

Floristic diversity of a Voluntary Natural Reserve (VNR) of Sucrivoire on the right bank of the Bandama river in Zuenoula, in the West Centre of Côte d'Ivoire.

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Abstract— Several surveys and inventories were conducted with surface survey method using plots, measuring 200 m² and supplemented with mobile method in Sucrivoire Voluntary Natural Reserve on the right bank of the Bandama river. The analysis of the data collected focused on diversity and floristic richness and used phytoecological methods such as the ACP. The obtained results concern 200 identified botanical species among which 81 % of dicotyledone and 19 % of monocotyledone belonging to 152 genera and 56 families. The ecological factor most pronouncement being the toposequence, the determination of the diversity indices of various strata showed that for each of it the flora is very diversified and homogeneous in general such as indicated by the coefficient of similarity of Sørensen which remains upper to 50 %. However, this flora is dominated by the families of Euphorbiaceae, Poaceae, Rubiaceae, Mimosaceae, Asteraceae, Caesalpiniaceae and Sterculiaceae which characterize his phytogeographique position. In this floral diversity, the ACP revealed a single group of floral procession, which mean that the three strata constitute a single forest block dominated by Phanerophytes in 66,33 % and containing 12 species with particular status and 17 species considered as commercial forest essences. All these characteristics confirm the good state of preservation of the flora of the right bank of the Bandama river set up as a Voluntary Natural Reserve by Sucrivoire. This sugar canne structure so makes the flora of this site one of the reservoir of biodiversity of the future green frame of Côte d'Ivoire.

Keywords— floral Diversity, Voluntary Natural Reserve, Bandama river, Sucrivoire, Côte d'Ivoire.

I. INTRODUCTION

The loss of drilled surfaces in Côte d'Ivoire has been estimated at 12 million hectares since 1960 until the present day (Sodefor, 1994). Currently, the Ivorian forest cover represents less than 20% of its original extent (Koulibaly *et al*, 2010). To safeguard the scarcity of forest that still exists and to counter the environmental threat posed by deforestation, in 2002, the State established a forest policy with new conservation approaches, including incentives for the creation of Voluntary Natural Reserves (VNR). It is into this policy that Sucrivoire sugar canne structure aims to protect the forest relics of its domain. The riparian forest along the right bank of the Bandama river is considered as the most important.

In fact, wherever it is practised elsewhere, there are many benefits in terms of multifunctionality in rural development, such as the creation of income and the provision of services to other agricultural products. Thus, in the regions where sugar industries are established, many populations are flooded, at the same time

constituting a significant human pressure on the flora, including that bordering the Bandama river, on which the irrigation of sugar cane plantations is heavily dependent. This forest plays an important role in protecting nests and the cleanup of waterways, and human pressure directly threatens its local biodiversity.

In order to assess the impact of this healthy Sucrivoire decision and then to update the knowledge on the plant biodiversity of these foresters, a floristic inventory was carried out on the right bank of the Bandama river in the Sucrivoire domain in Zuenoula, central-western of Côte d'Ivoire.

This study proposes to characterize this vegetation along the Bandama river.

II. RESEARCH PROCEDURE

The site of study

The sugar canne domain of Sucrivoire at Zuenoula is situated in the west central region of Ivory Coast, in Marahoué, between 7°25 ' 45 " of latitude North

and 6°02' 35" of longitude West as Fig. 1 shows it. The relief is little accidented and presents an average height of 250 meters. Zuenoula is situated in the sector mesophile of the Guinean domain (N'Da *et al.*, 2008) and represent a zone of climatic transition enter half the South more watered (1200 to 1800 mm rains/year) and the drier North (1100 to 1600 mm rains/year). The annual average

temperatures vary between 25 and 28°C. The major part of arable land is established on ferrallitical grounds reshaped and weakly desaturated with a mosaic of forest and savanna (N'Da *et al.*, 2008). The current population of the complex sugar bowl of Zuenoula is 15000 people against 2600 people in 1991 (N'Guessan, 2011) and more than 11000 people live around this complex (Sifca, 2011).

