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Typology and Floristic Diversity of Urban Green Spaces Along an Urbanisation Gradient: Implications for Ecological Resilience in Lomé and Kara (Togo)

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ABSTRACT

Urban green spaces (UGS) are essential to the sustainability of cities through the ecosystem services they provide (climate regulation, biodiversity conservation, and improvement of the living environment). In West Africa, rapid urbanisation is compromising their development, and in Togo, data on their typology and floristic diversity remain limited. This study, conducted in Lomé and Kara, aims to fill this gap by characterising the types of UGS and their floristic composition for better sustainable management. Based on field surveys, floristic inventories, and administrative data, a typology adapted from the AIVF reference system was used, and diversity was assessed using the Shannon (species richness and relative abundance) and Pielou indices (balanced distribution of individuals). The results indicate greater diversity in Lomé than in Kara according to four functional categories, with a total of 14 types of EVUs and 368 species (82 species/hectare) identified in Lomé, compared to 12 types and 225 species (78 species/hectare) identified in Kara. This reflects a more pronounced gradient of artificialisation in the capital. Floristic homogenisation is observed in both cities, dominated by exotic species such as *Azadirachta indica* (Fabaceae), *Mangifera indica* (Meliaceae), and *Senna siamea* (Poaceae). The contrasts in the distribution of biological and phytogeographical types reflect the socio-ecological specificities of the two urban contexts. These results highlight the influence of Urban and bioclimatic factors on ecosystems, underscoring the need to integrate native species to enhance cities' ecological resilience.

1. INTRODUCTION

Urban green spaces (UGS) constitute vital components of the urban fabric, playing a fundamental role in maintaining ecological balance and urban resilience [1-4]. They improve air quality and regulate temperature [5, 6]. UGS contribute to sustainable rainwater management by promoting infiltration and limiting runoff, which helps to prevent flooding and improve urban water quality [7]. Urban parks and gardens host a variety of recreational, sporting, and cultural activities, strengthening community cohesion [8, 9]. They also contribute to the beautification of the urban environment and can increase property values in neighbouring areas [10-12]. Some UGS also serve as places to learn about nature, ecology, and environmental issues, particularly for younger generations [8]. Additionally, these spaces are reservoirs of biodiversity, sheltering plant and animal species adapted to human-altered environments and promoting ecological connectivity and the regeneration of urban ecosystems [13, 14].

However, the rapid growth of cities, coupled with extensive urbanisation, is exacerbating the fragmentation and gradual disappearance of these spaces. This threatens their ecological integrity and reduces their capacity to provide essential ecosystem services [15-18]. Knowledge of UGS requires an understanding of their floristic and typological characteristics, which are closely linked to the specific climatic, socio-economic, and development conditions of each territory. In European and North American cities, urban vegetation mainly comprises exotic species that were introduced for their resilience to urban conditions and ornamental value [19, 20]. Conversely, in Asia, particularly in Beijing and Tokyo, the structure of UGS is closely linked to landscaping policies that promote the harmonious integration of green spaces and urban infrastructure. Several studies have been conducted in various cities in Africa, such as Portonovo, Malanville, Cotonou in Benin, Marrakech in Morocco, Ziguinchor in Senegal, Bujumbura in Burundi, and Nairobi in Kenya, where research has also highlighted phenomena of fragmentation, floristic regression, and pressures linked to rapid urbanisation on the typology and floristic diversity of UGS [21-27]. Furthermore, these studies emphasise the ecological, aesthetic, and educational roles of urban green spaces, as well as their contribution to mitigating the negative effects of urbanisation.

In Togo, there is a lack of knowledge regarding the typology

and floristic composition of UGS. While some earlier studies have provided valuable insights on urban forestry in select cities across the country [28-36], these studies are limited in scope, geographically dispersed, and often outdated. This lack of documentation is particularly concerning given the rapid urbanization underway in Togo, with an urbanization rate estimated at 42.9% according to the most recent national population census [37]. Lomé, the capital city, with an annual urban growth rate of about 3.2% [38], alone accounts for 63% of this urban population, while the Kara region represents 28.9%, resulting in increasing pressure on vegetated land and an accelerated transformation of the urban landscape. In this context, Lomé, located in the humid Guineo-Congolian ecological zone in the south, and Kara, situated in the drier Sudanian-Guinean zone in the north, serve as emblematic examples of contrasting urban dynamics, both ecologically and socio-spatially. This north-south gradient, characterized by distinct climatic, ecological, and demographic profiles, provides a relevant framework for analyzing the differential impacts of urbanization on the structure, typology, and floristic diversity of UGS.

Analysing the typology and floristic diversity of UGS is an essential step in understanding their contribution to environmental quality and the well-being of city dwellers. Indeed, the structure of these spaces reflects local ecological conditions as well as landscaping choices influenced by anthropogenic and climatic factors. In light of these considerations, the objective of this study is to characterise the floristic diversity and distribution of UGS in Lomé and Kara. The aim is to contribute to the implementation of sustainable management strategies that are adapted to local realities. It will thus enhance existing knowledge by providing a detailed analysis of the types of UGS and their floristic composition, while contributing to a better understanding of urban ecological dynamics and the development of conservation and planning policies for sustainable urban development.

2. METHODOLOGY

2.1 Study area

This study was conducted in Lomé and Kara, the two largest urban centers in Togo, a country located in West Africa. Lomé, the national capital, is situated at the southernmost tip of the country in the Maritime Region, between latitudes 6°05' and 6°50' North and longitudes 1°00' and 1°50' East (Figure 1). Located within Ecological Zone V [39], Lomé comprises two administrative prefectures (Golfe and Agoè-Nyivé) subdivided into 13 municipalities. The city experiences a Guinean sub-equatorial climate characterized by an average annual rainfall of approximately 800 mm and a mean temperature of 28°C. The local soils are heterogeneous, including marine sands, alluvial deposits, and sandy clays.

Kara, Togo's second most important city, lies over 400 kilometers north of Lomé, within Ecological Zone II [40]. It spans three of the four municipalities of the Kozah Prefecture—namely Kozah 1, Kozah 2, and Kozah 3. Kara is subject to a Sudanian tropical climate with distinct dry and wet seasons, and receives an average annual rainfall ranging from 1100 to 1700 mm. The city's soils are predominantly composed of basic igneous rocks [40].

