), Euphorbiaceae (FIV = 19.87), Apocynaceae (FIV = 11.58), Verbenaceae (FIV = 10.51), Annonaceae (FIV = 10.42) and Moraceae (FIV = 10.07) (Table III).

Table 2. Importance Value Indices Species

Species	DeR	DoR	FreR	IVI
<i>Daniellia oliveri</i>	7,57	14,76	4,55	26,90
<i>Piliostigma thonningii</i>	8,81	5,15	5,28	19,24
<i>Pericopsis laxiflora</i>	9,41	5,99	2,93	18,33
<i>Anogeissus leiocarpus</i>	5,08	8,27	3,33	16,69
<i>Vitellaria paradoxa</i>	4,07	7,73	4,06	15,87
<i>Terminalia glaucescens</i>	4,21	4,82	4,23	13,26
<i>Detarium senegalense</i>	5,97	3,58	2,93	12,48
<i>Parkia biglobosa</i>	1,83	5,12	3,17	10,12

IVI = Importance Valeur Index of species; DeR = Relative Density of species; DoR = Relative Dominance of species; FreR = Relative Frequency of species.

Table 3. Family Importance Value

Family	DomR	DenR	DivR	FIV
Fabaceae	24,30	48,89	24,30	97,48
Combretaceae	7,48	11,57	7,48	26,53
Rubiaceae	8,41	5,06	8,41	21,89
Euphorbiaceae	6,54	6,79	6,54	19,87
Apocynaceae	5,61	0,37	5,61	11,58
Verbenaceae	4,67	1,17	4,67	10,51
Annonaceae	3,74	2,94	3,74	10,42
Moraceae	3,74	2,59	3,74	10,07

FIV = Family Importance Value; DenR = Relative Density of family; DomF = Relative Dominance of family; DirR = Relative Diversity of family.

3.3.2 DIVERSITY INDEX AND STRUCTURAL DISTRIBUTION

The diversity and equity index obtained were respectively 3.56 and 0.76. The number of individuals on all plots is 5,746 woody plants species for 6.5 ha or 884 stems/ha. The burial area is estimated at 8332.24 m², for all plots surveyed, i.e. 12.82 m²/ha. The mean diameter of woody plants is estimated at 12.41 cm.

Table 4. Values of dendrometric parameters of forest relics

Structural Parameters	Values
Density (N/ha)	884 ± 12
Mean Diameter (cm)	12,41 ± 0.82
Burial surface (m ² /ha)	12,82 ± 0.96
Shannon Index	3,56
Equity index	0,76

Plants species with a diameter up to 60 cm include *Pseudocedrela kotschyi*, *Vitex doniana*, *Parinari curratellifolia*, *Daniellia oliveri*, *Azalia africana*, *Parkia biglobosa*, *Vitellaria paradoxa* and *Pterocarpus erinaceus*.

The distribution by diameter class are indicated that diameter between 5 and 10 cm is most abundant (502 stems). It has a decreasing inverted "J" distribution, reflecting a predominance of small diameter individuals. This distribution adjusts better with an exponential function whose equation is $Y = 1346.2e^{-1.017x}$ ($R^2 = 0.96$). In addition, the distribution of basal area by diameter class shows that large diameter individuals between 10 and 15 cm, such as *Piliostigma thonningii*, *Terminalia glaucescens*, *Parkia biglobosa*, *Entada abyssinica*, *Anogeissus leiocarpus*, *Isobertia doka*, etc., account for most the total basal area (Fig. 5).

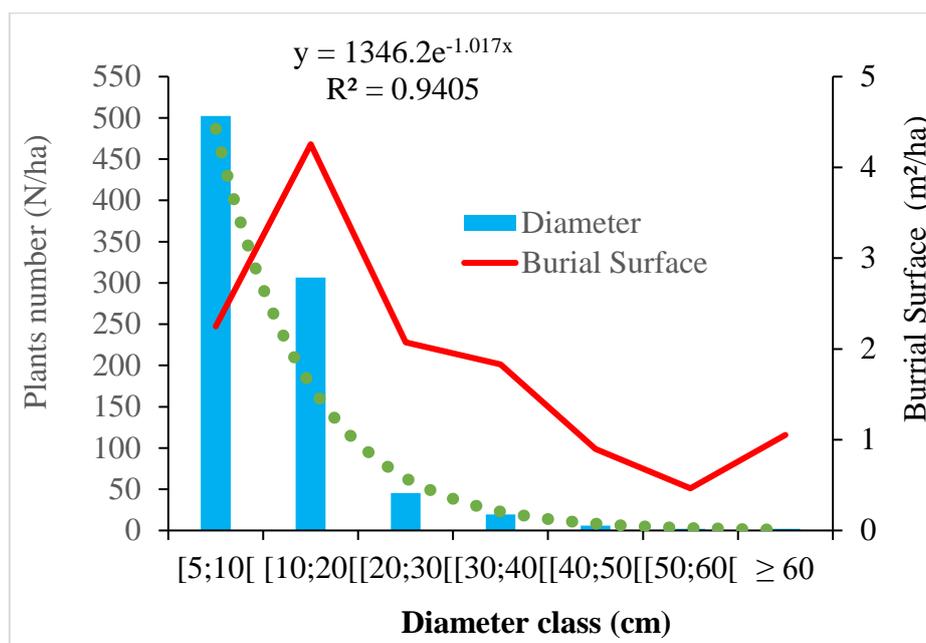


Fig. 5. Distribution des ligneux et de leur surface terrière par classes de diamètre