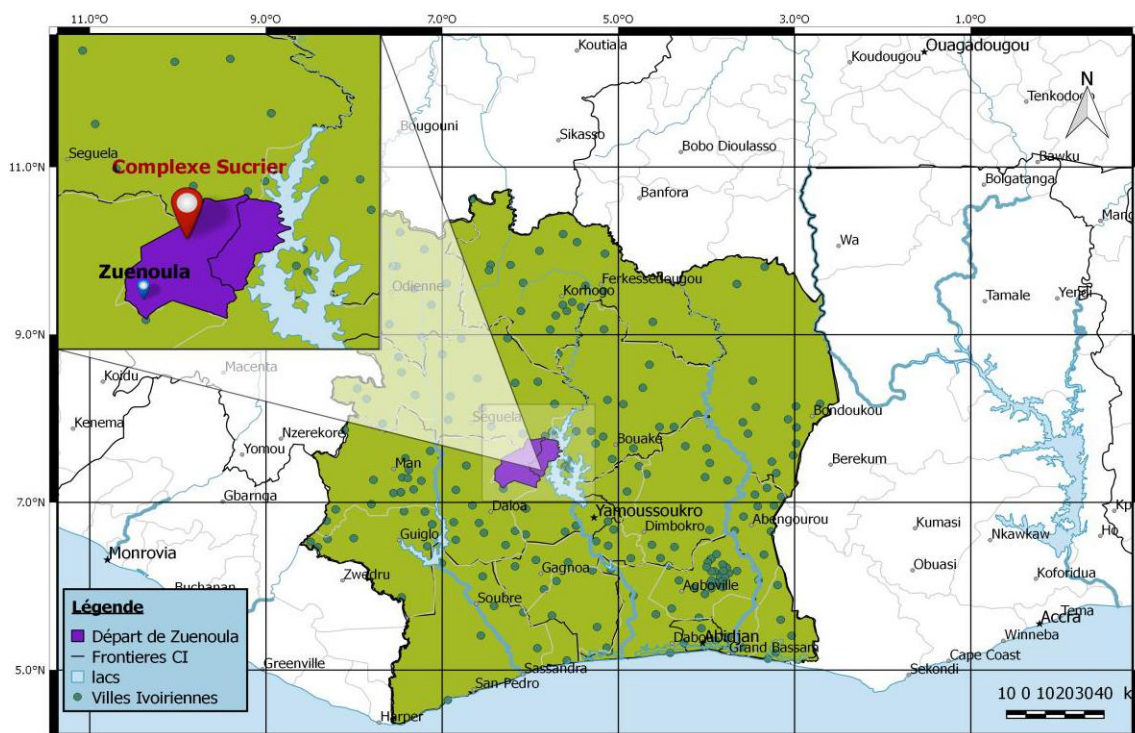


Fig. 1 : geographic localisation of Zuenoula

Material

All the botanical species met in this forest constitutes our biological material. The harvest required a technical material constituted by a machete, a ribbon-meter, some pickets, a camera, a rope and a florae stemming from the National Center of Floral (CNF) as well as a map of land use in 1/25000 edited by the SEMAT in 2013-2014.

Methods

The VNR which lines the right bank of the Bandama river extends over 6825 meters in length for 200 meters in width and presents a toposequence which is the most important ecological factor from north to south. For the floral statements, about three strata two thousand meters in lengths each were distinguished according to the toposequence : the north stratum which is a tray, the central stratum which is a slope and the south stratum which is a low tray. Five small places measuring 20 x 20 m distant some of the others of 30 meters in the width and 100 meters in the length were delimited in every stratum. In each of the small places, the systematic statement of

the species was made by mentioning only once the presence of the species. The visit of small places was repeated four times over two consecutive years in dry season and in rainy season.

Outside small places, random itinerant statements were realized with collection of samples of species.

The collected samples were placed in herbarium for the identifications. For every sample, photos were realized to contribute to the determination of the species. The identification of the species was made thanks to the existing florae: Lebrun and Stork (1991; 1997), Kouamé (1998b) and Ake-assi (2001; 2002).