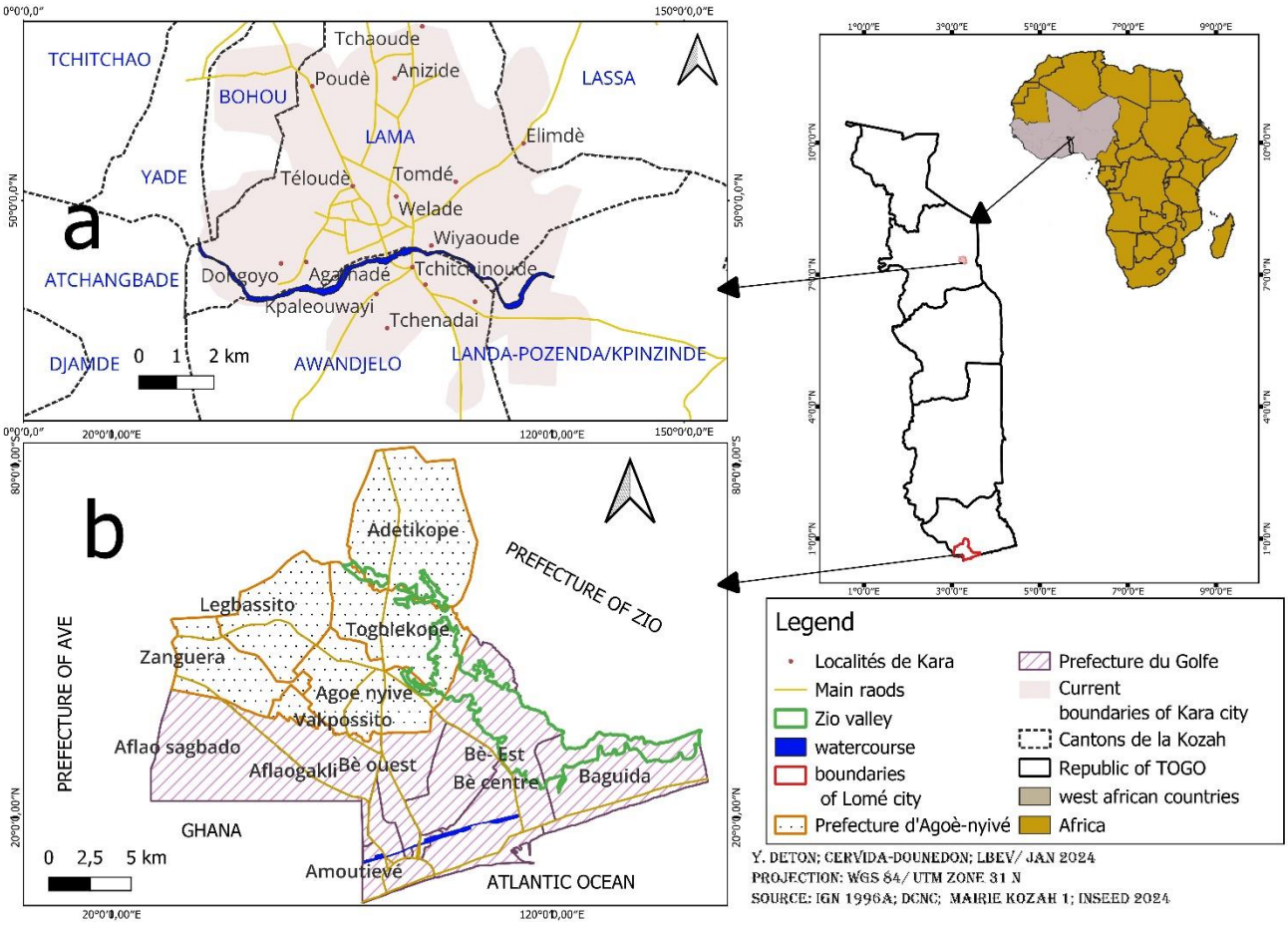

Figure 1. Study area map (a) Lomé city, (b) Kara city

2.2 Data collection

The lists of green spaces in Lomé and Kara were obtained from local municipalities and institutions involved in urban planning, including the Ministries of Environment and Urban Planning, as well as municipal and prefectural technical services. This data was cross-referenced and validated using Landsat 9 OLI_TIRS satellite images with a resolution of 30m × 30m acquired between February and March 2022, a period corresponding to the dry season, in order to minimise cloud cover, and then validated by field surveys to confirm the existence and condition of the identified green spaces. The geographic coordinates of each site were recorded using a Global Positioning System (GPS) device.

2.3 Data processing and analysis collection

Each identified green space was described to highlight its functional characteristics, drawing upon the typology established by Jancel [41], and later adopted by Benkouachi and Alatou [42]. In addition, the classification was guided by the framework developed by the "Association des Ingénieurs des Villes de France" (AIVF), which distinguishes twelve types of UGS [43, 44], ranging from parks to managed natural areas, including spaces adjacent to roads, public buildings, educational and sports institutions, among others. This typology was adapted to reflect local specificities. The various types were then grouped into four categories based on their functional characteristics. Furthermore, the floristic diversity of each UGS was assessed using field-collected botanical data.

The floristic inventory was conducted using the method of establishing plots of varying sizes. The dimensions for the green spaces are as follows: 500 metres by 4 metres on either side of the roads and 20 metres by 20 metres in other types of green spaces. In each plot, all species present were recorded and their abundance assessed using the Braun-Blanquet scale (where: (+: rare species, coverage from 0 = 0 to 1%; 1 = 1 to 5%; 2 = 5 to 25%; 3 = 25 to 50%; 4 = 50 to 75%; 5 = 75 to 100%), a scale commonly used in phytosociological studies in West Africa). For each type of UGS, a minimum of three replicate plots ($n \geq 3$) were established to capture within-type variability. Each floristic survey was carried out in a standard 100 m² plot (10 m × 10 m), a sampling unit that is widely used in floristic studies in tropical, urban, and peri-urban environments [45, 46]. This plot size was selected to ensure comparability across heterogeneous urban landscapes while remaining manageable for field inventory. The use of multiple standardised plots per UGS type enhances the statistical robustness of floristic comparisons across Lomé and Kara.

2.4 Processing and analysis of floristic data

Reference documents such as the analytical flora of Togo [47] and the flora of Benin [48] were used to identify these species and determine their origin (local or exotic). The data collected was then entered into Excel spreadsheets to represent the quantitative data. The Shannon diversity index and Pielou's evenness index will be calculated to determine the specific diversity of green spaces.

❖ Species Richness

Species richness, denoted as S, refers to the number of species present in a given green space. However, this metric alone is insufficient to fully assess the diversity of planted trees within green areas. Thus, species richness, the Shannon diversity index, and Pielou's evenness index are commonly used to compare different plant communities or the same community across different time periods. In addition to these, other diversity indices were also calculated**.**

❖ Shannon Diversity Index

The Shannon index takes into account both species richness and the evenness of individual distribution among species. Expressed in bits, the index typically ranges between 0 and 5. A higher index value indicates greater biodiversity and ecological stability. The formula for the Shannon index is:

$$\mathrm{Ish} = -\sum_{i=1}^{s}\left(\frac{n_i}{n}\right)\log_2\left(\frac{n_i}{n}\right)$$

where,

Ish = Shannon diversity index

S = total number of species (species richness)

n_i = number of individuals of species i

n = total number of individuals across all species

$\frac{n_i}{n}$ = proportion of individuals belonging to species i

❖ Pielou's Evenness

This evenness measures the uniform distribution of individuals among species, ranging from 0 (strong dominance of one species) to 1 (balanced distribution), and corresponds to the ratio between effective diversity (H) and theoretical maximum diversity (H_{max}).

$$\mathrm{Eq} = \frac{\mathrm{Ish}}{H_{max}}$$

With

$$H_{max} = \log_2 S$$

where,

Eq = Pielou's evenness index

Ish = Shannon diversity index

H_{max} = maximum possible diversity if species were equally abundant

S = total number of species

3. RESULTS

3.1 Typology of green spaces in Lomé and Kara

The census results revealed a diversity of green spaces in both cities, categorised as 14 types in Lomé and 12 types in Kara. These types were then categorised into four main functional groups (Table 1).

