



Conservation of Voluntary Nature Reserves: Physical Characterization of Flora of the Biodiversity Zones of the Zuénoula Sugar Complex (Central West, Côte d'Ivoire)

Voui Bi Bianuvrin Noël Boué ^{a*}, Kouassi Kouadio Claude ^a, Koulibaly Annick ^a,
Kouadio Ange Sonia Colombe Fodio ^a and Kpan Kedin Quentin ^b

^a *Laboratoire d'Amélioration de la Production Agricole, Unité de Formation et de Recherche (UFR) en
Agroforesterie, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire.*

^b *Service Diversification de l'unité Agricole du Complexe Sucrier, BP 291 Zuénoula, Côte d'Ivoire.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Conservation of voluntary nature reserves: physical characterization of flora of the biodiversity zones of the Zuénoula sugar complex (Central West, Côte d'Ivoire).

Objective: To protect and conserve biodiversity zones of the Zuénoula sugar complex for abundant and sustainable sugar production in Côte d'Ivoire.

Methods: A study of the perimeter boundaries and floristic structure of conservation areas was conducted in vegetation formations consisting of gallery forests, riparian forests and forest islands. The perimeter boundaries were determined by mapping the ecological sites with a GPS. The floristic list was established from surface and itinerant survey methods.

Results: The three ecological sites were delimited and mapped on an area of 139.55 ha. The flora, mostly from the Guinean-Congolese region, was rich in 106 species and dominated by Mesophanerophytes. It belonged mainly to the Caesalpiniaceae, Moraceae and Sterculiaceae families. The gallery forests FG3 and FG5 were the most stable. In addition, all environments were diverse and indicated a uniform distribution of species. Six vulnerable species including

*Corresponding author: E-mail: noelboue@gmail.com

Azeliaafricana and *Mallotusoppositus*, two Red List species including *Miliciaexcelsa* and *Triplochitonscleroxylon* and 41 species of Least Concern including *Albiziaadianthifolia* and *Lanneanigritana* were identified.

Conclusion: The ecological reserves of Zuénoula are rich and diversified in plant species. Their implementation allows for the reduction of industrial pollution.

Keywords: Côte d'Ivoire; sugar complex; biodiversity conservation; gallery forests; forest island; riparian forest.

1. INTRODUCTION

Tropical forests play a crucial role in the major climatic balances and constitute the largest reservoir of biodiversity on the planet [1]. They provide many essential services to humans such as quality water, food and climate regulation. Across sub-Saharan Africa, natural resources continue to be central to the livelihoods of rural people. Local norms and customs influence the daily forms of resources to use by populations [2].

Currently, the Ivorian forest cover represents less than 20% of its original extent [3]. Ecosystems and habitats are protected by several legal and institutional instruments. However, if the protection of ecosystems and habitats may seem easy in protected areas, it nevertheless remains difficult in rural areas where land tenure security is not mastered [4]. Indeed, many problems still remain in rural areas, especially related to customary rights on forest land and to the shortcomings and inconsistencies of land laws, which accentuate the conversion into agricultural areas [5]. This practice endangers the survival of several animal and plant species in our different regions. Indeed, since the beginning of the 20th century, the natural ecosystems which contain a great specific diversity have radically degraded by the effect of anthropogenic disturbances such as deforestation, agriculture, urbanization and galloping demography [6].

In order to safeguard the still existing relics, Côte d'Ivoire has implemented a new approach to conservation, including incentives for the creation of voluntary nature reserves [7]. These reserves have many advantages: water purification, soil protection, mitigation of natural disasters, well-being, improved income through leisure and tourism, etc. [8].

Thus, within the framework of sustainable management and taking into account the standards and certifications in force, the sugar complex of Zuénoula (Côte d'Ivoire) has adopted

a biodiversity conservation approach. It is based on the management of ecosystems through the protection of forest strips of forest and the reforestation of certain endangered species. In addition, it also has in its specifications a social aim at leaving certain portions of land to the local population for other crops [7]. Unfortunately, these ecological sites reserved for the conservation of biodiversity are infiltrated by the local population. Indeed, everywhere else where it is practised, sugarcane cultivation has many advantages in terms of multifunctionality within the framework of rural development: job creation, income and provision of services to other agricultural productions. Thus, in the regions where sugar industries are located, many populations flock [9]. These populations exert a strong pressure on the flora and fauna, including those in biodiversity conservation areas.

In order to assess the effect of this anthropogenic pressure on the forest relics preserved by the Sucrivoire Company and thus update knowledge on the biodiversity of these ecological sites, this study was initiated. The general objective is to analyze the forest fragments of the integrated agricultural unit of the Zuénoula sugar complex in order to develop an action and management plan aimed at protecting and sustainably conserving the biodiversity areas. Specifically, it involves (1) mapping the ecological reserves and characterizing the existing forest plant formations and (2) determining the floristic diversity of the ecological sites of the Zuénoula sugar complex.

2. MATERIALS AND METHODS

2.1 Study Zone

The study was carried out at the sugar complex of Zuénoula (centre-west of Côte d'Ivoire). It is located from 7°30' and 7°40' North latitude and 6°5' and 6°15' West longitude [10] Fig. 1. The area benefits from an equatorial and subtropical transition climate with a dry season (November-February) and a rainy season (March-October).

The average temperature varies between 26.7°C to 29°C. The average rainfall varies between 93.61 to 209.34 mm [11]. The relief is characterized by flat plateaus (200 to 400 m) with large plains, some lowlands and hills with an average altitude of 260 m [12]. The vegetation is from the Guinean domain of the mesophilic sector [13]. The soils are varied, ferrallitic, hydromorphic, little evolved or browned [12].

2.2 Ecological Site Mapping

All the cartographic data were obtained on the basis of the work of [14] which themselves were derived in part from [15] and [16]. They were made following three steps: the acquisition and storage of geographical data, the projection and digitization of information and finally the cartographic drafting.