Data analysis

After identification of samples, every species was tidied up in his family and its genrera taxonomique. The absolved frequency (Fa) and the relative frequency (Fr) of every species were considered. The frequency absolved from every species is equal to the total number of its presences in the whole of the statements made in three strata. The relative frequency of a given botanical species defines itself as the centesimal report of its

absolute frequency and the total number of statements (Nr) made on a given site (Godron, 1971) as indicates it the following formula :

$$Fr = (Fa \times 100) / Nr$$

The floral diversity and somme diversity indices were considered to characterize the flora :

- the diversity indices of generic and specific (report genera/families and species/genra) which give an idea of the degree of floral diversity as well for all the studied zone as for the strata;
- Sørensen (1948) similarity coefficient (Cs) which formula is:

$$Cs = \frac{2c}{(a + b)} * 100$$

In this formula, (a) represent the number of species of the plot of land A, (b) represent the number of species of the plot of land B which we compare with the list A and (c) is the number of species common to the plots of land A and B. Cs varies between 0 and 100 % and if Cs is upper or equal to 50 %, then both compared plots of land are very close and can be considered as floristically homogeneous (Aman *et al.*, 2004). The data analysis also concerned the

degree of preservation of the zone of study and its face through :

- the biological spectre defined by the percentage of the species belonging to the same biological type according to the classification of Raunkiaer (1905) taken back by Aké Assi (1984) and Kouamé (1998b). For every species, the considered biological type is the one observed at the time of the execution of the statements on the ground;
- the presence of species with particular status and wooden exploitable essences of work;
- the ecological profile through the analysis in main component (ACP) according to Romane (1972) with the software STATISTICA 7.1.

III. RESULTS

Floral diversity

Floral inventories in all three strata allowed us to identify 200 plant species across 152 genera and 56 botanical families. Table 1 shows details of the distribution of species within genera and families at the stratum level. Enrolment at the different taxonomic levels varies across strata but in a non-significant proportion at $p = 0.05\%$. This flora contains 161 species, 81% of which belong to the dicotylédones class and 37 species housed in monocotylédones or 19% as it's showed by Fig. 2.

Table 1: Species, genera and families partitioned by class

	stratum 1			Stratum 2			stratum 3		
	Es	Ge	Fa	Es	Ge	Fa	Es	Ge	Fa
Mono.	30	11	7	15	7	4	11	5	3
Dico.	148	141	43	128	103	23	154	109	43
Total	178	152	50	143	110	27	165	114	49

Mono. : Monocotyledones; Dico. : Dicotyledones; Es: species; ge: Genera; Fa: families

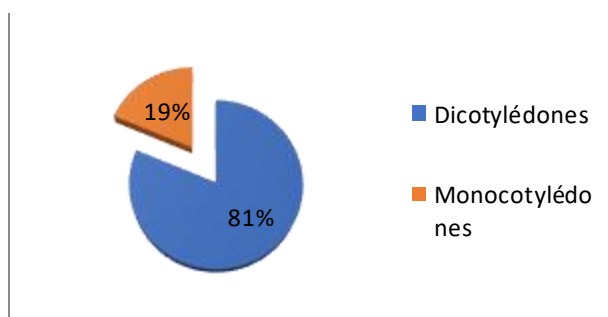


Fig. 2: Percentage of species following broad taxonomic levels of the study area

The data which are listed in the table 1 have been used to determine the different diversity indices. Thus, for general flora, the values of the generic (2,71) and specific (1,32) diversity indices of the right bank of the Bandama river

are low. However, with respect to the diversity indices for each stratum presented in Fig. 3, the south stratum has the smallest generic diversity index with a value of 2,33. This is the most diverse stratum and is followed by stratum 1

with 3,04 as value and finally by the stratum 2 with a value of 4,07. In terms of specific diversity, the tray (stratum 1) has the greatest specific diversity (1,17) followed by the stratum 2 with a value of 1,3 and then the

stratum 3 (1,45). Sørensen similarity coefficient calculated for the three strata is presented in Table 2. The values are greater than 50% and reflect a homogeneity of flora from the tray to the bottom of the slope.

