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Dahliafleur Partial Nature Reserve of Bingerville (Southern Côte d'Ivoire): sanctuary of biodiversity in a heavily urbanized environment

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Abstract

In a context of unbridled erosion of biodiversity, it is important to protect, and conserve protected areas by carrying out studies, in particular on the flora and vegetation of which they are composed. A study was carried out in the Dahliafleur Reserve in Côte d'Ivoire, with the overall aim of assessing the level of biodiversity conservation. The methods used in this study were surface and itinerant surveys. The results revealed that there are three types of plant formations in the Dahliafleu Partial Nature Reserve, in order of importance: secondary forests (76.38 ha), fallow land (59.53 ha) and bamboo groves (10.17 ha). The flora is rich in 224 species divided into 186 genera and 105 families, the most important of which are the Fabaceae, Apocynaceae, Euphorbiaceae and Rubiaceae. Most of its flora consists of species from the Guinean Congolese or forest zone. The reserve has 39 species with special status, which shows its importance and the interest of its protection against anthropic pressures. According to the Forest Stewardship Council (FSC), three (03) High Conservation Value (HCV) categories have been reached. These are HCV1, HCV2 and HCV4. The data obtained from the study highlights the biodiversity conservation value of the Dahliafleur reserve. Resilience strategies must therefore be adopted by the reserve manager, ranging from conservation to enhancement of this biodiversity.

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Introduction

Biodiversity, which is the diversity and variability of living organisms within and between species and ecosystems, provides us with goods and services called ecosystem services. According to the Millennium Ecosystem Assessment (MEA) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), these are the benefits that humans derive from ecosystems. Biodiversity provides services to humans that enable them to live (Diallo *et al.* 2013; Keymeulen 2022). Humans depend on plants for food, fuel, wood, medicine and many other services (Doffou *et al.* 2021). Biodiversity is therefore essential for human survival. Despite this importance, we are witnessing a degradation of biodiversity (Bureau *et al.* 2020; Kpula *et al.* 2021). Biodiversity is nowadays subject to erosion and transformations caused by forms of development that are increasingly incompatible with its preservation. Demographic growth and the massive exploitation of resources for speculative purposes are leading to the degradation of natural environments (Ahononga *et al.* 2020; Mumbere *et al.* 2022). This degradation is becoming increasingly rapid, with species, ecosystems and even landscape types disappearing, leading to an irreversible decrease in the richness of our planet (Norro 2017; Bureau *et al.* 2020).

Côte d'Ivoire has not been spared this degradation of biodiversity (Dahan *et al.*, 2021; Kouamé *et al.*, 2021). The creation of protected areas is now recognized as a fundamental tool for achieving the protection of the environment in general and of ecosystems in particular (Dien 2018; Lambini *et al.* 2019). Côte d'Ivoire has a network of 13 national parks and nature reserves covering 21.038 km². The country's parks and nature reserves are poles of biodiversity conservation. Notwithstanding this conservation role, we also see degradation of these protected areas due to anthropogenic pressures (Assalé *et al.* 2016; Gnahoré *et al.* 2021). Riparian populations, in search of arable land and many species with various virtues, therefore exert very strong pressures on these protected areas so that their surfaces do not stop being eaten (Vroh *et al.* 2010; Konan *et al.* 2019). This is the case of the Dahliafleur Partial Nature Reserve (DPNR) which is located in a heavily urbanized town of Bingerville.

The DPNR would constitute a green lung for the municipality of Bingerville prone to an unbridled race of real estate promotions and therefore subject to the destruction of green spaces. This destruction could affect people's quality of life. To do this, studies must be conducted to show the role of this Reserve and to draw the attention of the populations and the municipal and state authorities to the need to preserve this gem of nature. Thus, a study was conducted to assess the level of conservation of the DPNR. Specifically, this involved (i) determining the different types of land use in the Reserve, (ii) analyzing the Reserve's plant diversity, (ii) assessing the Reserve's conservation value.

Material and methods

Description of study area

The Dahliafleur Reserve is located in the municipality of Bingerville in the District of Abidjan in the south of the Côte d'Ivoire (Fig. 1). The Reserve covers an area of 148 ha. It is limited in its northern part, by the villages "Carrière I and II" and by the Ebrié lagoon in its eastern part (Monssou, 2018). To the south and west, residential areas limit it. The corresponding climate is of the subequatorial type (Edlin *et al.* 1971). It is characterized by high rainfall and high humidity, daytime temperatures average 25 ℃ to 30 ℃ annually and abundant rainfall reaches 350 mm in the month of June (Asseh 2019). It has two seasons, a rainy and a dry one. The rainy season spans two periods: March to July and September to November. The dry season is also spread over two periods: from December to February and the month of August.

Vegetation mapping

Mapping was carried out on 2020 images in three stages, namely image pre-processing, extraction of information from the images, and verification and description of the land use types observed during pre-processing. The images were acquired from the USGS site (http://earthexplorer.usgs.gov/). The land cover

map was produced using supervised classification (Douffi, 2015).