Recreational and Social Green Spaces (RSGS) include parks, squares, cottage gardens, camping areas, and green spaces around stadiums or monuments (Figure 2). In Lomé, these spaces are varied and well distributed, offering places for leisure, relaxation, and socialising, while in Kara, their presence is more limited, concentrated around family gardens and a few public squares.

At the same time, green spaces along roads and accompanying infrastructure (GSRI), which include trees lining roads and vegetation strips along roadsides, are more visible in Lomé, where they contribute to urban beautification, thermal regulation, and noise reduction, although they are rarely used for recreational purposes (Figure 3).

Table 1. Functional categories and types of urban green spaces identified in Lomé and Kara

Functional Category	Corresponding Types of Green Spaces		Primary Function of the Category	Examples	Specific Observations / Usages
	Lomé	Kara			
Recreational and Social Green Spaces (RSGS) with 16.78% of UGS in Lomé and 5.43% of UGS in Kara	- Urban parks and squares -Home gardens/ household gardens -Campgrounds, reception areas, hotels -Green spaces in stadiums and sports complexes -Landscaped green spaces in public squares and monuments	-Home gardens/ household gardens -Campgrounds, reception areas, hotels -Green spaces in stadiums and sports complexes -Landscaped green spaces in public squares and monuments	Provide residents with areas for relaxation, recreation, play, and social interaction	Municipal Park, neighbourhood square, community garden	Publicly accessible; multifunctional spaces used for leisure, cultural activities, physical exercise, and gatherings
Green spaces along roads and accompanying infrastructure (GSRI) with 29.53% of UGS in Lomé and 11.96% of UGS in Kara	- Green spaces alongside roads -Trees lining public roads, grouped together or not	-Trees lining public roads, grouped together or not	Enhancement of urban aesthetics, thermal regulation, and mitigation of nuisances (noise, air pollution)	Linear or clustered tree plantings along major avenues or roads	Structuring role in the urban landscape; secondary ecological value (e.g., supporting biodiversity)
Green Spaces Integrated into Public Urban Infrastructure (GSPUI) with 32.21% of UGS in Lomé and 35.87% of UGS in Kara	-Green spaces accompanying public buildings -Green spaces in social and educational establishments	-Green spaces accompanying public buildings -Green spaces in social and educational establishments	Enhancement of architectural structures, landscape integration, and microclimatic improvement	Schoolyard garden, vegetated area around a hospital or administrative center	Semi-public usage contributes to urban environmental health and aesthetics; it supports the well-being of users
Green spaces with a specific function: ecological, cultural or institutional (GSECI) with 21.48% of UGS in Lomé and 46.74% of UGS in Kara	- Research gardens / botanical gardens -Fallow fields, kitchen gardens -Cemeteries -Green spaces associated with religious institutions -Administrative reserves	- Research gardens / botanical gardens -Fallow fields, kitchen gardens -Cemeteries -Green spaces associated with religious institutions -Administrative reserves	Targeted objectives: scientific research, contemplation, spirituality, cultural heritage, and land-use planning. Ecological preservation and human-nature reconnection	University Botanical Garden, vegetated cemetery, green area of a religious center, urban kitchen garden, sacred forests, managed wetlands, forest remnants	Restricted or specific-use areas; sometimes partially open to the public; heritage value often protected by legal or traditional norms; key role in cultural identity and environmental education; low degree of artificialization; strong support for biodiversity

Figure 2. RSGS. (a) Square paths; (b) Hotel GS; (c, d) Landscaped green spaces in public squares and monuments

Figure 3. GSRI. (a, c) GS of educational establishments; (b) GS of health centres; (d) GS integrated into the autonomous district town hall of Greater Lomé

Figure 4. GSPUI. (a, c) UGS in schools; (b) UGS in health centres; (d) UGS integrated into the autonomous district town hall of Greater Lomé

Figure 5. GSECI. (a) GS of religious centre; (b) UL Botanical Garden; (c) Fields and fallow land; (d) Sacred forest relic

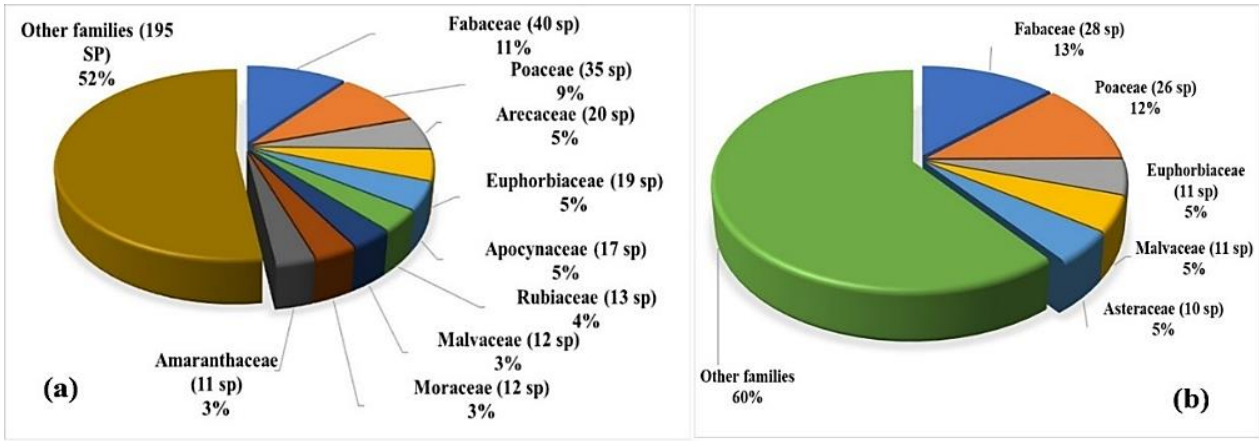

Figure 6. Specific spectrum of families (sp: species) (a) Lomé, (b) Kara

In addition, green spaces integrated into public buildings (EVBP), located around administrative buildings, schools, hospitals, and shopping centres, are present in both cities and contribute to architectural aesthetics and microclimatic comfort, while fulfilling a semi-public function that promotes the well-being of users (Figure 4).