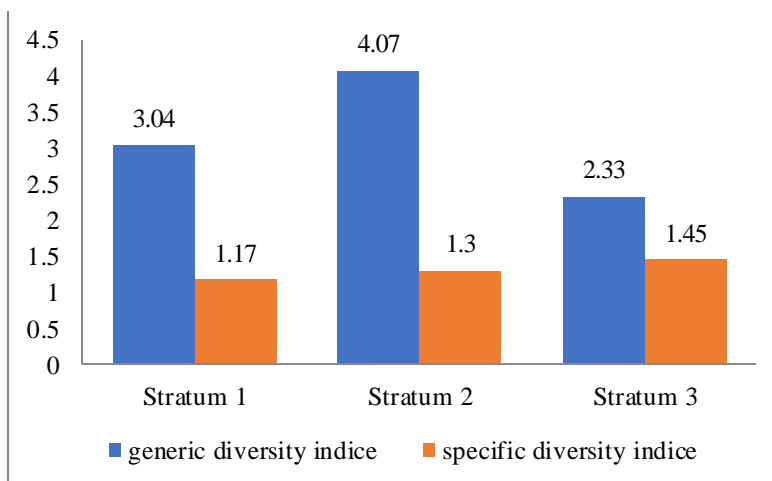


Fig. 3: diversity indices of generic and Specific for all three strata

Table 2: Calculated Sørensen similarity coefficients for strata taken two to two

	Stratum 1	Stratum 2	Stratum 3
Strate 1	-	73,39	83,38
Strate 2	-	-	70,19

However, it appears in this flora, among the 56 botanical families identified, 15 families most represented in number of species. Table 3 lists these, as well as the number of species, genera and specific diversity indice for each family. Considering this indice of diversity, the Fabaceae and Euphorbiaceae, which are the families best

represented in number of species, find themselves less diverse than Poaceae, Sapindaceae, Rubiaceae and Annonaceae. Of all species surveyed at the three stratum level, 28 species are also abundant and ubiquitous, as shown in Table 4, which lists these species and their relative frequency.

Table 3: List of families best represented in number of species and their specific diversity indice within the flora of the right bank of the Bandama river at Sucrivoire domain.

N°	Families	Nbre. species	Nbre. genera	Ids
1	Fabaceae	17	13	1,31
2	Euphorbiaceae	12	9	1,33
3	Poaceae	12	12	1
4	Caesalpiniaceae	10	6	1,67
5	Rubiaceae	10	9	1,11
6	Asteraceae	9	7	1,29
7	Combretaceae	8	2	4
8	Mimosaceae	8	5	1,6
9	Moraceae	7	2	3,5
10	Sterculiaceae	7	4	1,75
11	Annonaceae	6	5	1,2
12	Sapindaceae	6	6	1
13	Dioscoreaceae	5	1	5
14	Verbenaceae	5	4	1,25
15	Vitaceae	5	1	5

Table 4: List of species best represented in number of individuals by their relative frequency in the right bank flora of the Bandama river at Sucrivoire domain.

N°	Noms des espèces	Fa	Fr
1	<i>Combretum zenkeri</i> Engl. & Diels	15	100
2	<i>Paullinia pinnata</i> L.	10	66,67
3	<i>Ficus sur</i> Forsk.	10	66,67
4	<i>Olex subscorpioidea</i> Oliv.	8	53,33
5	<i>Cissus petiolata</i> Hook.f.	7	46,67
6	<i>Lecaniodiscus cupanioides</i> Planch.	7	46,67
7	<i>Nauclea latifolia</i> Sm.	7	46,67
8	<i>Cola caricaefolia</i> (G. Don) K. Schum.	7	46,67
9	<i>Lonchocarpus sericeus</i> (Poir.) Khunt.	7	46,67
10	<i>Chromolaena odorata</i> (L.) R. M. King & H. Rob.	7	46,67
11	<i>Clerodendrum buchholzii</i> Gürke	7	46,67
12	<i>Cochlospermum planchonii</i> Hook.f.	7	46,67
13	<i>Ceiba pentandra</i> (Linn.) Gaerth.	6	40
14	<i>Parkia biglobosa</i> (Jacq.) Benth.	6	40
15	<i>Bridelia ferruginea</i> Benth.	6	40
16	<i>Diospyros mespiliformis</i> Hochst. ex A. DC.	6	40
17	<i>Pouteria alnifolia</i> (Bak.) Roberty	6	40
18	<i>Crotalaria retusa</i> Linn.	6	40
19	<i>Desmodium salicifolium</i> (Poir.) DC.	6	40
20	<i>Alchornea cordifolia</i> (Schum. & Thonn.) Müll.Arg.	5	33,33
21	<i>Cryptolepis sanguinolenta</i> (Lindl.) Schltr.	5	33,33
22	<i>Antiaris toxicaria</i> var. <i>africana</i> (Engl.) C.C. Berg	5	33,33
23	<i>Cola gigantea</i> A. Chev.	5	33,33
24	<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz	5	33,33
25	<i>Phoenix reclinata</i> Jacq.	5	33,33
26	<i>Cola laurifolia</i> Mast.	5	33,33
27	<i>Mallotus oppositifolius</i> (Geisel.) Müll. Arg.	5	33,33
28	<i>Desmodium velutinum</i> (Willd.) DC.	5	33,33