Flora inventory

Two field survey techniques were used. These were the surface survey and the roving survey. These two types of survey are complementary. The surface survey consisted of delimiting 100 m² (10 m × 10 m) plots in different plant formations. Within this area, all plant species encountered were identified and their scientific names recorded on a survey sheet bearing the plot number. The plots were laid out in a north-south direction. Itinerant surveys were carried out in all plant formations present in the Reserve (Fig. 2). This survey only covered species not found in the surface surveys. Species observed during this second type of survey were noted and samples were collected to complete the general floristic list.

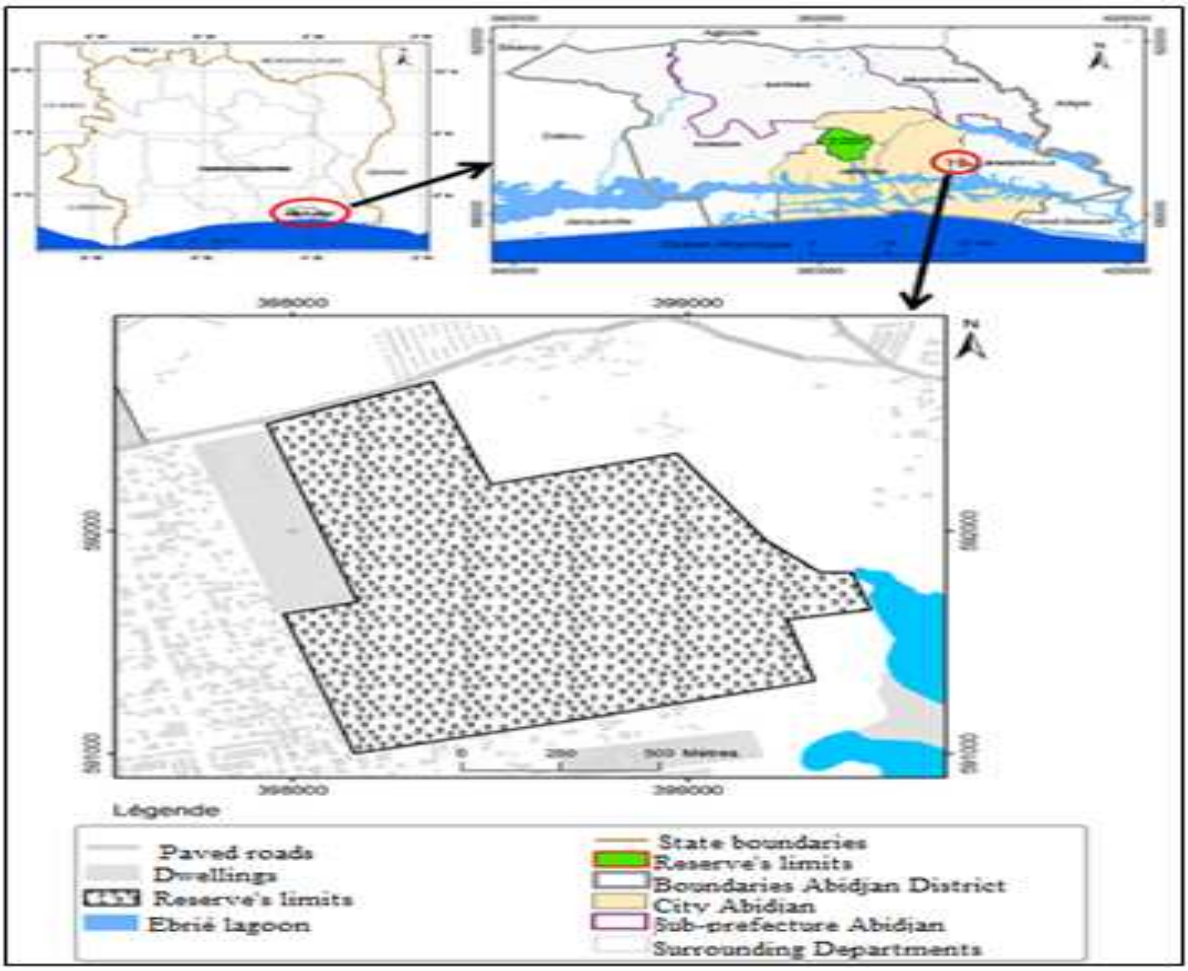

Fig. 1. Location of study area.

Map data analysis

The themes selected for the supervised classification of the year 2020 were used to characterize land uses. After supervised classification, these themes were exported from "ENVI" to "ArcGis 10" GIS software in "shapefile" format. Using the software's "Clip" function, the scene covering the Dalhiafleur Partial Nature Reserve was extracted. The 2020 land use status was obtained on each of the Reserve-scale maps.

Floristic richness and composition analysis

The total number of species inventoried for the different plant formations was determined.