2.3 Study of the Flora of Plant Formations in Conservation Areas

Floristic richness was determined from an intensive inventory using the surface survey method combined with a roving inventory. The area survey is a quantitative and exhaustive method consisting of inventorying in plots of fixed area, all the individuals of plants of diameter at breast height (DBH) generally higher or equal to 10 cm. This method has been used by many

authors such as [17] and [18]. This inventory was carried out by randomly placing 10 plots of 20 m x 20 m (400 m²) in each of the plant formations that make up the ecological reserves. The ecological formations were gallery forests (F1, F3, F5, and F6), riparian forests (FR1, FR2) and forest islands (IF4) see Fig. 2. The itinerant inventory in addition to the first was carried out along a route, noting all the species encountered without determining their number, as recommended by [19].

2.4 Methods of Analysis of Floristic Data

2.4.1 Floristic composition and use value of species

The floristic composition allowed us to determine all the species that make up the inventoried plots. It led to the elaboration of the floristic list. The use value of the species was sought through the determination of the species with particular status on each site. These species were highlighted by comparing the floristic list obtained with that of [20] to determine the endemic species of Upper Guinea (HG) and those of [21] and [22], for the determination of rare and endangered species of the Ivorian flora [21]. The species richness of a given site is the number of species, genera and families found at that site [19]. The nomenclature was made according to the Cronquist classification [23].

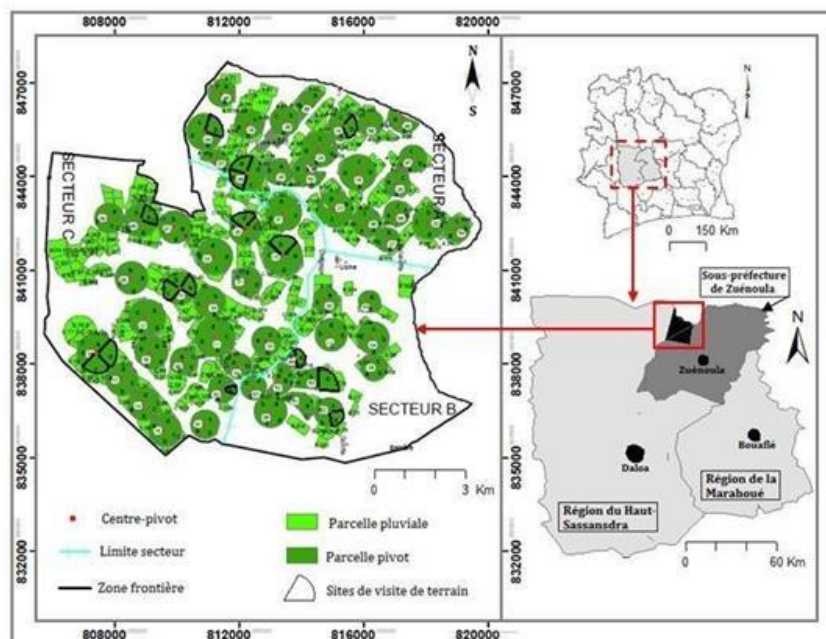


Fig. 1. Location of the study site

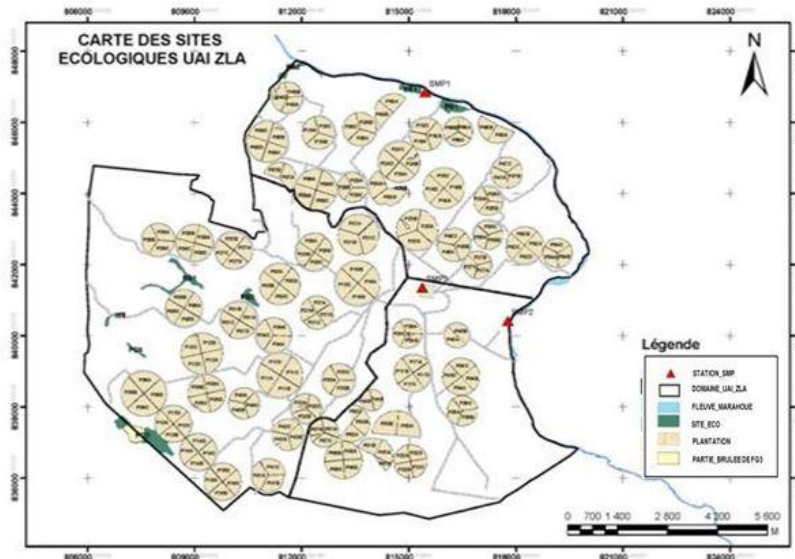


Fig. 2. Map of voluntary nature reserves in the Zuénoula sugar complex

FG1-Gallery Forest 1; FG3-Gallery Forest 3; FG5-Gallery Forest 5; FG6-Gallery Forest 6; IF4-Forest Island 4; FR1-Riparian Forest 1; FR2-Riparian Forest 2

2.4.2 Biological and chorological types

Biological type is a classification proposed by [24] and [25] in order to organize all plants according to the positioning of survival organs. The terminologies used have been adapted from the work of [26] and [27]. They are Chamephytes, Epiphytes, Geophytes, Hemicryptophytes, Theophytes and Phanerophytes (Nanophanerophytes, Microphanerophytes and Megaphanerophytes).

Chorology is the study of the distribution of taxa in correlation with the history of the earth and climates [28]. The chorological type is used to define the phytogeographic distribution range of a species. The type phytogeographic distribution types were established according to the major chorological subdivisions for Africa proposed by [19].

2.4.3 Floristic diversity of conservation areas

Floristic diversity is the distribution of species on a given surface. Its evaluation was made according to the diversity index of [29] and the equitability index of [30]. Shannon's H' index is used to quantify and compare the floristic diversity of plant formations. It takes into account the number of species and their abundance [31]. The values of H' vary between 0 and $\ln S$ (maximum diversity). For environments containing only one species, H' is equal to zero,

while for those containing a high number of species, H' is high and tends towards $\ln S$. The Pielou index (E) expresses the regularity and equitable distribution of individuals among species [32]. It allows to appreciate the changes in the structure of a community. This index varies from 0 to 1. When it tends towards 0, it describes a state of dominance of individuals of one species over the others. If E tends towards 1, then the distribution of individuals between species is regular. These two indices have the formula [29,30]:

$$H' = - \sum_{i=1}^s \frac{n_i}{N} \ln \frac{n_i}{N} \quad (1)$$

$$E = \frac{H'}{\ln S} \quad (2)$$

With n_i -number of individuals of species i ; N -total number of individuals; S -total number of species.

