ORIGINAL ARTICLE

PHYTODIVERSITY AND CONSERVATION VALUE OF URBAN PLANT FORMATIONS IN COTE D'IVOIRE: CASE OF THE BINGERVILLE BOTANICAL GARDEN

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ABSTRACT

Context: Since its creation, the floristic knowledge of the botanical garden of Bingerville, located in the South of Côte d'Ivoire, remained sketchy. **Objective:** The present study aimed at characterizing the state of the flora and the conservation value of the biodiversity of this urban space. **Methods:** A floristic inventory was carried out according to the "tour de champ" technique, in the 29 plots of the botanical garden. **Results**: The inventoried flora is composed of 419 species distributed among 290 genera belonging to 81 families. The most diversified families, by order of importance, are Fabaceae (15.27%), Euphorbiaceae (5.97%), Malvaceae and Poaceae (5.73%). This flora is characterized by the predominance of microphanerophytes with 80.91%, followed by therophytes with 7.64%. On the chorological level, it is essentially composed of exotic species (42.72%) and species of the Guinean-Congolese endemism centre (27.21%) which present more than half of the species (69.93%). The zoochory (59.43%) proved to be the main adaptation to the dissemination of species diaspores. The site contains 51 species of special status, 15 of which are listed on the IUCN red list and threatened with extinction. **Conclusion**: The knowledge of this information shows that the botanical garden can be a privileged environment for the conservation of biodiversity in Côte d'Ivoire.
Keywords: *Floristic richness, endemism, urban space, Bingerville, Côte d'Ivoire.*

1. INTRODUCTION

Cities are nowadays home to a relatively large number of plant formations that are either planted or natural [1], represented by road alignment plantations, parks, and public or private botanical gardens [2, 3]. Regarding botanical gardens, these are areas developed by public, private or associative institutions (sometimes with mixed management), which aim to collect, preserve and protect local or exotic plants. These sites are of capital and growing importance in several fields such as environmental education, research, pharmacopoeia, and the ecological role of the absorption of CO_2 by cities [4].

In Côte d'Ivoire, the Bingerville botanical garden, created during the colonial period, experienced a great period of glory from 1952 to 1979, offering happiness to nature lovers [5]. Unfortunately, with the advent of the situation experienced by Côte d'Ivoire in the 1980s, it gradually lost its prosperity, and its scientific and ornamental values could not be preserved. Moreover, this garden which was, a few years ago, contiguous to the town of Bingerville, is today absorbed by the dwellings. Urbanization works and their corollaries of human activities undermine the existence of the botanical garden. Thus, due to the combined effect of the economic crisis and urbanization, the Bingerville botanical garden has gradually fallen into a state of degradation. Indeed, because of the lack of financial means to maintain and protect the garden, it is annexed by dwellings and public buildings, the buildings are in ruins and the equipment is in poor condition [6]. Left in a state of neglect for several years, it was rehabilitated in 1996. Its administration is currently ensured by the forestry administration which aim to carry out sustainable management. This management requires knowledge of its scientific state and the services it provides to populations [7]. Indeed, it is a site of relaxation, an education centre, and a meeting point, but above all a field of scientific research and regulation of CO_2 in the atmosphere. The main objective of this work is to highlight the importance of the botanical garden in the conservation of biodiversity in a context of strong anthropogenic pressure. Specifically, it aims to: (i) evaluate the floral richness of the garden space; (ii) assess its potential for biodiversity conservation.

2. MATERIAL AND METHODS

2.1. Study site

The Bingerville botanical garden, with an area of 55 hectares, is located in the northern part of the said city, more precisely between 5°21'44'' and 5°21'46'' North latitude and 3°53' 16'' and 3°53'22'' West longitude (Figure 1). The

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climate of the area is characterized by a bimodal rainfall regime (april-july and october-november) with an average annual rainfall of 1650 mm. The average monthly temperatures vary between 25°C and 29°C. The original vegetation, most of which was destroyed as part of the extension of the city of Abidjan, was characterized by dense evergreen forests with *Turraeanthus* africanus and *Heisteria parvifolia* [8].

2.2. Materials

The material used for the study differs, on the one hand, in biological material made up of plant species from the Bingerville botanical garden and on the other hand, in technical equipment usually used by the botanist (GPS, 50 m tape measure, data collection sheets, pruning shears, newsprint, etc.).