For each of the species inventoried, we then noted the family, genus, biological types and phytogeographical distribution. The nomenclature of plant species adopted in this study is that of Hutchinson and Dalziel (1972) revised by Lebrun and Stork (1991-1997) and updated by APG IV.

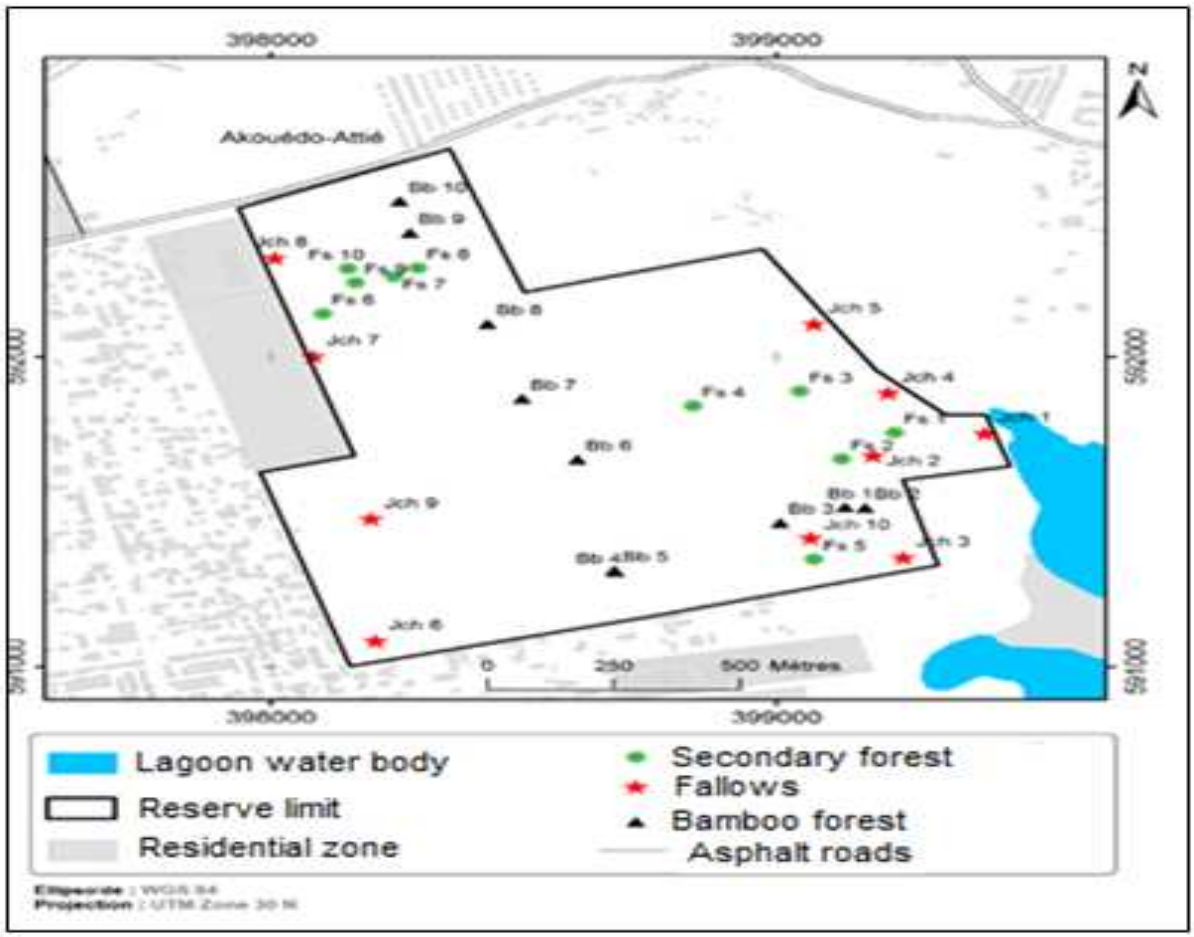

Fig. 2. Distribution of sample plots in Dahliafleur Reserve.

Specific diversity analysis

This was estimated from the Shannon (H'), Pielou (E), Simspson (DS) and Margalef (Rmg) diversity indices. These indices were calculated according to the following mathematical formulae:

$H' = - \Sigma (ni/N) \ln (ni/N)$

In this formula, H' is the Shannon index, ni is the number of individuals of a species i and N is the total number of individuals of all species. This index varies from 0 (only one species present) to ln S (all species present have the same abundance). For very diverse communities, H' can reach 4.5 (Kenth and Coker 1992) and ln S rarely exceeds 5 (Felfili *et al.* 2004). The equitability index is calculated by the following mathematical equation:

$E = H' / \ln S$

Where E is the equitability index of Piélou and S the total number of species of a biotope. Equitability ranges from 0 to 1. It tends towards 0 when almost all populations are concentrated on one species and towards 1 when all species have the same abundance. If this index tends towards 1, the medium in question is said to be balanced.