Combretum zenkeri and *Paullinia pinnata* with relative frequencies of 100% and 66.67% respectively are at the head of this floristic procession. Both of these species are invasive and occur in both agricultural, savannah and forest areas. Most of this flora belongs to the taxa of the Guinean-Congolese, Guinean-Congolese and Sudanese-Zambezi regions and finally the Sudanese-Zambian regions.

Statistical Analysis

Key Component (ACP) analysis explains the corelationship between taxonomic levels and ecological

descriptors. It focuses on the analysis of the factorial weight matrix and has extracted two components that account for the totality (100%) of the variability between ecological descriptor. The 1-2 design is characterized by 99.82% own values for the F1 axis and 0,18% own values for the F2 axis. The F1 axis represented all variables, forming a single group, while no variables contributed to the definition of the F2 axis. The results of this analysis are shown in Figure 4, which shows a single ecological procession group, indicating that the species in all three strata are virtually the same.

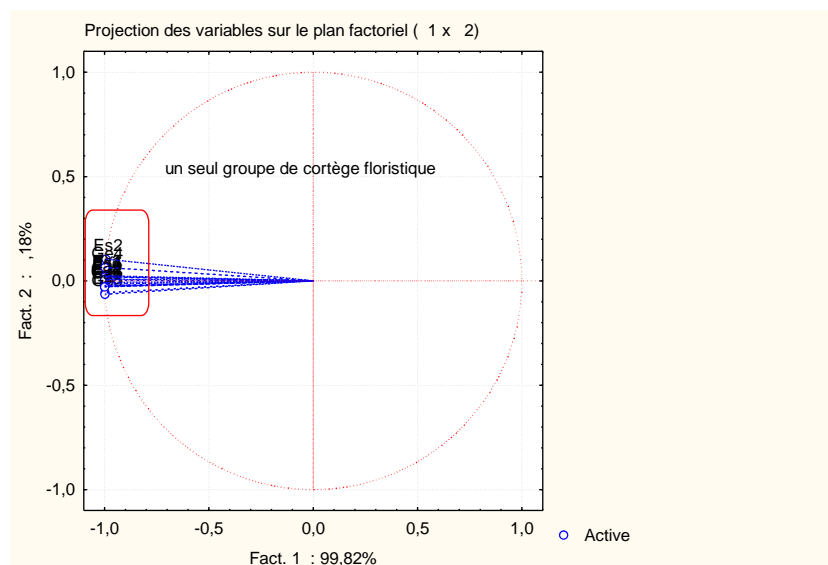


Fig. 3 : representation of the species and the ecological descriptor according to the ACP

Biological types

The identified species belong to diverse biological types and the Fig. 4 presents us the biological spectre of this plant training which gives an idea of its vertical architecture. Phanerophytes (Ph) which Ligneous plants are buds of which are situated higher than 50 cms above ground level, dominate this plant training with a 66,33 % representativeness and are followed by the climbing species or the lianas which represent 19,1 %. Phanerophyte groups here:

- Megaphanerophytes, big trees of more than 25 m of height, which represent 17,8 % of Phanerophytes and 8 % of the total flora, having representatives for *Nauclea latifolia*, *Pouteria alnifolia*, *Ceiba pentandra* and the most frequent *Parkia biglobosa*;
 - Mesophanerophytes or small trees measuring between 10 and 25 m of height which represent 40 % of Phanerophytes and 18,1 % of the total flora. The most frequent representatives are *Olex subscorpioidea*, *Lecaniodiscus cupanioides*, *Holarrhena floribunda* and *Phoenix reclinata*;
- classified as low risk.