2.3. Methodology

2.3.1. Data gathering: For this study, data were collected using the "field tour" method, which has been used by many authors [9,10,11]. The field tour is the floristic survey technique that allows knowing the different species of a plot in the most exhaustive way possible [12,13]. The method consisted of walking the plot in all directions until no new species were found in the plot. For the study, 29 plots in the botanical garden were used as observation areas (Figure 2). This method has the advantage of taking into account the heterogeneity of the plot [11]. This method also allows for the consideration of agro-ecological importance, fast-spreading species or indicator species of certain environmental characteristics [11]. The species collected are determined using several works [14] and take into account the Angiosperms Phylogeny Group classification [15].

2.3.2. Data analysis: The floristic richness focused on the determination of the number of species within the limits of the botanical garden. The floristic composition consisted of identifying the characteristics of the flora studied. It was a question of specifying: the families, the genera, the biological types and the chorological affinities.

Biological types and chorological affinities have been designated from those identified by previous studies [16,17,18]. These are the endemic species of Upper Guinea (HG), West african (GCW) and ivorian (GCi), species listed on the red list [19] and species that have become rare and threatened with extinction [20]. In addition, species with commercial value are exploitable in accordance with forestry legislation in Côte d'Ivoire. They are currently 84 in number for Côte d'Ivoire [21] and are divided into 3 categories: P1 (commonly traded species), P2 (sporadically traded species) and P3 (species to be promoted).

With the aim of appreciating the mode of regeneration and conservation of the vegetation of the forest, we carried out a classification of the species according to the modes of dissemination of the diaspores (seeds, fruits or any other part of plant being used for the dissemination of the 'species). This classification distinguishes anemochory, zoochory, hydrochory and autochorie [22].

The degree of domestication is expressed as a percentage and gives an idea of the evolution of the number of species planted in a given environment compared to the spontaneous species that grow over time [23]. In the case of the Bingerville botanical garden, many species were introduced after the creation of the garden. After the identification of all the plant species present in the garden, they were divided into two groups: the species planted voluntarily (objectives of the garden) on the one hand, and on the other hand, those which are there in a way spontaneous or accidental.

The specific contribution (CS) due to the absolute frequency of a species i (FSe) is the translation of its contribution within a given plant formation. It is obtained by the ratio of the absolute frequency of the species (FSe) to the sum of the absolute frequencies of all the species encountered ($\sum_i^n$ FSe) [24].

2.3.3. Equations

$$CS(e) = \frac{FS(e)}{\sum_i^n FS(e)} \times 100 \qquad (1)$$

Where:

CS(e) being the specific contribution and **FS**(e) the specific frequency of species i.

The specific contributions of species have been grouped according to the work of Mangara et al., (2010) [25]:

- Species with **CS**(e) < 1% are said to be minor species or species with more or less negligible representativeness;
- Those with **CS**(e) between 1% and 4% are called potential species;
- Those whose **CS**(e) is greater than 4% are called major or very representative species.

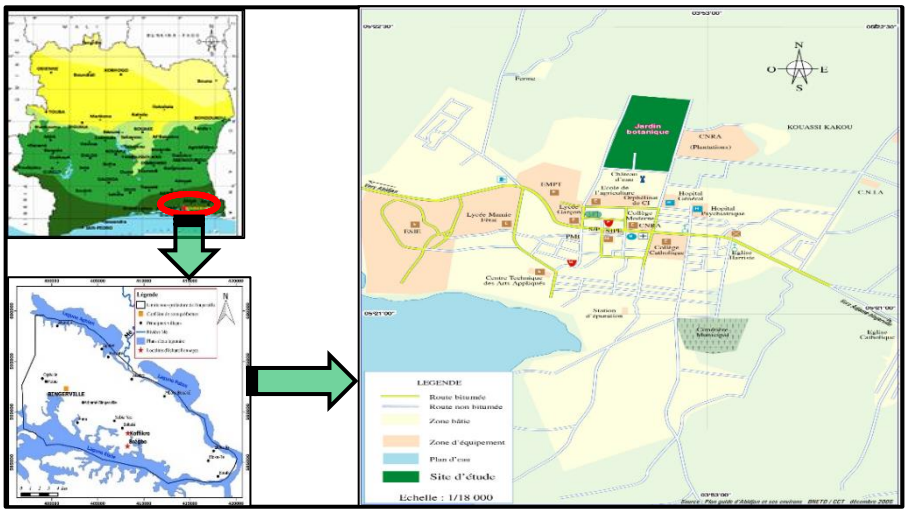

Figure 1: Geographical location of the Bingerville botanical garden.