The Simpson index (D) accounts for the bias induced by the abundance of certain species and depends on the number of rare species (Simpson 1949). It is calculated by the following relationship:

$$DS=1-\sum\left(\frac{Ni(Ni-1)}{N(N-1)}\right)$$

Ni is the number of individuals of a species i and N is the total number of individuals of all species.

The diversity index proposed by Margalef (1957) represents the average amount of information (measured in bits) provided by the determination of an individual belonging to one of the s species.

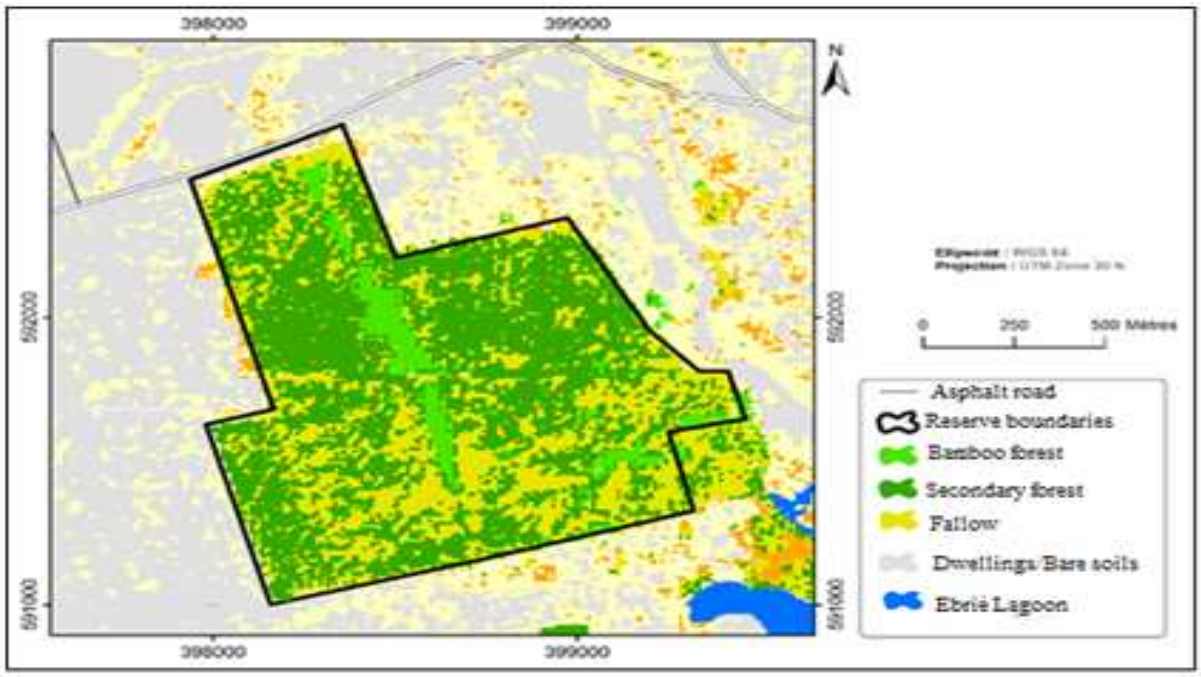

Fig. 3. Map of land use types in Dahliafleur Reserve.

It is zero in the case of a single species (n1 = N), maximum and approximately equal to log2 when the species are equally represented. Its mathematical expression is as follows:

RMg = (S -1)/ ln (N)

S is the total number of species and N the number of individuals.

Conservation value analysis

The conservation value of the Reserve was estimated in order to identify the priority status for conservation. This assessment was made with reference to the presence of species of special status in terms of the first High Conservation Value (HCV 1) advocated by the Forest Standardship Council (FSC).

These are firstly endemic species based on the lists of species drawn up by Aké-Assi (2001; 2002), Poorter *et al.* (2004) and secondly rare and/or endangered species both internationally and nationally according to IUCN (2019) and Aké-Assi (1998). With regard to endemism, we distinguished endemics to the West African forest blocks (GCW) among which those specific to the Ivorian territory are designated by GCi (Aké Assi, 2001; 2002). Species endemic to the forests of the Upper Guinea phytogeographical region are designated by HG. The last criterion assessed is the presence of particular habitats that can be classified as HCV3, characteristic of rare, threatened or endangered ecosystems, habitats or refuges.

Statistical analysis

One-way analyses of variance (ANOVA 1) or non-parametric Kruskal-Wallis tests were used to compare the mean values of the diversity indices of the different biotopes. The last test was carried out for the comparison of the mean values of the equitability indices whose data had unequal and non-standardised variances. The significance of the test is determined by comparing the probability P associated with the test statistic at the threshold $\alpha = 0.05$. When the difference analysed is significant, the means are compared. The XLSTAT software version 2014.5.03 was used to perform these tests.

Results

Main vegetations in the Dahliafleur Reserve

The field surveys allowed the identification of three (03) types of vegetation: fallow land, secondary forests and bamboo groves (Fig. 3). Secondary forests are old fallows that have reached a high level of reconstitution. This vegetation is mostly found in the north with some patches in the south of the Reserve.