2.4.4 Statistical data analysis

ArcGis 8.0 software was used to determine areas and maps of ecological sites. Geographical coordinates were transferred for mapping. Families, genera, and species were analyzed from the general floristic list. A factorial correspondence analysis (FCA) coupled with a hierarchical ascending classification was used to

group the species and to establish the relationship between the set of inventoried species, the biodiversity zones and the status of these species.

3. RESULTS

3.1 Mapping of the Ecological Reserves of the Sugar Complex

The voluntary forest reserves covered a total area of 139.55 hectares. Three types of forest vegetation were identified: the Forest Island (FI), the Gallery Forests (FG) and the Riparian Forests (FR) see Figs. 3 and 4. The IF4 forest plot (Fig. 3) is located to the east of the Sugar Estate and near the pivot 05 (irrigation system). It covers an area of 7.28 hectares. The specific species were: *Erythrophleum suaveolens*, *Ficus exasperata* and *Opilia celtidifolia*. The second type consisted of gallery forests, FG1; FG3; FG5 and FG6 (Fig. 4). The gallery forest FG1 (22.07 hectares) was located to the east of the sugar domain and completely downstream of pivot 5. Its specific species were: *Costus dubius*, *Cussonia arborea*, *Glyphaea brevis*, *Lansea*

acida (Fig. 4A). The gallery forest FG3 located at the bottom of pivot 13 was the largest; it extended over an area of 60.5 hectares and had the following specific species: *Combretum racemosum*, *Dalbergina welwitschii*, *Millettia zechiana*, *Telosma africanum* and *Xylopia aethiopica* (Fig. 4B). The Gallery forest FG5 (11.6 hectares) was located between pivot 1 and pivot 3. Species specific to this forest formation were: *Abrus canescens*, *Celtis mildbraedii*, *Cissus aralioides* and *Hymenocardia acida* (Fig. 4C). The Gallery forest FG6 (3.79 hectares) was located at the bottom of pivot 36 with specific species: *Amphimas pterocarpoides*, *Borassus aethiopicum* and *Mondia whitei* (Fig. 4D). The third type of vegetation formation was the riparian forests that bordered the Marahoué river (Fig. 5): FR1 (24.52 hectares) and FR2 (10.23 hectares). Species specific to the FR1 forest were, *Acacia mimosoides*, *Cassia mimosoides*, *Myrianthus serratus* and *Parinari congensis* (Fig. 5A). The riparian forest FR2 was located just below pivot 46 and the specific species were: *Acridocarpus smeatmannii* and *Annona senegalensis* (Fig. 5B).

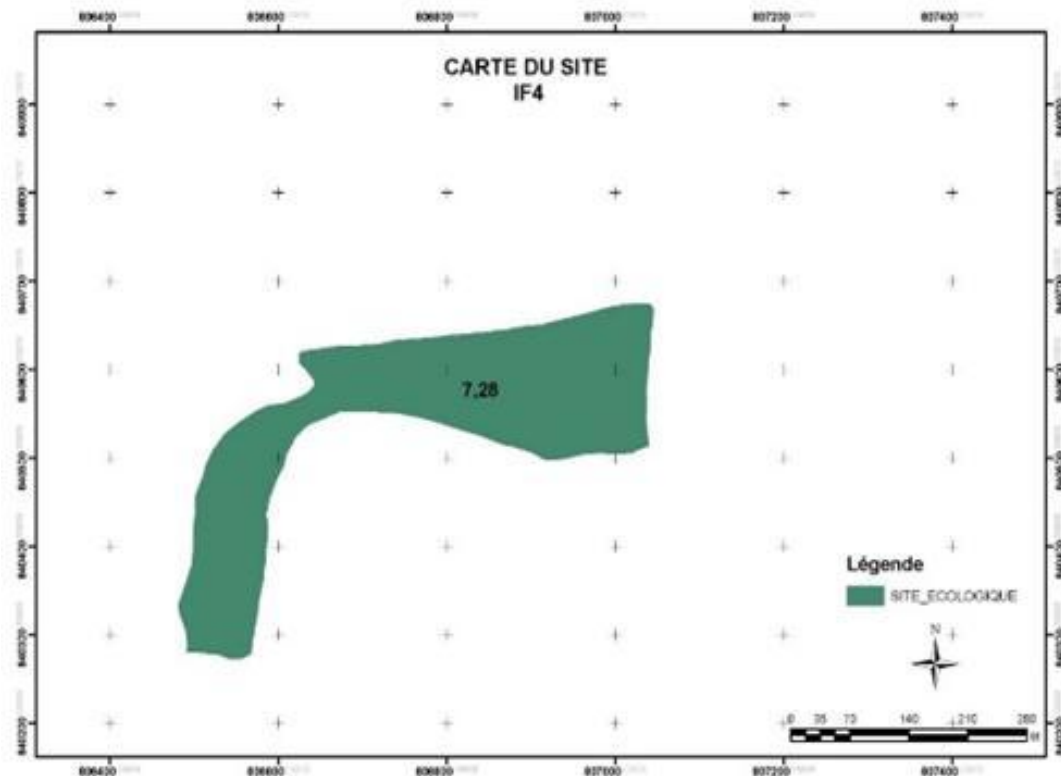


Fig. 3. Map of Forest Island 4 (IF4)