- Microphanerophytes, ligneous plants measuring between 2 and 10 m of height, represent 42,22 % of Phanerophytes and 19,10 % of the total flora and the most frequent are *Ficus sur*, *Cola caricaefolia*, *Lonchocarpus sericeus* and *Bridelia ferruginea*;
- Nanophanerophytes which are small ligneous plants measuring between 0.5 and 2 m of height represents 46,67 % of Phanerophytes and 2,1 % of the total flora.

Species having special Status

There are twelve species showed in the table 5 which have special status representing 4,16% of all species with one species endemic to Côte d'Ivoire (*Baphia bancoensis*), eight species endemic to the West African Forest Block (*Eriosema molle*, *Dalbergia oblongifolia*, *Hymenocardia acida*, *Premna hispida*, *Dialium guineense*, *Aframomum sceptrum*, *Dioscorea sibarensis*) and three listed on IUCN red-listed species (2012) : *Ricinodendron heudelotii*, *Terminalia ivorensis* and *Triplochiton scleroxylon*

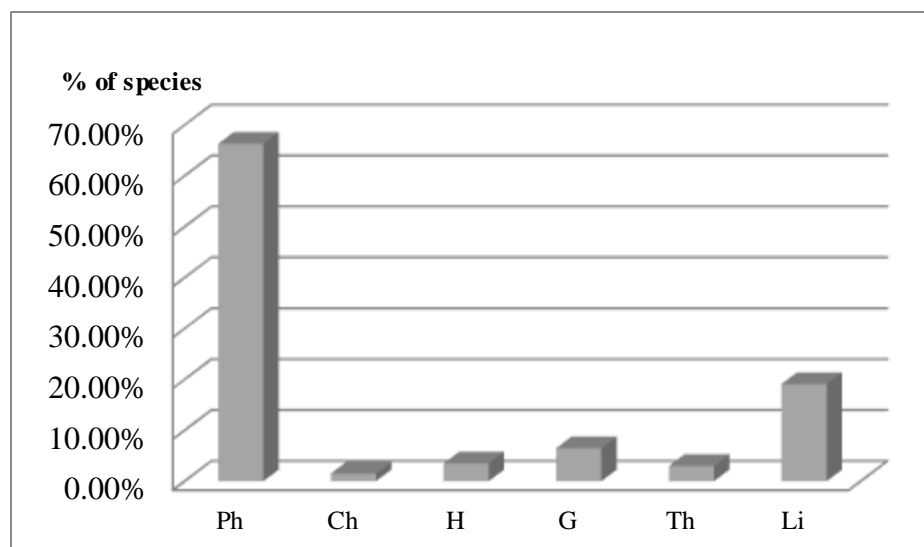


Fig. 4: the biological spectre of the flora of the right bank of the Bandama river at Sucrivoire domain

Ph: Phanerophytes; **Ch:** Fiepytes (woody or herbaceous perennial plants, rooted, whose regenerating buds are located near the soil, below 50 cm); **H:** Hemicryptophytes (rooted plants whose bud is on the surface of the soil, and whose aerial portion dies during the adverse season); **G:** Geophytes (plants whose buds are well buried in the soil. bulb and rhizome geophytes); **Th:** The Thérophytes (plants that survive with seeds).

In addition, 17 species were identified as commercial forest species in this study. These forest species were subdivided into three categories based on the market

criteria used by Kouamé (1998a) in Côte d'Ivoire. Table 6 lists these species and their position on the marketing scale.

Table 5: List of species of special status identified.