The indicator species of this vegetation are *Albertisia cordifolia* (Mangenot and Miege) Forman (Menispermaceae), *Entandrophragma utile* (Dawe and Sprague) Sprague (Meliaceae), *Leptoderris miegei* Aké Assi and Mangenot (Fabaceae), *Nephthytis afzelii* Schott (Araceae), etc. This vegetation covers an area of 76.38 hectares, or 51.48% of the reserve's total area (Table 1).

Table 1. Areas of different vegetations in Dahliafleur Reserve.

Types of vegetation	Areas	Percentages
Secondaryforests	76.38	51.48
Bambooforests	10.17	6.85
Fallows	59.53	40.12
Total	146.08	98.45

The second type of vegetation encountered is represented by the bamboo forests which are vegetation made up mainly of one species, *Bambusa vulgaris* Schrad (Poaceae). This vegetation is found exclusively in the centre of the Reserve. Other species cover the undergrowth of this vegetation. These are *Cercestis afzelii* Schott (Araceae), *Cnestis ferruginea* DC (Connaraceae), *Dichapetalum angolense* Chodat (Dichapetalaceae), *Phyllanthus reticulatus* Poir (Phyllanthaceae), etc. The bamboo grove covers an area of 10.17 hectares, or 6.85% of the reserve's total surface area. The last type of vegetation is represented by fallows. These fallows were once cultivated land that was then left to be abandoned to allow for the reconstitution of vegetation and soil fertility. Fallow land is mostly located on the southern periphery of the reserve.

Its surface area is evaluated at 59.53 hectares, i.e. 40.12% of the total surface area of the reserve. Species such as *Acridocarpus longifolius* (G. Don) Hook. fil. (Malpighiaceae), *Albertisia cordifolia* (Mangenot and Miege) Forman (Menispermaceae), *Alstonia boonei* De Wild (Apocynaceae), *Aubrevillea platycarpa* Pellegr. (Fabaceae), *Cola caricaefolia* (G.Don) K.Schum (Malvaceae).

Table 2. Average values of the flora diversity indices in Dahliafleur Reserve.

Types of vegetation	Specificrichness	Shannon index	Simpson index	Equitabilité index	Margalef index
Fallows	30.9 ± 9.7^{b}	2.8 ± 0.2^{b}	0.92 ± 0.03^{b}	0.96 ± 0.04^{ab}	3.7 ± 0.60^{a}
Secondaryforests	28.4 ± 5.1^{b}	2.6 ± 0.2^{b}	0.9 ± 0.03^{b}	0.94 ± 0.04^{a}	3.2 ± 0.3^{a}
Bambooforests	7.3 ± 1.7^{a}	1.6 ± 0.39^{a}	0.78 ± 0.08^{a}	0.2 ± 0.02^{b}	2.1 ± 0.5^{b}
Test statistics	*χ^2=19.7; p-value=0.0001*	*χ^2=19.6; p-value=0.0001*	*χ^2=7.2; p-value=0.0265*	*χ^2=7.2; p-value=0.0265*	*F=0.9; p-value=0.3*

Mean values with the same letter are not significantly different at the 5% level.

Floristic richness and composition

The compilation of surface and itinerant surveys in the present study has enabled 224 species to be recorded in the Dahliafleur Reserve, divided into 186 genera and 105 families.

The most diverse families in order of importance as shown in Fig. 4 are the Fabaceae (17% of species), the Apocynaceae (7%), the Euphorbiaceae (4%) and the Rubiaceae (4%). Nine biological types have been identified in the Reserve (Fig. 5).

The biological spectrum of the entire Dahliafleur Reserve indicates that microphanerophytes dominate all types of vegetation. Thus, in the secondary forests, they represent more than 50% of the species inventoried, about 60% in the fallows and more than 80% in the bamboo forests. Only three (03) biological types are represented in the bamboo forests where nanophanerophytes and therophytes are weakly represented with a cumulative proportion of about 13%. Of all species recorded, 72% are typically forest or Guineo- Congolese (GC), 23% are species from the forest-savanna transition zone or Guineo-Congolese and Sudano-Zambezian (GC-SZ) and 4% are introduced species (i). Savannah or Sudano-Zambezian (SZ) species are poorly represented with only 1% of species recorded (Fig. 6).

Table 3. List of special status species identified in the Dahliafleur Reserve.