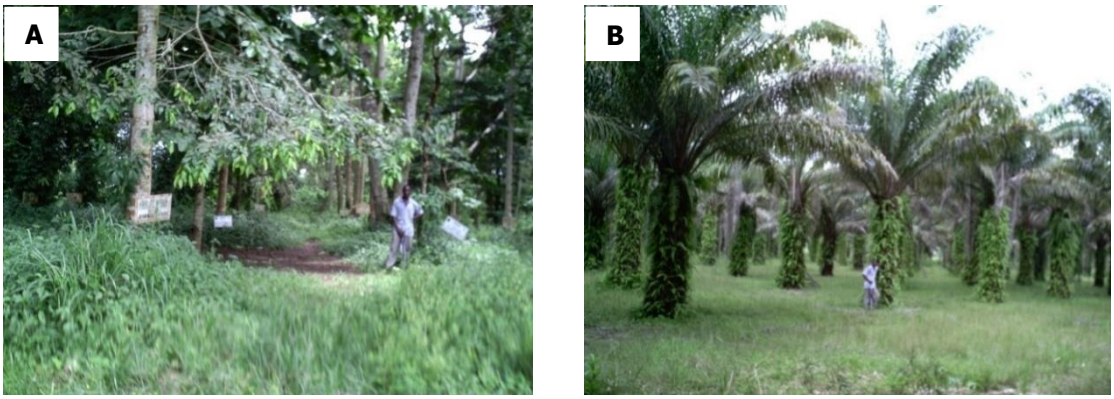

Figure 2: View of some biotopes of the botanical garden. A: Henri Konan BEDIE plot; B: plot of the palm grove.

3. RESULTS

3.1. Taxonomic structure of flora

The current flora of the Bingerville botanical garden is composed of 419 taxa divided into 290 genera belonging to 81 families (Table 1). This flora is composed of 411 species of Angiosperms (98.09%) where Dicotyledons are the most important with 349 species (83.29%). Gymnosperms follow with 6 species (1.43%), then Pteridophytes are poorly represented with 2 species (0.48%). The most important families in terms of species (Figure 3) are the Fabaceae, with 64 species (15.27%), the Euphorbiaceae, with 25 species (5.97%), the Malvaceae, the Poaceae, with 24 species (5.73%) and the Apocynaceae, with 15 species (3.58%). The most represented genera with at least 5 species are *Cassia*, with 9 species (2.15%), Ficus, with 7 species (1.67%), *Citrus*, with 6 species (1.43%), *Clerodendrum*, *Cyperus* and *Solanum*, with 5 species each (1.19%).

The flora of the botanical garden can be divided into three morphological types. It is characterised by a high representation of trees, with 259 species (61.81%), followed by herbs, with 124 species (29.59%). The lianas are poorly represented, with 32 species (7.64%).

3.2. Biological spectrum of flora

Analysis of the biological spectrum (Figure 4) shows a strong dominance of phanerophytes with 80.91% or 339 species. Among these, microphanerophytes and mesophanerophytes are the most represented with respectively 38.66%, i.e. 162 species and 25.06%, i.e. 105 species). Following the phanerophytes, come the therophytes, with 7.64%, i.e. 32 species, the geophytes and the hemicryptophytes, with 19 species, i.e. 4.53% each. Epiphytes, with 1 species (0.24%), are the least represented biological type.

3.3. Chorological spectrum of flora

Analysis of the chorological affinity spectrum showed that introduced species dominate the flora of the botanical garden at 42.72%, i.e. 179 species (Figure 5). This chorological group is followed by the Guinean-Congolian (GC, GCW) species

group, with 114 species (27.21%) and the transition zone (GC-SZ) species group, with 105 species (25.06%). The species of the Sudan-Zambezi zone (SZ) are less represented, with 13 species (3.10%).

3.4. Modes of dissemination of flora diaspores

The taxa of Bingerville botanical garden can be divided into three modes of dissemination of diaspores (Figure 6). They are zoochory, anemochory and autochory. Zoochory is the mode of the most observed dissemination, with a proportion of 59.43% (i.e. 249 species), whereas endozoochory is the most representative type of dissemination (45.58%). Next come anemochory (27.68%) and autochory (12.88%).