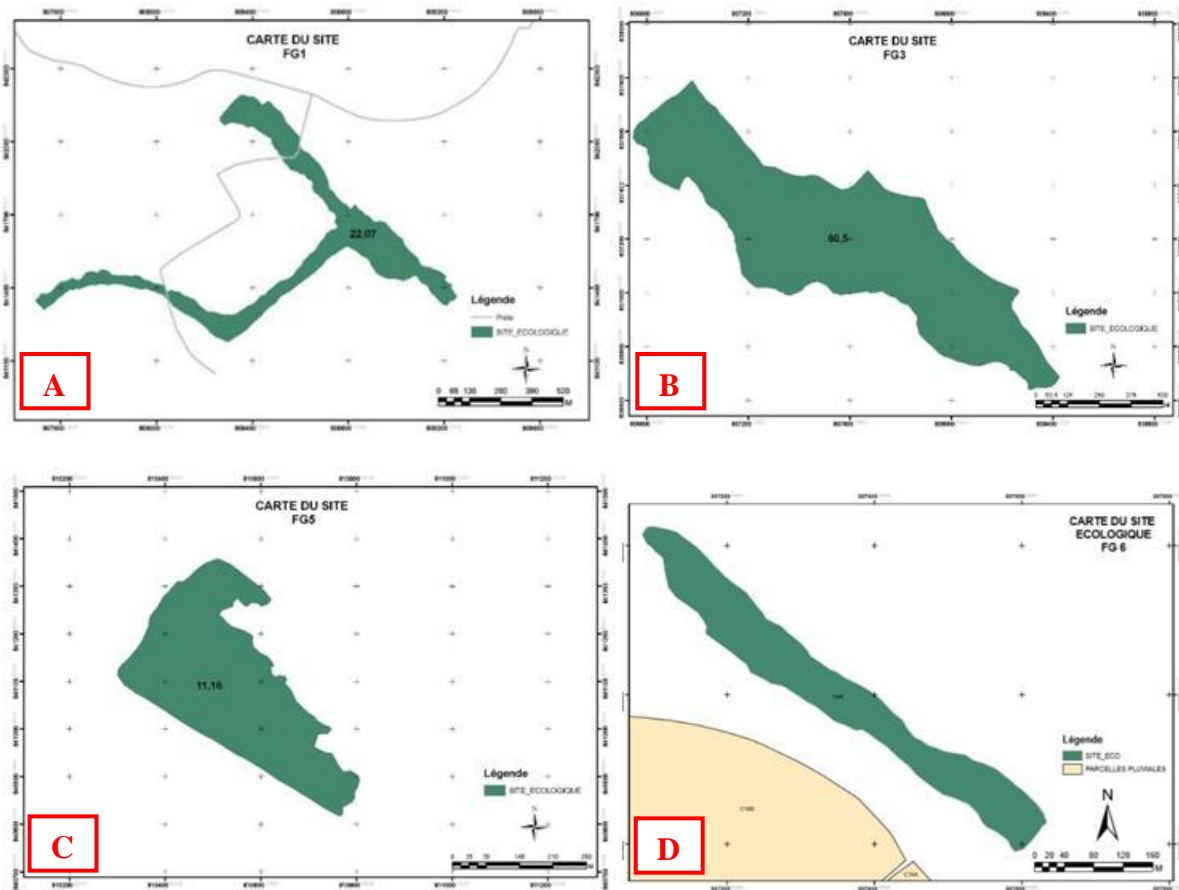


Fig. 4. Map of gallery forests identified on the voluntary reserves of the Zuénoula sugar complex
 A-Gallery Forest 1 (FG1); B-Gallery Forest 3 (FG3); C-Gallery Forest 5 (FG5); D-Gallery Forest 6 (FG6)

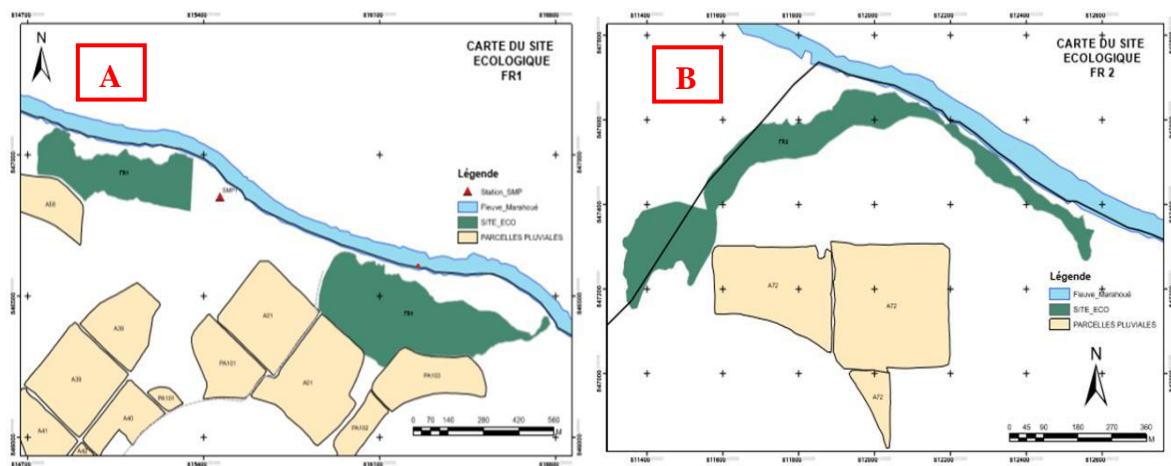


Fig. 5. Map of riparian forests identified in the voluntary reserves of the Zuénoula sugar
 A-Riparian Forest 1 (RF1); B-Riparian Forest 2 (RF2)

3.2 Biological Characteristics of Plant Formations

3.2.1 Floristic richness of the nature reserves

The floristic inventory identified 106 species distributed among 90 genera and 37 botanical families (see Appendix). The most important families in terms of number of species were, Caesalpiniaceae, Moraceae and Sterculiaceae with 7 species each (Fig. 6). In this flora, 19 frequent species were noted, including *Ceiba pentandra*, *Cola cordifolia*, *Phoenix reclinata* and *Spondias mombin*. In addition, 15 species exploitable timber including *Triplochiton scleroxylon*, *Antiaris toxicaria* and *Terminalia superba* were inventoried. Finally, 51 species have been recognized as having a special status. Among them, six species, *Azelia africana*, *Albizia ferruginea*, *Mallotus oppositus*, *Nesogordonia papaverifera*, *Pouteria alnifolia*, *Pterygota bequaertii* were vulnerable. Only one species, *Raphia sudanica* was near threatened. Two timber species, *Milicia excelsa* and *Triplochiton scleroxylon* presented a minor risk. Finally, the species *Uvaria tortilis* was the only endemic of Upper Guinea.

3.2.2 Biological and chorological types of ecological plant formations

The biological spectrum of all species showed that mesohanerophytes with 64.08% were the most dominant. Geophytes with 2.91% representativeness were the least numerous (Fig. 7). Megaphanerophytes represented 10% of Phanerophytes and 9.71% of the total flora with species such as *Celtis mildbraedii*, *Milicia excelsa*, *Ceiba pentandra* and *Parkia biglobosa*.