Finally, Green spaces with a specific function; ecological, cultural or institutional (GSECI), such as botanical gardens, cemeteries, fields and fallow land, religious green spaces and administrative reserves, are more diverse in Lomé than in Kara; they serve specific purposes such as research, spirituality or ecological conservation, while being relatively unspoilt and having high heritage and cultural value (Figure 5).

3.2 Floristic inventory

Floristic analysis reveals greater species richness in the green spaces of Lomé (Figure 6(a)), with a total of 368 species divided into 98 families, compared to 225 species belonging to 63 families in Kara (Figure 6(b)). In Lomé, the most represented families, accounting for 47.86% of the species recorded, are Fabaceae (40 species, or 11%), followed by Poaceae (35 species, 9%), Arecaceae (20 species, 5%), Euphorbiaceae (19 species, 5%), Apocynaceae (17 species, 5%), Rubiaceae (13 species, 4%), Malvaceae (12 species, 3%), Moraceae (12 species, 3%) and Amaranthaceae (11 species, 3%). In Kara, although diversity is lower, Fabaceae (28 species, 13%) and Poaceae (26 species, 12%) also dominate, followed by Euphorbiaceae and Malvaceae (11 species each, or 5%), then Asteraceae (10 species, 5%). Unlike Lomé, no family in Kara exceeds the threshold of 30 species, illustrating the lower floristic diversity in this city.

3.3 Frequency distribution of species

In Lomé, the floristic composition of green spaces is marked by the strong dominance of *Azadirachta indica* A. Juss., which reaches a relative frequency of 60.42%, reflecting a relatively homogeneous plant landscape (Figure 7(a)). In addition, 62 species, representing 16.84% of the flora, have intermediate frequencies between 5% and 50%, including Elaeis guineensis Jacq. (32.64%), *Mangifera indica* L. (29.86%), *Khaya senegalensis* (Desv.) A. Juss. (25.00%) and *Cocos nucifera* L. (24.31%). However, the majority of species, i.e., 304, have frequencies of less than or equal to 5%. The specific distribution curve follows a logarithmic function with a good

fit (R^2 = 0.82), confirming a relatively homogeneous floristic structure dominated by a single highly represented species.

In Kara (Figure 7(b)), the specific distribution is even more unbalanced, with three main species, *Azadirachta indica*, *Senna siamea* (Lam.) H.S.Irwin & Barneby and *Mangifera indica*, each reaching or exceeding 50% frequency, highlighting an even more marked floristic dominance than in Lomé. The majority of other species have very low frequencies, often less than 5%. As in Lomé, the distribution follows a well-adjusted logarithmic trend, reflecting a floristic structure dominated by a small number of species adapted to urban constraints and often chosen for their ornamental or functional uses.