N°	Espèces	Familles	Chorologie and Status
1	<i>Aframomum sceptrum</i> K Schum.	Zingiberaceae	GCW
2	<i>Baphia bancoensis</i> Aubrév.	Fabaceae	GCI
3	<i>Cola caricaefolia</i> (G. Don) K. Schum.	Sterculiaceae	GCW
4	<i>Dalbergia oblongifolia</i> G. Don	Fabaceae	GCW
5	<i>Dialium guineense</i> Willd.	Caesalpiniaceae	GCW
6	<i>Dioscorea sansibarensis</i> Pax	Dioscoreaceae	GCW
7	<i>Eriosema molle</i> Hutch. ex Mi Ine	Fabaceae	GCW
8	<i>Hymenocardia acida</i> Tul.	Euphorbiaceae	GCW
9	<i>Premna hispida</i> Benth.	Verbenaceae	GCW
10	<i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Pax	Euphorbiaceae	LR
11	<i>Terminalia ivorensis</i> A. Chev.	Combretaceae	VU
12	<i>Triplochiton scleroxylon</i> K. Schum.	Sterculiaceae	LR

GCI: Species endemic to Ivorian flora; GCW: Species endemic to the West African Forest Bloc; LR: Low risk species; VU = Vulnerable species.

Table 6: Commercial species found in the flora of the right bank of the Bandama river at the Sucrivoire domain level.

N°	Espèces	Familles	catégorie
1	<i>Antiaris toxicaria</i> var. <i>welwitschii</i> (Engl.)	Moraceae	1
2	<i>Ceiba pentandra</i> (Linn.) Gaerth.	Bombacaceae	1
3	<i>Erythrophleum suaveolens</i>	Caesalpiniaceae	1
4	<i>Mansonia altissima</i> (A. Chev.) A. Chev var	Sterculiaceae	1
5	<i>Pouteria alnifolia</i> (Bak.) Roberty	Sapotaceae	1
6	<i>Terminalia belerica</i> Roxb.	Combretaceae	1
7	<i>Terminalia ivorensis</i> A. Chev.	Combretaceae	1
8	<i>Terminalia mentaly</i> H. Perrier	Combretaceae	1
9	<i>Terminalia scimperiana</i> Hochst.	Combretaceae	1
10	<i>Triplochiton scleroxylon</i> K. Schum.	Sterculiaceae	1
11	<i>Sterculia setigera</i> Del.	Sterculiaceae	2
12	<i>Sterculia tragacantha</i> Lindl.	Sterculiaceae	2
13	<i>Lannea acida</i> A. Rich.	Anacardiaceae	3
14	<i>Lannea nigritana</i> (Sc. Elliot) Keay var.	Anacardiaceae	3
15	<i>Parkia biglobosa</i> (Jacq.) Benth.	Mimosaceae	3
16	<i>Albizia adianthifolia</i> (Schumach.) W.F.	Mimosaceae	2
17	<i>Albizia ferruginea</i> (Guill. & Perr.) Benth.	Mimosaceae	2

IV. DISCUSSION

Floral diversity

Floristic inventories carried out in the Sucrivoire Voluntary Natural Reserve on the right bank of the Bandama River in Zuénoula have identified 200 plants species belonging to 152 genera and 56 families. In 2012, Kouassi *et al* counted 471 species from 96 botanical families identified in Zuenoula area in 2012. This is indicative of the emergence of new frontier species in this area, thanks to the protected domain character of this forest block. This vegetative formation lonely contains 42,46% of the species of the domain and 60% of the families present and are more diversified at the tray and the bottom of the slope. But as a whole it is a well diversified homogeneous block as reflected in the diversity indices, the Sørensen coefficient of similarity and the ACP results.

Also, Kouassi *et al.* (2012) noted on the site as a whole 13 important families in numbers of species headed by Fabaceae, Rubiaceae, Poaceae and Euphorbiaceae that we find among the 15 most represented families, the most diverse of which are the Sapindaceae, Poaceae, Rubiaceae and Annonaceae. The flowering procession of this plant formation dominated by the families of Euphorbiaceae, Poaceae, Rubiaceae, Mimosaceae, Asteraceae, Caesalpiniaceae and Sterculiaceae is the characteristic of the phytogeographic position of this area, which Guillaumet and Adjanohoun called in 1971 a transition zone between the forest and the savannah belonging to the Guineo-Congolese (GC) and Sudanese-Zambia (SZ) complex.