Mesophanerophytes represented 66% of Phanerophytes and 64.08% of the total flora; the most frequent species were *Olax subscorpioidea*, *Mangifera indica* and *Phoenix reclinata*. Microphanerophytes represented 19% of the Phanerophytes and 18.45% of the total flora and had as species, *Cola laurifolia*, *Azadirachta indica* and *Ficus exasperata*. Nanophanerophytes represented 5% of the Phanerophytes and 4.85% of the total flora and had as species, *Cassia mimosoides*, *Costusdubius* and *Annona senegalensis*. The flora list is dominated by species from the Guinean-Congolese (GC) zone with 49%, followed by species from the area straddling the Guinean-Congolese and South Zambesian zones with 37%. Species from the Soudano-zambezi zone and those endemic to the western block of Togo were under-represented with 1% and 5% respectively (Fig. 8).

3.2.3 Floristic diversity of ecological reserves

The average Shannon index for all ecological sites was 2.43. It varied from 2.04 to 2.70 across environments (Fig. 9A). The highest values were observed in FG3 and FG5 with 2.70 and 2.68 index respectively. The lowest value was observed in FG6 (2.04). From one ecological site to another, the Shannon index showed a significant difference ($F = 5, 343; P = 0.0046$). The equitability index showed a mean value of 0.92 (Fig. 9B). It ranged from 0.90 to 0.93 with the highest values in IF4 (0.94) and the lowest in FG1 (0.90). The Piélou index values did not show any significant difference from one ecological sites to another ($F = 0.751; P = 0.619$).

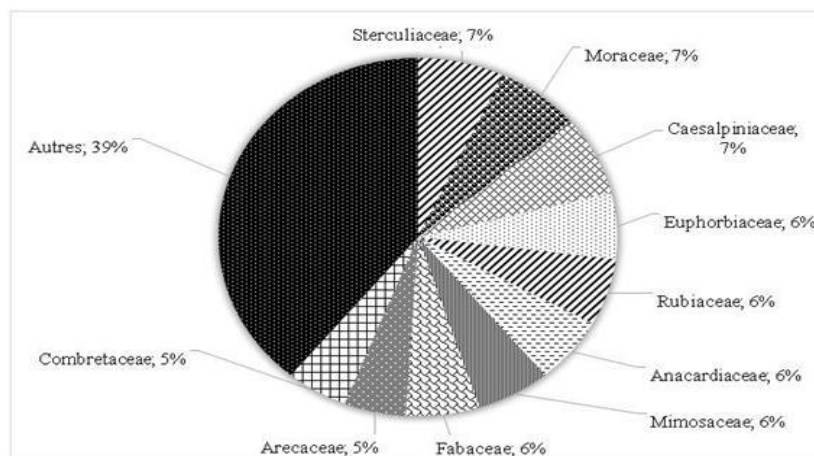


Fig. 6. Distribution by family of species recorded at the Zuénoula sugar complex
Autres-Others

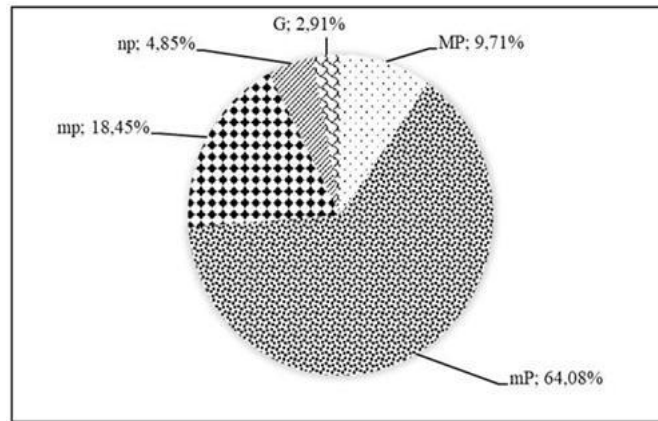


Fig. 7. Biological spectrum of species recorded in the voluntary forest reserves of the Zuénoula sugar complex

mp-Microphanerophyte; *mP*-Mesophanerophyte; *MP*-Meganerophyte; *np*-Nanophanerophyte; *G*-Geophyte

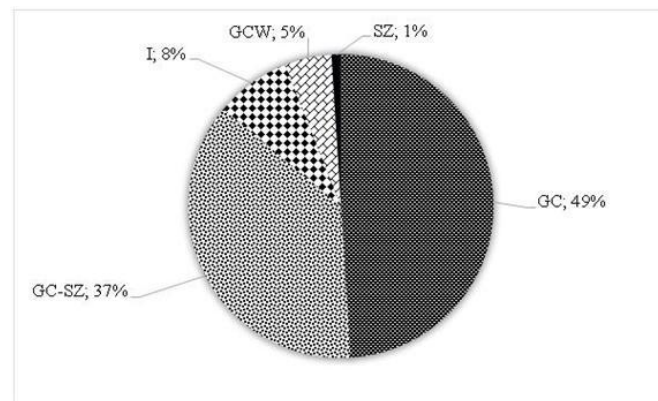


Fig. 8. Chorological spectrum of species inventoried in the voluntary forest reserves of the Zuénoula sugar complex

GC-taxon of the Guinean-Congolese region; *GCW*-taxon endemic to the forest block in western Togo; *I*-taxon introduced or cultivated; *SZ*-taxon of the Sudan-Zambezi region; *GC-SZ*-taxon of the transition zone between the Guinean-Congolese region and the Sudan-Zambezi region

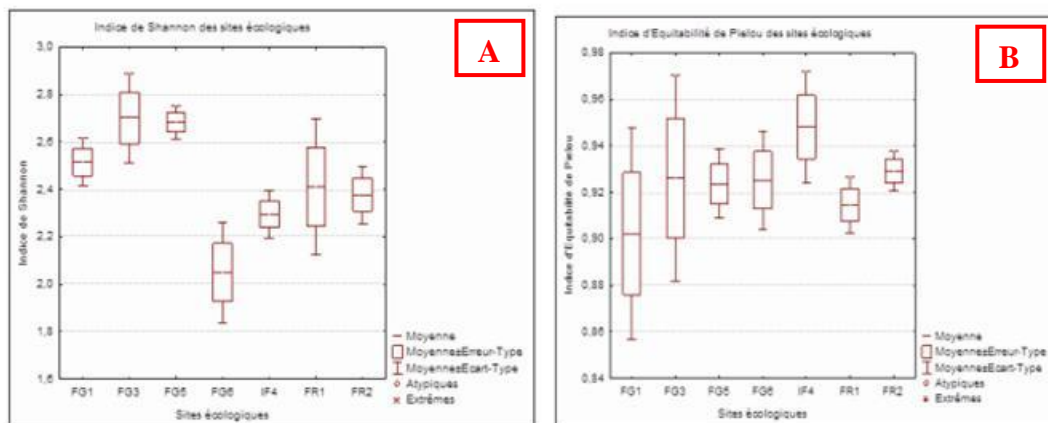


Fig. 9. Variation of Shannon (A) and Pielou (B) indices according to the ecological sites of the Zuénoula sugar complex