3.5. Degree of domestication of flora

The degree of domestication of the taxa inventoried in the garden is presented in Figure 7. This figure indicates that the species planted, within the framework of the objectives of the garden, represent 69% (i.e. 290 species) of the flora of the garden (Figure 8). Spontaneous species and cultivated taxa constitute the invasive species of the Garden and represent 31.26% (i.e. 129 species) of the flora (Figure 9). Species that grew naturally (spontaneous species) encompass 27% (i.e. 114 species) of the flora. As for the species cultivated by the surrounding populations in the garden, they represent 4% (i.e. 15 species) of the flora.

Table 1: Distribution of inventoried species according to major taxonomic levels of the Bingerville botanical garden.

Taxonomic levels	Trees	Lianas	Herbs	Global flora
Species	259	32	124	419
Genera	183	24	91	290
Families	49	15	37	80
Dicotyledons	253	34	62	349
Monocotyledons	-	2	60	62
Gymnosperms	6	-	-	6
Pteridophytes	-	-	2	2

3.6. Special status species: endemism, conservation and commercial values

The floristic richness of the botanical garden established during the study revealed 51 species (12.17%) with special status (Table 2). Among this group of species, 8 species (1.91%) are endemic to West Africa (GCW), 6 species (1.43%) are identified as endemic to Upper Guinea (HG). 4 species (0.95%) are cited as rare and threatened with extinction of the Ivorian flora by Aké-Assi (1998) [20]. In this same category, there are 32 species that are listed on the IUCN Red List (2020) [19], whereas vulnerable species are more numerous (15 species, or 3.58%). In addition, there are 37 species (8.83%) of high commercial value. Among these forest species, 28 are the main species (P1), which are commonly marketed, 4 are sporadically marketed species (P2) and 5 are species to be promoted (P3).

3.7. Species-specific contribution

The notion of specific contribution, which expresses the amplitude of the representativeness of a species in a phytocenosis, in direct relation to its absolute frequency, was determined for each species in the garden (Table 4). It made it possible to identify species which have a specific contribution greater than 1 and which are the most representative species. These species, 13 in number, contributed 14.73% to the flora of the botanical garden. *Cassia mimosoides* and *Thunbergia erecta* are the species with the highest specific contribution to the garden.

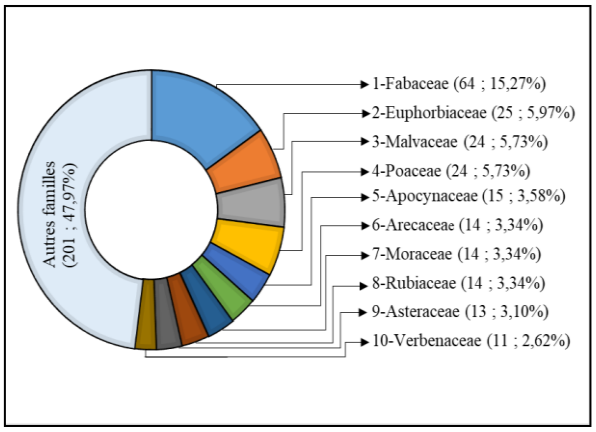

Figure 3: Spectrum of dominant families of the flora of the Bingerville botanical garden.

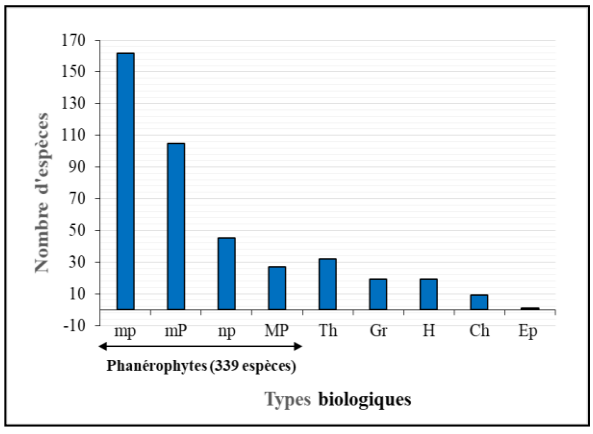

Figure 4: Spectrum of biological types of the flora of the Bingerville botanical garden.