N°	Species	Endemism		Rare and Endangered Plant according AkéAssi and IUCN
1	*Agelaeanitida*	GCW		
2	*Albertisiacordifolia*	GCi	HG	
3	*Albertisiascandens*	GCW	HG	
4	*Anthocleistanobilis*	GCW	HG	
5	*Acridocarpuslongifolius*		HG	
6	*Anthocleistanobilis*	GCW	HG	
7	*Aubrevilleaplatycarpa*			PRE
8	*Baisseazygodioides*		HG	
9	*Baphiabancoensis*	GCi		
10	*Buxusacutata*			PRE
11	*Cnestisracemosa*	GCW	HG	
12	*Cola caricaefolia*	GCW	HG	
13	*Cola heterophylla*			PRE
14	*Copaiferasalikounda*	GCW	HG	vu
15	*Commelinaerecta*	GCW		
16	*Dalbergia oblongifolia*	GCW		
17	*Dichapetalumfilicaule*	GCW	HG	
18	*Dichapetalumtoxicarium*		HG	
19	*Diospyros vignei*	GCW	HG	PRE
20	*Entandrophragma utile*			vu
21	*Leptoderrismiegei*	GCi	HG	
22	*Maesobotryabarteri*	GCW		
23	*Manotes expansa*	GCW		
24	*Milicia excelsa*			PRE /LR/nt
25	*Miliciaregia*	GCW	HG	PRE/LR/nt
26	*Mussaendagrandiflora*	GCW	HG	
27	*Myrianthuslibericus*		HG	
28	*Nephthytisafzelii*		HG	
29	*Neuropeltisprevosteoides*	GCW	HG	
30	*Ourateaschoenleiniana*	GCW		
31	*Rinoreaoblongifolia*	GCW	HG	
32	*Salacia nitida*	GCi		
33	*Tabernaemontanaafricana*		HG	
34	*Tiliacoradinklagei*	GCW		
35	*Trichoscyphachevalieri*	GCW		
36	*Turraeanthus africanus*			vu
37	*Vitex micrantha*	GCW		
38	*Whitfieldiacolorata*		HG	
39	*Xylopiavillosa*		HG	

GCW =Endemic species of West African forests; GCi =Endemic species of the Ivorian Territory. LR/nt =minor risk species; HG :Endemic species of the Upper Guinean forests; IUCN : International Union for Conservation of Nature (2020); vu : vulnerable species ; PRE :Rare and Endangered Plant.

Specific diversity indices

The specific richness averages range from 7.3 for bamboo forests to 30.9 for fallow (Table 2). Comparison of the means of this index shows that the value of this index is significantly higher in fallow compared to secondary forests (*Kruskal–Wallis test; p-value=0.0001*). Fallow is the richest type of vegetation flourishing. In general, the averages of the diversity indices recorded in this study are low. The Pielou index tends towards 1 in fallow and secondary forests. This means that in both types of vegetation, species are distributed fairly. On the other hand, in bamboo groves, this value tends towards 0, revealing that the species in bamboo groves have different abundances and that one species dominates in this type of vegetation.

Table 4. Distribution of species with special status in the different types of vegetation in Dahliafleur Reserve.

Types of vegetation	Endemicspecies			IUCN (2019)		Aké Assi (1998)
	GCi	GCW	HG	LR/nt	Vulnerable	PRE
Fallows	2	12	12	1	2	2
Secondaryforests	2	5	9	0	2	2
Bambooforests	1	2	2	0	0	0

GCW =Endemic species of West African forests; GCi =Endemic species of the Ivorian Territory. LR/nt =minor risk species; HG:Endemic species of the Upper Guinean forests; IUCN: International Union for Conservation of Nature (2020); PRE :Rare and Endangered Plant.

Conservation value

The Dahliafleur Reserve is a refuge for species of special status. The number of these species is estimated at 39 listed in Table 3. These include 33 endemic species, four of which are endemic to Côte d'Ivoire, 22 to Haute Guinée (HG) and 21 to the West African Forest Block (GCW). 13 species are endemic to both Upper Guinea and the West African Forest Block. There are an estimated nine rare and/or endangered species according to IUCN (2019) and Aké Assi (1998). There are six identified by Aké Assi as Rare. Rare and Endangered (PRE). Three others are classified by IUCN as vulnerable species (vu). Two are classified as minor risk species (LR/nt). Endemic and special status species are found in abundance in fallow areas. Bamboo forests are less abundant (Table 4).

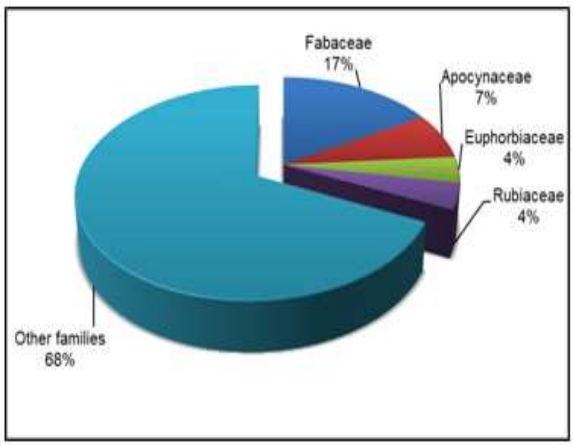

Fig. 4. Spectrum of dominant families in Dahliafleur Reserve.