FG1, FG2, FG3 FG5 and FG6-forests 1, 3, 5 and 6; *IF4*-forest block 4; *FR1*-Riparian forest 1; *FR2*-Riparian forest 2

3.2.4 Relationship between species and ecological sites

The projection of plant formations and species on the axes (X, Y, and Z) revealed three distinct groups. These groups were distributed in a factorial plan formed by the first three components F1, F2, F3. These axes explained 58.66% of the observed variability with 21.64% applied to the F1 axis, 19.70% applied to the F2 axis and 17.32% applied to the F3 axis. Group 1 was associated with riparian forests FR1 and FR2. Group 2 was associated with gallery forests FG5 and FG3 and then with the forest island IF4. Group 3 was associated with gallery forests FG1 and FG6 (Fig. 10). The hierarchical bottom-up classification presented the clustering of species

and plant formations into three groups. These groups were located at distances of 0.15, 0.15 and 0.05 respectively (Fig. 11). Group 1 contained the Riparian forests FR1 and FR2 made up the species, *Bombax buonopozense*, *Cola laurifolia*, *Salacia sthulmanniana*, *Paullina pinnata* and *Terminalia glaucescens*. Group 2 contained the Gallery forests FG3, FG5 and the forest island IF4. It is composed of the species, *Berlinia grandiflora*, *Spondias mombin*, *Mezoneuron benthamianum*, *Pterocarpus santalinoides* and *Periploca nigrescens*. Group 3 contained the gallery forests FG1 and FG6 and was composed of the species, *Cissus cymosa*, *Bridelia micrantha*, *Albizia spp.*, *Newbouldia laevis* and *Trichilia prieuriana*.

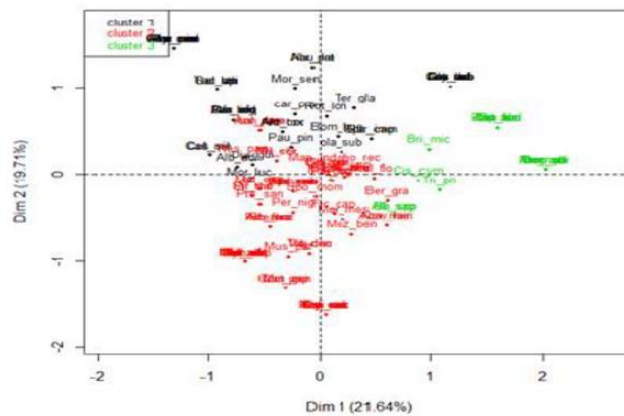


Fig. 10. Diagram of plant formations of species from the ecological sites of the Zuénoula sugar complex

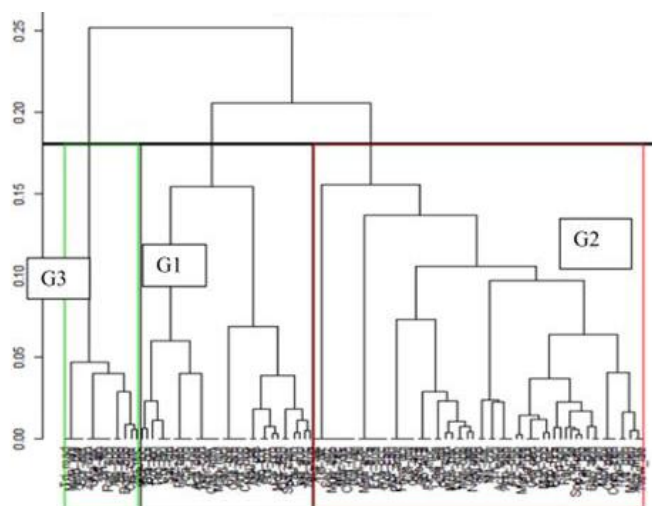


Fig. 11. Ascending hierarchical classification of species from the ecological sites of the Zuénoula sugar complex
G1-group 1; G2-group 2; G3-group 3

4. DISCUSSION

The cartography of the ecological reserves has made it possible to produce their various maps. The total area of these sites is 139.55 hectares. It can be said that the botanical study of ecological reserves that associated the mapping constitutes a first step in safeguarding biodiversity [33]. Indeed, the cartographic study made it possible to verify and confirm the limits of the plant formations, because its limits were not well known either by the managers or by the local populations. This contributes to the safeguarding of the integrity as it is done for sacred forests in Côte d'Ivoire and Benin. Indeed, according to [34], this approach is essential and a priority in the definition of a forest management framework because the absence of clear and tangible benchmarks facilitates their erosion. Comparing our results with those of [35], who found a total area of 120.24 hectare for these same sites, we note that the areas of the different sites are higher. This difference can be explained by the protection of the sites.

The study made it possible to draw up a floristic list of 106 species divided into 90 genera and 37 families. These species belong mostly to the families Caesalpiniaceae, Moraceae and Sterculiaceae, Euphorbiaceae, Rubiaceae, Anacardiaceae, Mimosaceae and Euphorbiaceae. The abundance of species in these families testifies to a floristic reshuffling of the ecological sites of Zuénoula. Indeed, the ecological zone to which the sugar complex belongs is in the guinean-congolese forest domain, which is the preferred zone for Rubiaceae [27]. These species found in all the sites are also indicative of low level of plant diversity. Indeed, this value of floristic richness remains lower than that obtained by [35] who identified 471 species on all sites. This difference could be due to a larger number of ecological sites inventoried by these authors who visited 14 of them, equivalent to twice the number of our study. Moreover, the difference may also be due to the nature of the species surveyed. Indeed, our study was based only on the ligneous flora, whereas the first authors were interested in all the plant flora. We also note that the low number of ecological sites is a consequence, among other things, of the declassification of areas of good fertility for the cultivation and production of sugarcane. In terms of average species richness on a one hectare site, the study area is average (0.79 per hectare) and higher than [36].