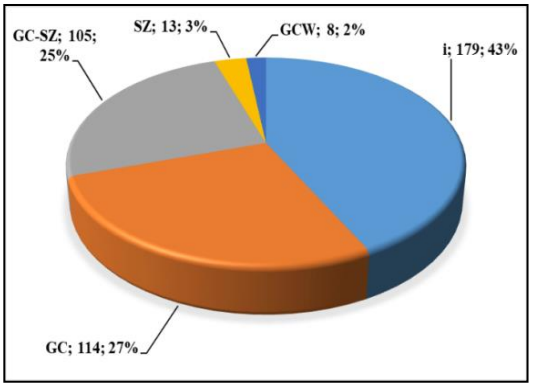

Figure 5: Spectrum of chorological affinities of the flora of the Bingerville botanical garden.

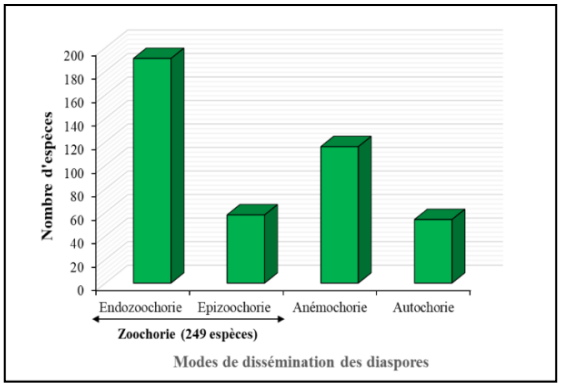

Figure 6: Spectrum of the modes of dissemination of the diaspores of the species of the Bingerville botanical garden.

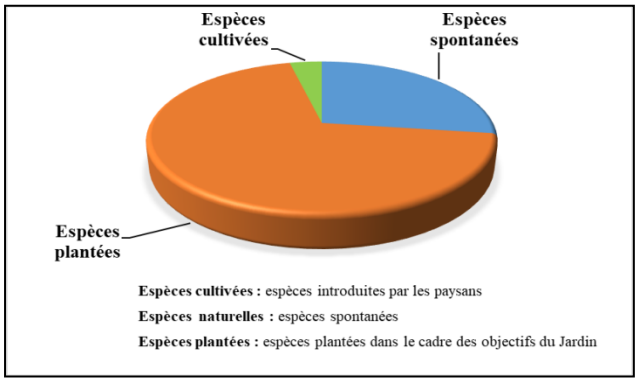

Figure 7: Distribution of species according to the degree of domestication of species in the Bingerville botanical garden.

Figure 8: View of species planted in the botanical garden. **C**: *Crescentia cujete* (exotic species); **D**: *Tarrietia utilis* (local species).

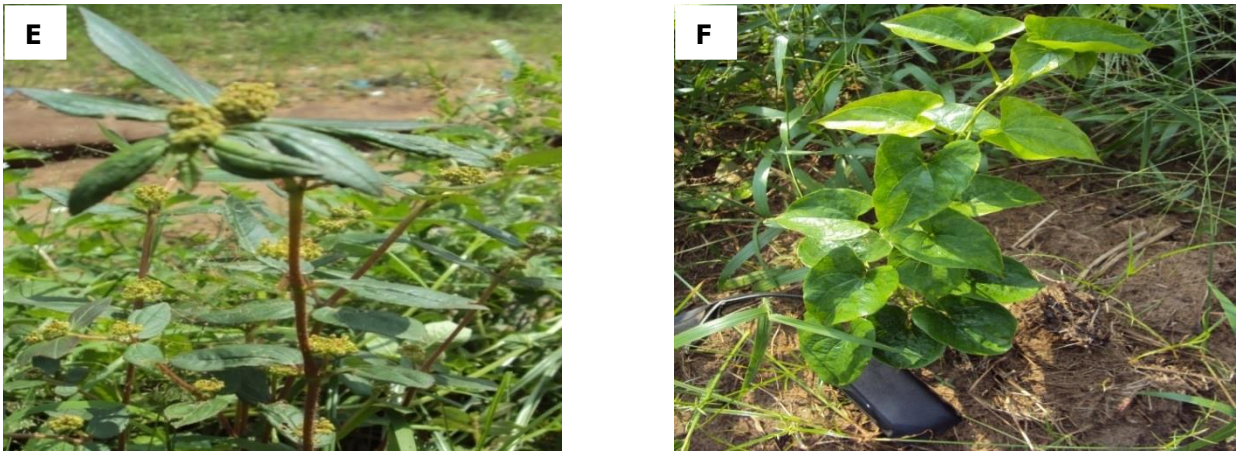

Figure 9: View of spontaneous and cultivated species in the botanical garden. **E**: *Euphorbia hirta* (spontaneous species); **F**: *Dioscorea cayenensis* (cultivated species).