Discussion

Main vegetations in the Dahliafleur Reserve :mThe study identified three vegetation types: secondary forests, fallows and bamboo forests. As already mentioned by Konan *et al* (2021), secondary forests is the most widespread vegetation type in the Dahliafleur Reserve. Bamboo forests occupy the smallest area contrary to the findings of Konan *et al.* (2021).

Floristic richness and composition

The comparative analysis with the whole of the flora of Côte d'Ivoire shows that the Dahliafleur Reserve is relatively undiversified. It has only 5.26% of the national flora. This low richness can be explained by the homogeneity of the vegetation. According to MBayongone (2008), the greatest floristic diversity is linked to habitat diversity or environmental heterogeneity. However, the flora inventoried during this study is higher compared to the studies already carried out in the Reserve by Asseh (2019) who counted 106 species and Konan (2020) who counted 107 species. The dominant botanical families are Fabaceae. Apocynanceae. Euphorbiaceae and Rubiaceae. The representativeness of this group of families can be explained by the fact that the majority of African forests in general (Sonké. 1998) and ivorian forests in particular (Adou Yao *et al.*, 2005; Vroh, 2013) are dominated by species from these families. Phanerophytes are the most abundant in the three types of vegetation encountered in the Dahliafleur Reserve. This dominance of phanerophytes does not deviate from the high diversity of tree species often reported in tropical forests (Blanc *et al.* 2003). Our results are confirmed by Sokpon (1995) and Habiyaremye (1997) who also highlighted the dominance of phanerophytes in their study areas. According to these authors, phanerophytes usually form almost the entire plant community in the forest and other biological types are poorly represented. Specifically. the high proportions of

microphanerophytes and nanophanerophytes are the result of the dominance of families such as Rubiaceae and Euphorbiaceae (Bakayoko. 2005). The low representation of hemicryptophytes. geophytes and therophytes. most of which are heliophilic species. is explained by the dominance of phanerophytes which reduce their establishment (Bangirinama *et al.* 2010). Guineo-Congolese species are largely dominant in the Dahliafleur Reserve with more than 72% of the species inventoried. According to Sonké (1998). the high proportion of these species in the floral procession of a forest is proof that it belongs to the Guineo-Congolese region of White (1983). According to White (1983). the Guineo-Congolese flora is very pure with more than 80 to 90 percent endemic species and only about 10 percent binding element species. This dominance also reflects the high level of conservation of the site. The flora has not lost its specificity despite the presence of traces of anthropization. crops and fallow.

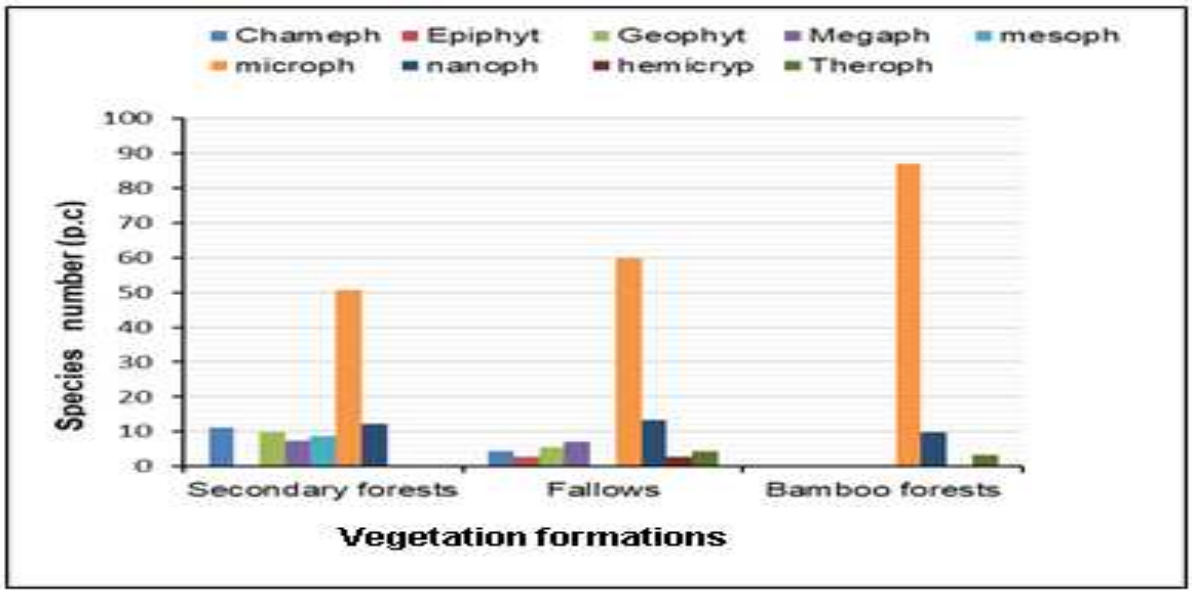

Fig. 5. Distribution of biological types by type of vegetation in Dahliafleur Reserve.
Megaph= megaphanerophytes; mesoph= mesophanerophytes; microph= microphanerophytes;nanoph= nanophanerophytes; chameph= chamephytes; hemicryp= hemicryptophytes; theropht= therophytes; geophyt= geophytes; epiphyt= epiphytes.