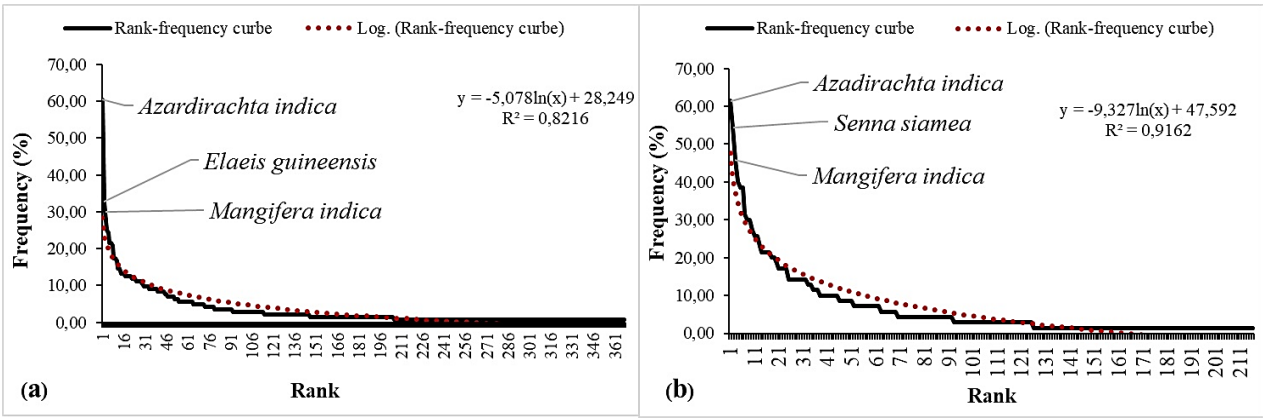

Figure 7. Frequency distribution of species (a) Lomé, (b) Kara

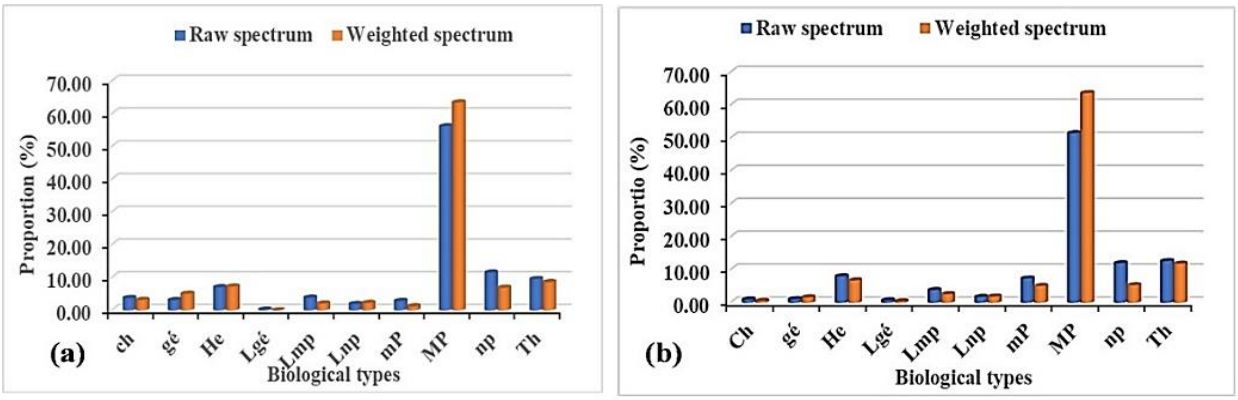

Figure 8. Biological types of flora in green spaces (a) Lomé, (b) Kara

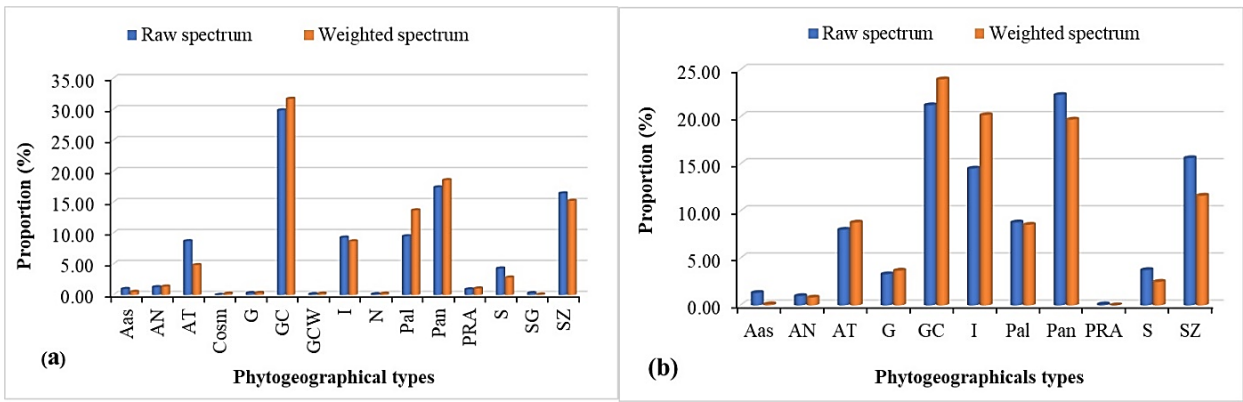

Figure 9. Phytogeographic types of flora in green spaces (a) Lomé and (b) Kara

3.4 Biological and phytogeographical spectra

As illustrated in Figure 8, the analysis of biological types indicates that in Lomé and Kara, macrophanerophytes (MP) predominate significantly in the urban floral composition. In the city of Lomé, these values are approximately 65% and 70% respectively, whereas in Kara, the corresponding figures are slightly lower, at around 55% and 65%. This predominance is indicative of a substantial presence of large trees in both cities, with a more pronounced ecological impact in Lomé. Conversely, the Kara site is distinguished by a more balanced biological diversity, characterised by a greater representation of therophytes (TH), nanophanerophytes (NP), and other biological types. This suggests a more varied and potentially less homogeneous urban vegetation than that of Lomé.

With regard to phytogeographic types (Figure 9), in Lomé,

the phytogeographic spectrum shows a clear predominance of species of Guineo-Congolese (GC) origin, representing approximately 32% in the raw spectrum and more than 35% in the weighted spectrum. The pantropical (Pan) and palaeotropical (Pal) types follow with significant proportions: approximately 15% to 20% for each in both spectra. There is also a notable representation of Sudano-Zambesian (SZ) species (~13% in the weighted spectrum), but very low in the raw spectrum.

In contrast, in Kara (Figure 9(b)), the distribution is more balanced, although Guineo-Congolese (GC) types are also the most represented (~20% raw, ~22% weighted). Intertropical (I) and pantropical (Pan) types also occupy an important place (between 15% and 20%). Unlike Lomé, the proportion of Sudano-Zambesian species is slightly more visible here (~10% weighted). Other types, such as Afro-tropical (AT) and Sudanese (S), remain very marginal in both cities.

3.5 Floristic assessment of green space types

3.5.1 Recreational and Social Green Spaces (RSGS)

The flora of GSEC in the city of Lomé has a higher species richness (175 species in 61 families) compared to that of the city of Kara (69 species in 31 families). In fact, in the city of Lomé (Figure 10(a)), the flora of EVRS is dominated by several families, notably Fabaceae with 20 species representing 11% of the total, followed by Poaceae (18 species, 10%), Euphorbiaceae (14 species, 8%), Arecaceae (11 species, 6%) and Apocynaceae (10 species, 6%). The other families alone account for 59% of the floristic composition. In contrast, in the city of Kara (Figure 10(b)), Fabaceae remain dominant (7 species, or 12%). Research indicates that Euphorbiaceae have 6 species (10%), while Apocynaceae and Malvaceae each have 4 species (7%). It is evident that a significant proportion of the total is accounted for by other families (64%).