The species encountered in our study belong in majority to the guinean-congolese zone with 49% of presence. According to [37], the high proportion of these species in the floristic procession of a forest is proof that it belongs to the guinean-congolese region. [38] states that the guinean-congolese flora is very pure, with 80 to 90% of endemic species. This high value could be a sign of a good reconstitution of the vegetation in the plots studied.

All the environments inventoried are diversified with regard to the different indices calculated. This translates a good stability of the ecological environments. These indices are even very high, thus reflecting great stability of the conservation zones. Indeed, according to [39], when the specific diversity is high, the links between the different components of the biocenosis are complex. This complexity increases the stability of the system due to the many interactions between the different populations. Stability in gallery forests in particular, that of FG3 and FG5 is greater compared to other ecological environments. The equitability index indicates a uniform distribution of species across sites. Thus, the taxa found on the ecological sites of the Zuénoula Sugar Complex are equitably distributed in the environments inventoried, as the indices are close to unity.

The presence of special-status species clearly confirms the biodiversity conservation role played by these sites. The presence of these species in the different categories seems to be linked for some to an important and uncontrolled commercial exploitation, coupled with a weak natural regeneration. For other species, it would be a reduction of habitats mainly due to human activities such as bush fires which are recurrent during the infiltration of the population for the manufacture of charcoal.

The factorial correspondence analysis made it possible to categorize the environments and group them according to species. The first group 1 is characterized by riparian forests, which are located on the banks of the Marahoué River with little human activity. The floral procession is dominated by *Cola laurifolia* which is a species present on the banks of rivers and in West Africa. Group 2 is made up of gallery forests FG3, FG5 and the forest island IF4. These forests are delimited by hydromorphic zones (lowlands) exploited by the population for market gardening. The species encountered in this group are in the form of trees. The presence of forest

species such as *Lecaniodiscus cupanioides*, *Erythroxylum suaveolens* characteristic of the humid semi-deciduous forest shows that these forests have kept their climatic conditions which allow the installation and development of these species [40]. Group 3 is composed of gallery forests FG1 and FG6. These forests are bordered by cash crop plantations (coffee, cocoa, cashew) and food crops (cassava). They are subject to strong anthropic pressure (bush fires, hunting, frog fishing). The presence of *Borassus aethiopium* and *Raphia sudanica* species, which are savannah species, attests to the degradation of these forests.

5. CONCLUSION

The study carried out in voluntary nature reserves of Sucrivoire Zuénoula has made it possible to map these sites. Flora of seven voluntary nature reserves located in 139.55 hectares were inventoried. They were rich and diversified flora of 106 species included in 37 families and 91 genera. Fifty-one species with special status were recorded. The plant diversity of these environments showed a high stability and dissimilarity between them. The unique particularity of the various reserves allowed them to be grouped according to their plant species. This study confirms the importance of preserving these reserves and better studying them in order to enhance their role in biodiversity conservation.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Tchatat M, Ndoye O, Nasi R. Non-timber forest products (NTFPs); their place in the sustainable management of Central African moist forests. FORAFRI Project, study contribution for the Central African Regional Programme for the Environment. 1999;88. French.
2. Roe D, Nelson F, Sandbrook C. Community-based natural resource management in Africa: impacts, experiences and future directions. International Institute for Environment and Development, London, UK, Natural Resources Series. 2009;18:241. French.
3. Koulibaly A, Kouamé NF, Traoré D, Porembski S. Structure and regeneration of ligneous vegetation along forest-savanna transects in the Lamto reserve area (Côte d'Ivoire). *Annals of West African Botany*. 2010; 6:56-72. French.
4. Kouadio YJC, Soiret KSP, Blaise Kpan WB, Yao NO, N'Guessan KE, Kouassi KP, GOMEZ PJ. Conservation value of the Dodo Voluntary Nature Reserve (VNR), South West of Côte d'Ivoire (West Africa). *International Journal of Biological and Chemical Sciences*. 2018;12(6):2784-2796. DOI:https://dx.doi.org/10.4314/ijbcs.v12i6.24. French.
5. Kassoum T. Forest cover in Côte d'Ivoire: a critical analysis of the management situation of forests (classified, parks and reserves). *The International Journal of Social Sciences and Humanities. Invention*. 2018;5(02):4387-4397. DOI: 10.18535/ijsshi/v5i2.02. French.
6. Kouamé NMT. Spontaneous Vegetable species consumed in the department of Gagnoa, central- western Côte d'Ivoire: inventory, content of some nutrients and domestication trials. Single doctoral thesis, UFR Biosciences, University of Cocody-Abidjan. 2008;162.
7. Kouassi KC, Adji BI, Traoré K. 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. *International Journal of Environment, Agriculture and Biotechnology*. 2019;4(4):909-918. DOI: 10.22161/ijeab.444.
8. Kettunen MDN, Burner A, Berghöfer A, Vakrou A, Mulongoy KJ. Recognising the value of protected areas. *The Economics of Ecosystems and Biodiversity for National and International Policy Makers*. 2009;50.
9. Delo ZIR. Biological and sociological characterization of an agro-ecosystem: case of the Zuénoula sugar complex (Central-Western Côte d'Ivoire). Thesis for the Master's degree in Life and Earth Sciences, UFR Agroforestry, Jean Lorougnon Guédé University, Côte d'Ivoire, 2018;49. French.
10. Péné CB, Assa AD. Interannual variations in rainfall and water supply of sugarcane in