Specific diversity indices

The species diversity of the present study was estimated on the basis of the abundance of all the species sampled; this allowed the data obtained to be compared with those carried out elsewhere. This comparison is not at all easy given the differences in sampling methods. size and number of surveys generally observed in each research. Despite these methodological dissimilarities. this work has shown in all vegetation types of the Dahliafleur Reserve Shannon diversity index values < 3.5 bits. These values are low and reflect the low specific diversity in the Dahliafleur Reserve. According to Kent and Cooker (1992). a forest community is considered rich when it is characterised by a Shannon diversity index value greater than or equal to 3.5 bits. The Shannon index values recorded in this study are close to those found by Tankou *et al.* (2013) in the submontane sacred forests of Fongo-Tongo and Nkong-ni as well as those of Ali *et al.* (2014) in the sacred forests of the Lower Ouémé Valley in south-eastern Benin; they are, however, lower than the values of Noumi and Tiam (2016) recorded in the sacred forests of Mount Oku. Simpson's index is very sensitive to the distribution of individuals between species. It is an index directly representative of stand heterogeneity. It varies from 0 (minimum diversity) to 1 (maximum diversity) (Piélou. 1966; Pearson and Rosenberg. 1978). The Simpson diversity values noted in this study range from 0.78 to 0.92. These values are average and

reflect the average floristic diversity of the different vegetation types found in the Dahliafleur Reserve. The higher the index. the lower the relative weight of rare or scarce species. According to Dajoz (1982). high values of this index express a weak organisation of the ecological system and correspond to environmental conditions favourable to the installation of numerous species represented by a small number of individuals.

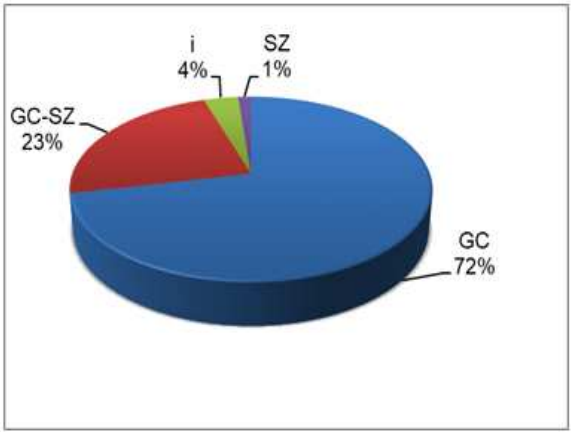

Fig. 6. Spectrum of chorological affinities in the Dahliafleur Reserve.

Conservation value

The Dahliafleur Reserve is a refuge for special-status species in that it contains a concentration of vulnerable, endangered or threatened species as well as endemic species. There are an estimated 39 of these species. This characteristic of the Dahliafleur Reserve gives it the first High Conservation Value (HCV 1) which requires a concentration of biological diversity including endemic species and rare threatened or endangered species of international regional or national importance.

The Dahliafleur Reserve is a protected area with an intact forest landscape of global, regional or national significance. This characteristic gives the Dahliafleur Reserve the second High Conservation Value (HCV 2). The Dahliafleur Reserve is a significant carbon store as previous studies have shown (Konan *et al.* 2021; Monssou. 2018). For this reason, the fourth High Conservation Value (HCV 4) is achieved. Moreover, endemism is considered an important indicator for assessing the priority and state of conservation of a specific area. The presence of endemic species indicates a preserved environment (Adou Yao, 2005).

However, their absence is a sign of a degraded environment as they are highly vulnerable to human disturbance and other kinds of environmental modification. The presence of large numbers of these species is also a sign of high biodiversity.

Therefore, their distribution is frequently used to indicate biodiversity hotspots (Myers *et al.* 2000).

Conclusion

The study carried out in the Dahliafleur Reserve has helped to improve knowledge of its conservation value through the characteristic flora. The study reveals that the different kinds of vegetation encountered are fallows, secondary forests and bamboo forests. A total of 224 species were inventoried. spread over 186 genera belonging to 105 families. The most diverse families in order of importance are the Fabaceae. Apocynaceae. Euphorbiaceae. and Rubiaceae. The species are classified into nine (09) biological types. Species from the Guineo-Congolese (GC) region are the most abundant. The Dahliafleur Reserve is a refuge for species of special status. The number of these species is estimated at thirty-nine (39). Among these, there are 33 endemic species and nine (09) rare and/or endangered species according to IUCN (2020) and Aké-Assi (1998). Species diversity is low in the Dahliafleur Reserve. But specifically, diversity is higher in the fallows than in the bamboo forests where this diversity is low. The Dahliafleur Reserve has conservation values HCV1, HCV2 and HCV4. A more in-depth ecological study would reveal other categories of HCVs that it could contain.

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