Table 2: Special status species inventoried in the Bingerville botanical garden.

List of species	Level of endemism		Conservation status		Commercial Value
	GCW/GCi	H.G.	IUCN	Ake-Assi	
Afzelia africana			Vu		P1
*Afzelia bella*var. grace	GCW				P1
Albizia adianthifolia			LC		
Alchornea cordifolia			LC		
Alstonia congensis					P2
Anthocleista nobilis	GCW		LC		
Antiaris africana					P1
Antiaris welwitschii					P1
Baphia nitida			LC		
Berlinia occidentalis	GCW				P3
Canarium schweinfurthii					P1
Ceiba pentandra			LC		P1
Chrysophyllum perpulchrum					P1
Cola reticulata	GCW	HG	Vu		
Copaifera salikounda	GCW				P2
Cordia vines	GCW				
Cyperus alternifolius			LC		
Detarium senegalense			LC		P3
Entandrophragma angolense			Vu		P1
Entandrophragma cylindricum			Vu		P1
Useful entandrophragma			Vu		P1
Erythrina vogelii				PRE	
Erythrophleum ivorense					P1
*garcinia kola*Heckel			Vu		
Guarea cedrata		HG	Vu		P1
Guirboutia ehie		HG	LC		P1
Irvingia gabonensis			LR/nt		
Khaya ivorensis			Vu		P1
Lophira alata			Vu		P1
Mansonia altissima					P1
Milicia exelsa			LR/nt	PRE	P1
Milicia regia	GCW	HG	Vu	PRE	P1
Nauclea diderrichii			Vu		P1
Panicum repens			LC		
Parkia biglobosa			LC		
Pericopsis elata			EN	PRE	
Piptadeniastrum africanum					P2
Pouteria altissima			LR/cd		P1
Pterocarpus santalinoides			LR/Ic		
Pterygota macrocarpa			Vu		P1
Pycnanthus angolensis					P1
Ricinodendron africanum					P2
Sterculia tragacantha					P3
Tarrietia utilized	GCW	HG			P2
Terminalia ivorensis		HG	Vu		P1
Terminalia superba					P1
Tieghemella heckelii			EN		P1
Triplochiton scleroxylon			LR/Ic		P1
Turraeanthus africanus			Vu		P1
Uapaca guineensis					P3
Vitellaria paradoxa			Vu		

Legend: **GCi**: taxon endemic to Côte d'Ivoire; **GCW**: taxon endemic to the forest block west of Togo, comprising Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea, Guinea Bissau, Gambia and Senegal; **HG**: Taxon of Upper Guinea; **PRE**: Rare plants, which have become rare and are in danger of extinction; **LC**: Least Concern; **LR/lc**: Low Risk/Least Concern**; LR/nt**: Low Risk/Near Threatened **Vu**: Vulnerable; **EN**: en danger.

Table 3: Plant species with a specific contribution greater than 1.

No.	Plant species	Absolute frequency	Specific contribution
1	*Cassia mimosoides*	27	1.23
2	*Thunbergia erecta*	27	1.23
3	*Dioscorea alata*	26	1.19
4	*Rhoeo spathacea*	26	1.19
5	*Lagerstroemia flos-reginae*	26	1.19
6	*Tarrietia utilized*	26	1.19
7	*Aframomum melegueta*	25	1.14
8	*Acacia auriculaeformis*	25	1.14
9	*Aspilia bussei*	24	1.09
10	*Cestrum nocturnum*	24	1.09
11	*Panicum repens*	23	1.05
12	*Sida rhombifolia*	22	1.00
13	*Detarium senegalense*	22	1.00

4. DISCUSSION

According to the floristic study in the Bingerville botanical garden, 419 plant species have been identified. This flora is relatively richer than those of certain natural formations in Côte d'Ivoire [26, 27]. This botanical garden owes its richness of floristics to the association of natural and anthropized biotopes found there. Indeed, when natural and anthropized biotopes coexist, their respective floristic corteges interconnect and increase the local floristic richness [28]. Fabaceae, Euphorbiaceae, Malvaceae, Poaceae and Apocynaceae are the dominant families. This same floristic procession has already been reported in several studies of Ivorian forests [26-29].