The natural form of this vegetable formation is dominated by Phanerophytes of which some are ubiquitous: *figus sur*, *Olex subscorpioidea*, *Lecaniodiscus cupanioides*, *Nauclea latifolia*, *Cola caricaefolia*, *Lonchocarpus sericeus*, *Ceiba pentandra*, *Parkia biglobosa*, *Bridelia ferruginea*, *Diospyros mespiliformis*, *Pouteria alnifolia*, *Antiaris toxicaria* var. *africana*, *Holarrhena floribunda*, *Phoenix reclinata*, *Cola laurifolia*, *Cola gigantea* and *Mallotus oppositifolius* and two lianas *Paullinia pinnata* and *Alchornea cordifolia*. Kouassi *et al.*, (2012) inventoried in the region 7 Phanerophytes ubiquitous against 16 today in this vegetable formation. This observation testifies of the good state of preservation of this forest because of the privilege it enjoys from Sucrivoire. Indeed, the classification of this vegetable formation in Voluntary Natural Reserve allows him to benefit from a protection against the human pressure and people activities which remain fatal for the vegetable and animal biodiversity of the site. Also, the important presence of lianas megaphanerophytes and mesophanerophytes testifies of the legitimacy of this protection which favors their stability.

The presence of 12 species with special status and 17 species considered as commercial forest species demonstrates the importance and quality of this flora that deserves preservation. These species have the potential to regenerate frontier biodiversity species (Aubréville, 1936). The flora studied is full of low-risk and vulnerable species (IUCN, 2012), endemic to Ivorian flora and the West African Forest as well as the classified upper

Sassandra Forest where Kouassi *et al.* (2015) counted 37 species with special status and 37 species considered as commercial forest species. The forest species presented here could be used for local reforestation or local forest management replace to exotic species such as *Tectona grandis* L. (Verbenaceae) which sometimes have difficulty adapting to the local environment and climate. This could skew the success rate of a local forest management policy.

Making this forest block and many other sites voluntary natural reserves that are private areas of particular scientific, ecological and tourist interest, Sucrivoire thus contributes to the conservation of biodiversity and shows its regional pattern for biodiversity in consultation with local actors such as SODEFOR and the Ministry of Agriculture. Voluntary natural reserves are now both a vector of regional strategies for biodiversity and a tool for the valorisation of the territories. Thus, the voluntary natural reserve on the right bank of the Bandama river is a key part of the regional schemes for the protection of nature and starts from the "biodiversity reservoirs" of the Ivorian green frame.

V. CONCLUSION

The Floristic Inventory work carried out in the Sucrivoire Voluntary Natural Reserve on the right bank of the Bandama river has identified 200 plants species belonging to 152 Genra that have left between 56 Families. The indices of specific diversity of the three strata, defined according to the toposequence of the study area, have shown that they are very diverse but constitute a single and very homogeneous forest block as shown by the results of the Sørensen coefficient of similarity and those of the statistical analysis which focused on the ACP. However, this flora is dominated by 15 families best represented in numbers of species and 28 most abundant and ubiquitous species.

The vertical structure of this flora is marked by the presence of a large population of species placed among the Phanerophytes (66,33%) at the time of the inventories as well as climbing or liana species that make up 19,1% of the Totole flora. One of the particularity of this flora which justifies its protection the presence of 12 species with special status with an endemic species in Côte d'Ivoire, eight species endemic to the West African forest block and three species listed on the IUCN red list. In this study, 17 species were identified as commercial forest species, thus forming a genetic database for the regeneration of these species.

This work has updated and improved knowledge of ripicole flora and demonstrates that this area is of

paramount ecological importance given both the large number of plant species it contains and the presence of species with special status and commercial forest species. It is essential that Sucrivoire accentuate the protection of this ripicole forest as well as other forest relics in its domain with the help of state structures, since it is a crucial area in the conservation of flora in Côte d'Ivoire and in the sub-region West Africa.

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