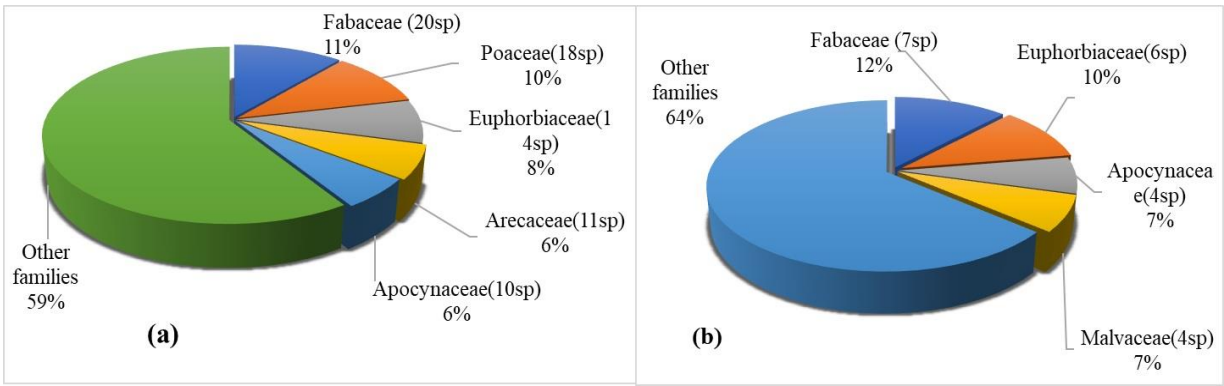

Figure 10. Specific spectrum of RSGS families (a) Lomé (b) Kara

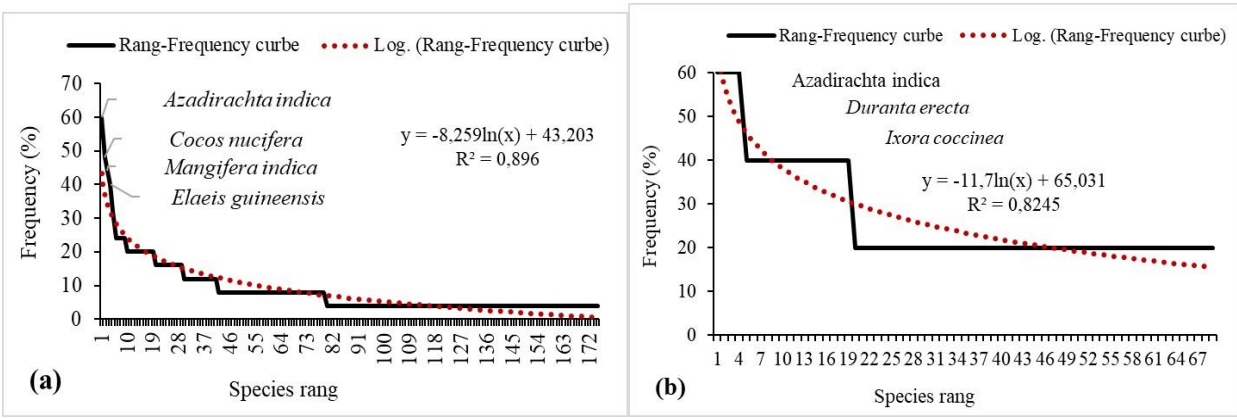

Figure 11. Frequency distribution of RSGS species (a) Lomé (b) Kara

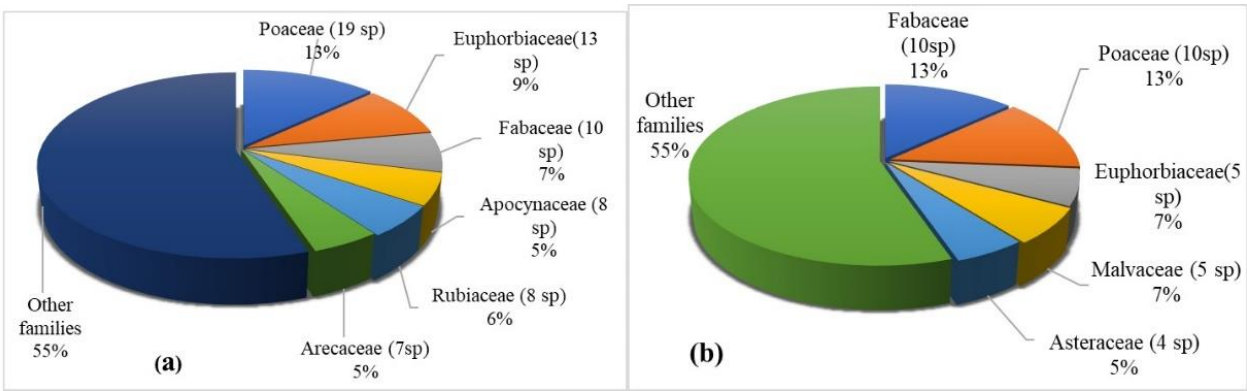

Figure 12. Specific spectrum of GSRI families (a) Lomé (b) Kara

The frequency of dominant species demonstrates a high concentration in Lomé (Figure 11(a)) around a few widely utilised species, such as *Azadirachta indica*, which dominates with a frequency of over 60%, followed by Cocos nucifera, Mangifera indica, and Elaeis guineensis, reflecting significant species heterogeneity. In Kara (Figure 11(b)), the distribution of frequencies is more homogeneous, although still dominated by certain ornamental species, namely Azadirachta indica, followed by *Duranta erecta* L., Ixora coccinea L., and *Senna siamea*.

3.5.2 Green spaces along roads and accompanying infrastructure (GSRI)

With regard to species richness, certain families are found to be highly dominant in both cities. In the city of Lomé, the most represented families are Poaceae (19 species, 13%), Euphorbiaceae (13 species, 9%) and Fabaceae (10 species, 7%), while in Kara, they are Fabaceae and Poaceae (10 species each, or 13%) as well as Euphorbiaceae and Malvaceae (5 species each, or 7%) (Figure 12).

Lomé exhibits a more balanced distribution of species, with a moderate prevalence of *Azadirachta indica*, followed by *Ficus polita, Khaya senegalensis,* and *Terminalia catappa* E, whose frequencies remain relatively stable. In contrast, in Kara, *Azadirachta indica* is dominant, with a much higher frequency, followed by a few secondary species such as *Mangifera indica* and *Senna siamea* (Figure 13). This reflects a more homogeneous and functionally less diverse flora.