4 DISCUSSION

The floristic analysis of forest relics of Korhogo department shows that they contain a significant woody potential by considering a diversity of surveyed woody plants species (107 stems). These species are indicative of relative high plant diversity. Indeed, this result is superior than those of [17], [18] in relics of dry dense forests of Benin. The abundance of Fabaceae lato sensu and Combretaceae observed by several authors [19], [20], [21] reveal a characteristic of Sudanian zone. According to these authors, these two families are indicative of a generally dry climate resulting from low rainfall and very high temperatures in this ecological zone. However, the emergence of Rubiaceae is due to humid nature of forest relics [20]). The spectrum of biological types shows a dominance of microphanerophytes. This confirms the most physiological widespread of Sudanese woody vegetation, which is characterized by a preponderance of shrub formations in forest relics [22], [23], [24]. The results obtained for phytogeographical spectrum indicate that flora in the study area is dominated by endemic species of Guinean-Congolese and Soudano-Zambian transition area (GC-SZ) and Sudano-Zambian species (SZ). [24] achieved similar results in classified forest of Badenou. Similar result was obtained in a private forest in Dianra department northern Côte d'Ivoire [25]. Nine (09) plants species of special status was inventoried in forest relics. Most of these are vulnerable species according to IUCN red list (2019). This gives particular interest for conservation of these forests located above the 8th parallel. Indeed, efforts to conserve endemic, rare and endangered species must be a priority [26].

Eight (08) woody plants species have an Importance Value Index (IVI) superior than to 10 and are ecologically important. [27] obtained a number of 14 ecologically predominant species in a study in northern Côte d'Ivoire. On this list, two species are in list of predominant species. These are *Piliostigma thonningii* and *Anogeissus leiocarpus*. In the north-east of Côte d'Ivoire, nine species have been identified by [28], among them two species, *Vitellaria paradoxa* and *Parkia biglobosa* are listed. These differences could be explained by climatic and soil conditions that may be more or less favorable to proliferation of plants. Regarding FIV, eight (8) families are ecologically important in the region. The predominance of Fabaceae than other families may be related to a fact that this family is grouping of three subfamilies (Caesalpinioideae, Mimosoideae and Faboideae), according to the classification of APG IV. Many individuals of Euphorbiaceae, are turned to Phyllanthaceae family. Thus, [27] in a study in savannah area reported that Caesalpinaceae, Sapotaceae, Euphorbiaceae, Mimosaceae and Chrysobalanaceae are predominant families, according to cronquist classification.

Two indices of diversity from plots. Shannon Index and Pielou Equitability Index were calculated in different plant formations surveyed. The Shannon index is 3.56 for the study area. This high value of this index shows that plant formations studied benefit to favorable ecological and stability conditions for maintaining several groups of woody plants species [23]. The equitability index tends to 1 in all forest relics (0.76). This value indicates that species are distributed in a regular basis and there is no dominance of a species within biotopes.

The density of woody plants species in relics forest is estimated at 884 stems/ha. This value is less than those of [24] 1891 stems/ha, and [23], 1503 stems/ha, in their studies but significantly superior than those reported by [29] in clear forest (335 stems/ha) and wooded savannah (380 stems/ha), in Wari-Marou-Igbomakro region in central Benin. These differences in results could be explained by different study methods or by a level of conservation of ecosystems studied. The basal area calculated is 12.82 m²/ha. This high value could be explained by good development of trees because of ecological conditions. Forest relics create a humid microclimate, which is an important factor for good development of trees.

The distribution in diameter classes indicates a gradual decrease in a number of plants from small diameters to large diameters. The resulting distribution is a "J-shaped inverted". This diametric structure shows a significant reduction in shoot density with increased diameter. Similar results were obtained by [22] in Lokoli Eco-Farm in Sinématiali department and [24] in classified forest of Badebou, in M'bengué department. According to [29] any undisturbed forest stand shows an exponential trend in diameter distribution, regardless of forest type and area.

5 CONCLUSION

The study showed that the forest relics of Korhogo department have a fairly diverse woody flora in terms of number of species, genera and families. The richness of the flora of these relics is also characterized by the presence of nine (09) woody plants species with special status according to IUCN Red List, and tlist of rare and threatened species of Aké-Assi (*Diospyros mespiliformis*, *Syzygium guineense*, *Detarium microcarpum*, *Isoberlinia doka*, *Azalia africana*, *Detarium senegalense*, *Khaya senegalensis*, *Vitellaria paradoxa*, *Pterocarpus erinaceus*). This gives particular interest for conservation and/or management of sustainable forest relics. The environment of these plants formations has a high woody density, medium basal area and a predominance of young plants. The ecological and structural characteristics of forest relics are very edifying and deserve special attention from riparian populations and authorities in charge of protection this biodiversity.

ACKNOWLEDGMENTS

The authors sincerely thank the "Programme Stratégique d'Appui à la Recherche Scientifique (PASRES) " for financial support and the "Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS) " for technical assistance.

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