The high presence of phanerophytes could be explained by the high diversity of tree species from local (mostly megaphanerophytes) or exotic (mostly microphanerophytes) tree plantations. The representativeness of nanophanerophytes is due to the colonization of garden space by spontaneous species. The low presence of therophytes could be explained by the absence of ploughing in the garden. Indeed, ploughing favours the conditions for germination of buried seeds, bringing them to the surface [30]. Ploughing also facilitates the propagation of vegetatively propagated species (geophytes) by cutting and spreading the organs of dissemination such as rhizomes, stolons and tubers [31].

The dominance of introduced species highlights the status of the Bingerville botanical garden, which is a site for the conservation of plant species from various backgrounds. This importance of exotic species reflects the desire of botanical garden managers to plant fast-growing ornamental species, for their shade or for landscape reasons in arboretums. Indeed, studies have shown a high proportion of these species in the 100-year-old and 20-year-old arboretums of the botanical garden [32]. The high proportion of Guineo-Congolese species (27.21%) is proof that the botanical garden retains part of its original floral identity, despite human activities. This is the result of the contribution of the natural forest present within the garden and the pioneer species that have colonized the fallow land and the arboretum for over 100 years. Similar results were observed in private gardens in the city of Yamoussoukro, in Côte d'Ivoire [33].

The spectrum of diaspore types reveals the dominance of endozoochore species (37.50%). The flora of the botanical garden is so far similar to that of dense secondary forests where the most frequent mode of dissemination is zoochory [29-34]. The zoochory of the botanical garden, as in many other biotopes [29-35], involves birds and frugivorous vertebrates present in the environment. The presence of non-negligible anemochorous species (27.68%) is due to the dominance of Fabaceae, of which the majority of species are trees with diaspores disseminated by the wind.

With regard to special-status species, their presence, number and variety show the importance of the botanical garden in the conservation of biodiversity. It serves as protection for so-called vulnerable, endangered, rare, endangered and endemic species [33]. The number of these species with special ecological status is estimated at 38. This characteristic of the Bingerville botanical garden 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 [26].

For the degree of domestication, despite the lack of maintenance of the garden, the inventory of taxa showed that planted species remain the most numerous compared to spontaneous species and cultivated species. This can be explained by the continuous reforestation carried out in the garden plots. Indeed, since 1996, this activity is much practised by the managers of the botanical garden [32]. The spontaneous species and the cultivated ones, although having a low percentage, however, present a better spatial distribution.

Within the perimeter of the botanical garden, certain species such as *Cassia mimosoides*, *Dioscorea alata*, *Aframomum melegueta*, *Aspilia bussei*, *Panicum repens* and *Sida rhombifolia* are characterized by a specific contribution of≥ 1%

constitute potential weeds which can prove to be very covering. Indeed, in previous work [36,37], cited by Traoré et al., (2005) [38], in their work in Burkina Faso showed that the most frequent species were also the most covered.

5. CONCLUSION

The study conducted in the Bingerville botanical garden has contributed to a better understanding of its conservation value through the characteristics of its richness and its floristic composition. It emerges from this study that the space of the botanical garden is rich in 419 species divided into 290 genera belonging to 81 botanical families. Fabaceae (15.27%) and Euphorbiaceae (5.97%) are the most represented families in the flora. Microphanerophytes (38.66%) and mesophanerophytes (25.06%) are the most numerous biological types. The flora presents a biogeographical diversity made up of 42.72% of introduced species and 27.21% of species from the Guinean-Congolese centre of endemism. These two groups of species total more than half (69.93%) of the listed species. The botanical garden is a refuge for species with special status characteristic of its value for the conservation of biodiversity. However, the high proportion of introduced species identified in this study to the benefit of native species is a factor in the loss of the floristic identity of the botanical garden. Also, the planting of local species should instead be encouraged through training and awareness raising for the managers of this site.

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