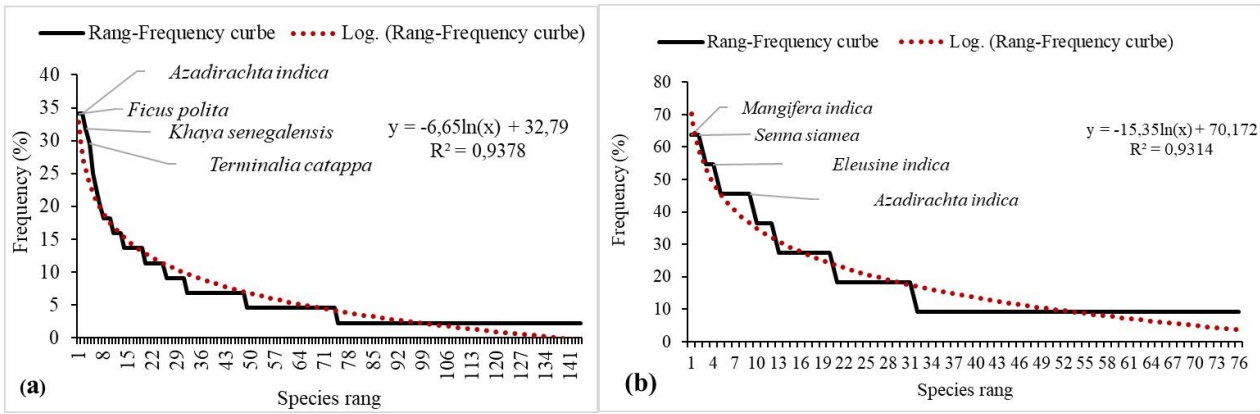

Figure 13. Frequency distribution of GSRI species (a) Lomé (b) Kara

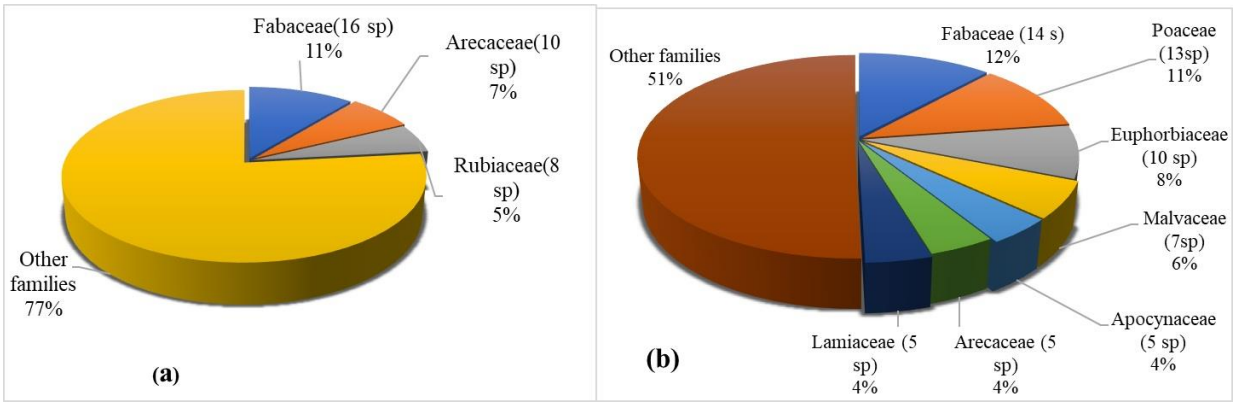

Figure 14. Specific spectrum of GSPUI families (a) Lomé (b) Kara

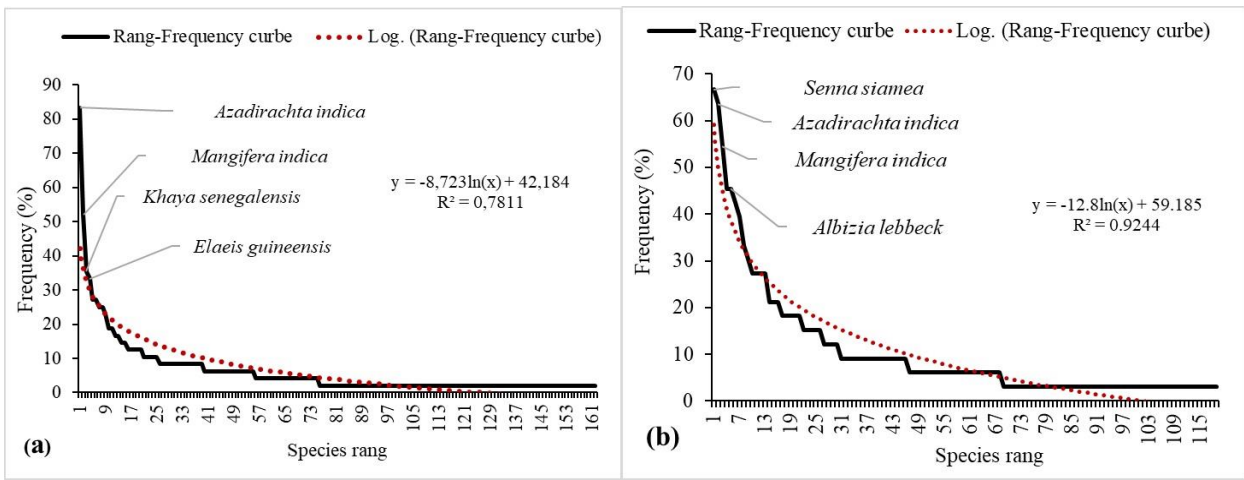

Figure 15. Frequency distribution of GSPUI species (a) Lomé (b) Kara

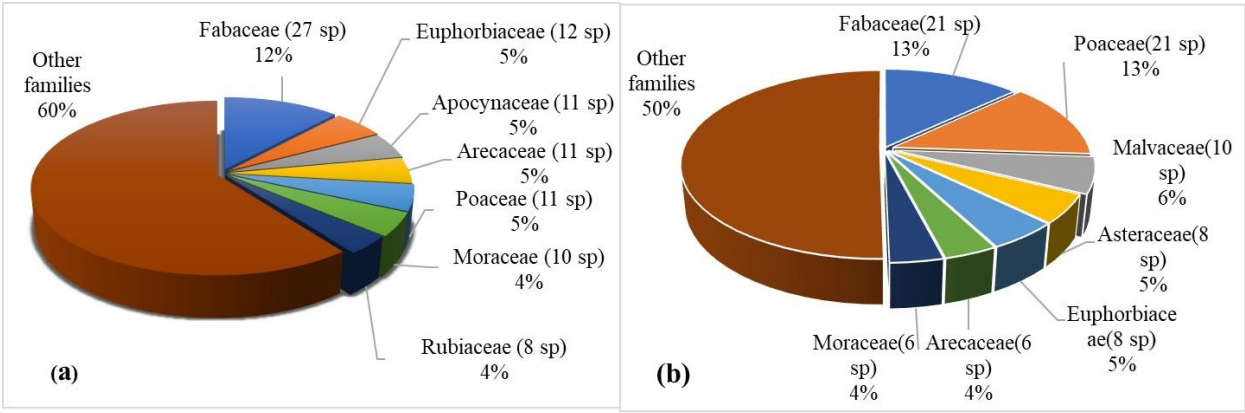

Figure 16. Specific spectrum of GSECI families (a) Lomé (b) Kara

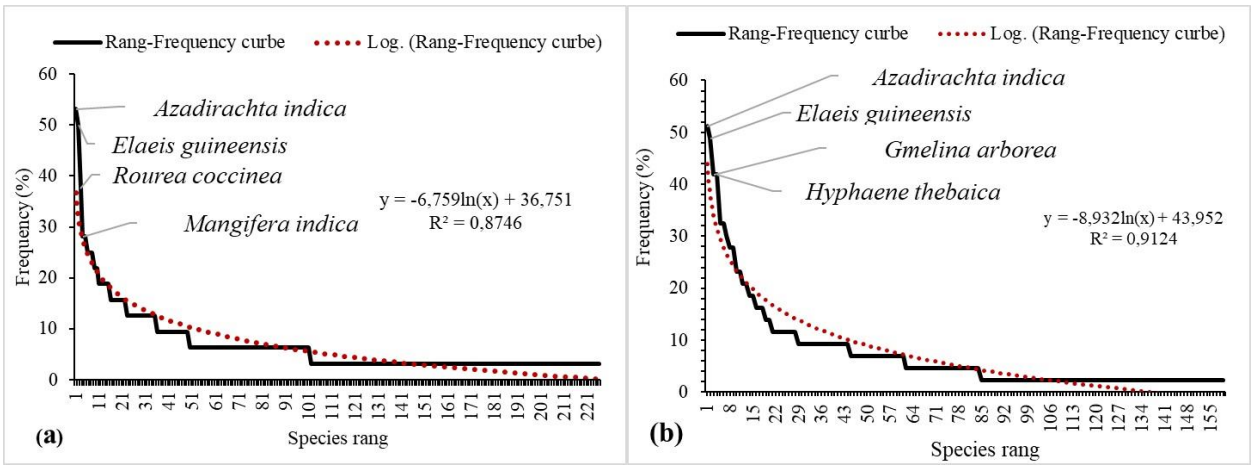

Figure 17. Frequency distribution of GSECI species (a) Lomé (b) Kara

Table 2. Shannon diversity index and Pielou evenness of UGS types in Lomé and Kara

Functional Category	Corresponding Types of Green Spaces	Shannon Diversity Index (Ish)		Pielou's Evenness (Eq)	
		Lomé	Kara	Lomé	Kara
Green spaces along roads and accompanying infrastructure (GSRI)	Trees lining public roads. grouped together or not)	1.85	2.96	0.53	0.33
	Green spaces alongside roads	11.05		0.09	
Green Spaces Integrated into Public Urban Infrastructure (GSPUI)	Green spaces in social and educational establishments	1.89	7.32	0.53	0.14
	Green spaces accompanying public buildings	10.94	9.33	0.09	0.10
	Campgrounds. reception areas. hotels	10.63	1.75	0.09	0.56
Recreational and Social Green Spaces (RSGS)	Landscaped green spaces in public squares and monuments	9.04	1.12	0.1	0.89
	Green spaces in stadiums and sports complexes	3.04		0.29	
	Home gardens/ household gardens	1.92	0.45	0.52	2.21
	Urban parks and squares	6.80		0.14	
Green Spaces with a Specific Function: Ecological, Cultural, or Institutional (GSECI)	Green spaces associated with religious institutions	11.08	7.04	0.08	0.14
	Fallow fields. kitchen gardens	10.07	11.61	0.09	0.09
	Cemeteries	-	1.05	-	0.13
	Research gardens / botanical gardens	7.34		0.13	
	Administrative reserves / Natural plant formations	1.85	10.55	0.53	0.09