- Côte d'Ivoire. Science and Global Change. Sécheresse. 2003;14(1):43-52. French.
11. Brou T. Peasant visions and environmental change in Côte d'Ivoire. *Annals of Geography*, Edition Arman collin, Paris, France. 2007;116(0653):65-87. French.
 12. Golé BTC. Semi-detailed mapping of soil fertility potential under sugarcane cultivation: case of the integrated agricultural unit of Zuénoula (Central-Western Côte d'Ivoire). Master thesis, UFR Earth and Mineral Resources Sciences, Félix Houphouët-Boigny University (Côte d'Ivoire). 2017;87.
 13. Guillaumet JL, Adjanooun E. The vegetation of Côte d'Ivoire. In: the natural environment of côte d'Ivoire. Submissions ORSTOM N°50 Paris, France. 1971;161-263. French.
 14. Kpangui KB. Contribution of geographic information systems to the study of the specific diversity of the arboretum of the national floristic centre (Côte d'Ivoire). Master's degree thesis, UFR Biosciences, University of Cocody-Abidjan, Côte d'Ivoire. 2010;82. French.
 15. Freycon V, Fauvet N. GPS, from the acquisition of surveys to their integration in a GIS. CIRAD-Forest, FORAFRI Series N°12, Montpellier (France). 1998;84. French.
 16. Lejeune P, Hellemans P. Effect of forest cover on the accuracy of a differential global positioning system. *Biotechnology, Agronomy, Society and Environment*. 2000;4(1):41-49.
URL:<https://popups.uliege.be/1780-4507/index.php?id=15431>. French.
 17. Koulibaly AV. Vegetation characteristics and regeneration dynamics, under the influence of land use, in forest-savanna mosaics in the Lamto Reserve and Comoé National Park regions of Côte d'Ivoire. Single doctoral thesis. University of Cocody-Abidjan (Côte d'Ivoire). 2008;137. French.
 18. Konan D. Evaluation of the impact of cocoa farming on the flora and vegetation in the semi-deciduous humid forest zone: case of Oumé department. Master's degree thesis in Botany, UFR Biosciences, University of Cocody-Abidjan, Côte d'Ivoire. 2009;61. French.
 19. Aké-Assi L. Flore de la Côte d'Ivoire: Descriptive and biogeographical study, with some ethnobotanical notes. Volumes I, II and III. Catalogue of vascular plants. Doctoral thesis in Natural Sciences, National University of Abidjan, Côte d'Ivoire. 1984;1205. French.
 20. Jongkind AG. Checklist of Upper guinea forest species in Biodiversity of West African Forests. CABI Publishing, Cambridge. 2004;447-447.
 21. Aké-Assi L. Impact of logging and agricultural development on the conservation of biological biodiversity in Côte d'Ivoire. *The Flamboyant*. 1998;46: 20-22. French.
 22. IUCN. The IUCN red list of Threatened Species; 2020.
Available:<http://www.iucnredlist.org>
 23. Lebrun JP, Stork AL. Enumeration of the flowering plants of tropical Africa: 4. Gamopetales: Clethraceae to Lamiaceae. Conservatory and botanical garden of Geneva. 1997;712.
 24. Raunkier C. The life form of plants and statistical plant geography. Clarendon press, Oxford. 1934;632.
 25. Aubréville A. Classification of biological types of vascular plants in tropical environments. *Adansonia*. 1965;3(2):153-196. French.
 26. Aké-Assi L. Flora of Côte d'Ivoire: systematic catalogue, biogeography and ecology. *Boissiera*. 2001;57(1):1-396. French.
 27. Aké-Assi L. Flora of the Côte d'Ivoire 2, catalogue, systematics, biogeography and ecology. *Boissiera*. 2002;58(2):1-401. French.
 28. Spichiger R., Pamard C. Research under the forest-savanna contact in Côte d'Ivoire: study of forest recruitment on plots at the edge of a forest island in the south of the Baoulé country. *Candollea*. 1973;28:21-37. French.
 29. Shannon CE. A mathematical theory of communications. *The Bell System Technical Journal*. 1948;27:379-423.
 30. Piélou EC. Species diversity and pattern diversity in the study of ecological succession. *Journal of theoretical biology*. 1966;10:370-383.
 31. Adou Yao CY. Farming practices and biodiversity dynamics in the classified forest of Monogaga (Côte d'Ivoire). Single Doctoral Thesis, Department of Man, Nature and Society, University MNHN, Paris, France. 2005;233. French.
 32. Sokpon N, Ametepe A, Agbo V. Sacred Forests and Biodiversity Conservation in

- Benin: The Case of the Adja Plateau in Southwest Benin. *Ann. Sc. Agron. Bénin/* 1998;1:47-64. French.
33. Adou Yao CY, Kpangui KB., Kouao KJ., Adou LMD., Vroh BTA, N'Guessan KE. 2013. Floristic diversity and conservation value of the Bokasso sacred forest (eastern Côte d'Ivoire)», *VertigO - The Electronic Journal in Environmental Sciences*. 2013;13(1). Online 16 April 2013, Accessed 13 May 2022. Available:<http://journals.openedition.org/vertigo/13500>, <https://doi.org/10.4000/vertigo.13500>. French.
34. Kokou K, Sokpon N. The Sacred Forests of the Dahomey Corridor. *Woods and forests of the tropics*. 2006;288(2):17-23. Available:doi.org/10.19182/bft2006.288.a20312. French.
35. Kouassi KE, Kouamé NF, Dibi NA, Akpatou KB, Ahon DB. Evaluation of the faunistic and floristic diversity of the forest relics of the Sucrivoire domains in Borotou-Koro and Zuénoula. Study report, Abidjan. 2012;158. French.
36. Hunter JT, Hunter VH. Vegetation of ironbark nature reserve and *Bornhardtia* voluntary conservation agreement, Northern Tablelands, New South Wales. *Cunninghamia*. 2003;8:93-110.
37. Sonké B. Floristic and structural study of the forests of the Dja wildlife reserve (Cameroon). Doctoral Thesis, Faculty of Sciences, Free University of Brussels (Belgium). 1998;321. French.
38. White F. The vegetation of Africa. A description memoir to accompany the Unesco/ AETFAT/UNSO map of Africa, UNESCO, Paris (France). 1983; 384.
39. Loubier JC. *Ecologie and SIG: A heritage management tool applied to natural tourist areas*. Proceedings of the 5th meeting Théo Quant. 2001;23:14. French.
40. Soro Y, N'dri AB, Bakayoko OA, Gignoux J. Vegetation analysis in a West African forest-savanna ecotone in a context of savanna afforestation. *PASRES Journal*. 2018;3(1):54-72. DOI: 10.13140/RG.2.2.27160.01289. French.

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