3.5.3 Green spaces integrated into urban public buildings (GSPUI)

A comparative analysis of GSPUI reveals that Lomé exhibits a greater floral diversity, with 162 species divided into 46 families, compared to 119 species and 44 families in Kara. In the city of Lomé, the most represented families are Fabaceae (16 species, 11%), Arecaceae (10 species, 7%), and Rubiaceae (8 species, 5%). In contrast, other families possess a lesser number of species, typically fewer than eight. In the genus Kara, the most represented families are Fabaceae (14 species, 12%), Poaceae (13 species, 11%), and Euphorbiaceae (10 species, 8%) (Figure 14).

The rank-frequency curves (see Figure 15) demonstrate a marked predominance of a single species in both cases. The most prevalent species in the former location was *Azadirachta indica*, with a frequency of over 80%, while in the latter location, *Senna siamea* was the most prevalent, with a frequency of around 70%. However, the curve declines more sharply in Lomé, reflecting a greater inequality in species distribution, while in Kara, the curve declines more gradually, suggesting a slightly more balanced distribution among secondary species.

3.5.4 Green spaces with specific ecological, cultural, or institutional functions (GSECI)

Lomé and Kara exhibit contrasting floristic profiles in their GSECI. A thorough examination of Figure 16 reveals that the city of Lomé exhibits a higher level of species richness in comparison to Kara. A total of 226 species were recorded in the city of Lomé, divided into 49 families. The most represented families are Fabaceae (27 species, 12%); Euphorbiaceae (12 species, 5%); Apocynaceae (11 species, 5%); Arecaceae (11 species, 5%); and Poaceae (11 species, 5%). In the region of Kara, a total of 159 species were documented, classified into 37 distinct families. The most represented families are Fabaceae (21 species, 13%), Poaceae (21 species, 13%), and Malvaceae (10 species, 6%).

In terms of specific dominance, *Azadirachta indica* is clearly dominant in both cities, reaching nearly 50% in Lomé and around 60% in Kara, where the frequency distribution exhibits a more precipitous decline, as indicated by the steeper slope (Figure 17).

3.6 Shannon diversity index and Pielou's evenness

An analysis of the Shannon index (Ish) and Pielou's evenness (Eq) applied to urban green spaces in Lomé and Kara reveals striking contrasts in terms of floristic diversity and species homogeneity (Table 2). Lomé has higher diversity values in several types of spaces, particularly green spaces along roads (Ish = 11.05; Eq = 0.09), campsites and reception areas (Ish = 10.63; Eq = 0.09), and religious centres (Ish = 11.08; Eq = 0.08). However, these spaces have very low evenness, indicating a strong dominance of certain species. In Kara, specific areas such as tree-lined avenues (Ish = 2.96; Eq = 0.33) and educational areas (Ish = 7.32; Eq = 0.14) also demonstrate notable floristic richness. However, this is invariably accompanied by an imbalanced distribution. A notable exception to this pattern is observed in the family gardens of Kara, which exhibit low diversity (Ish = 0.45) but remarkable evenness (Eq = 2.21), suggesting a very homogeneous distribution in a small sample of species.

Green spaces integrated into public buildings show high diversity in Lomé (Ish = 10.94) and Kara (Ish = 9.33), with low equity in both cases (Eq = 0.09–0.10). Similarly, fields and fallow land in Kara are characterised by high diversity (Ish = 11.61) but very low equity (Eq = 0.09), highlighting significant plant heterogeneity.

4. DISCUSSION

This in-depth comparative study reveals notable differences in the typology and floristic diversity of urban green spaces (UGS) between Lomé and Kara. These disparities reflect the complex interaction of socio-economic and climatic factors and specific planning practices in each urban context, thereby shaping the structure and composition of their plant heritage.

4.1 Typology of urban green spaces: A reflection of differentiated ecological and socio-urban dynamics

The typological analysis highlights greater functional diversity in Lomé's UGS (16 types of UGS), the most common of which are green spaces consisting of tree-lined avenues, notably *Azadirachta indica* (Meliaceae), *Delonix regia* (Fabaceae), and UGS in educational establishments dominated by *Terminalia catappa* (Combretaceae) and Mangifera indica (Anacardiaceae), reflecting the strong influence of urban infrastructure. In Kara, fallow fields constitute green spaces dominated by *Vitellaria paradoxa* (Sapotaceae), *Annona senegalensis* (Annonaceae), and natural plant formations featuring *Isoberlinia doka* (Fabaceae) and *Piliostigma thonningii* (Caesalpiniaceae), revealing a high degree of permeability between the city and its rural margins. This typology shows a presence that reflects differentiated anthropogenic pressures, with more artificialisation in Lomé, compared to a closer integration between the natural and built environments in Kara. Indeed, the typological comparison between Lomé and Kara reveals contrasting approaches to the management of green spaces. Lomé is characterised by a dense network of UGS with a social, recreational, and infrastructural purpose, reflecting its advanced urbanisation and the search for a well-planned living environment. Kara, on the other hand, has a high proportion of green spaces with ecological and institutional value, often linked to public institutions or plant relics, reflecting better integration of vegetation into the urban fabric and more marked preservation of natural elements. This complementarity highlights different challenges: strengthening leisure facilities in Kara and ecological preservation in Lomé, and underlines the need for territorialised governance of urban green spaces, adapted to each local context. Comparable studies in West Africa, notably in Benin [26, 43], Bujumbura in Burundi [25], Niamey and Maradi in Niger [49], confirm that the typological diversity of UGSs is a relevant indicator of urban planning, ecological connectivity, and socio-ecological resilience to climate change [20, 50]. The typology of urban green spaces is a key indicator of development priorities and anthropogenic pressures on the urban landscape [51] with direct consequences for urban sustainability, particularly in terms of loss of floral richness.

4.2 Floristic diversity and plant structures: Issues of urban resilience and conservation

In terms of flora, Lomé has a greater species richness (368 species) than Kara (216), with a predominance of *Azadirachta indica* (60.42%), Elaeis guineensis (32.64%), and *Mangifera indica* (29.86%), which are mainly found in structured public spaces (e.g., schools, hospitals, public parks). These species, most of which are exotic and anthropochorous, belong mainly to the Fabaceae, Meliaceae, Arecaceae, and Anacardiaceae families, reflecting a selection based on hardiness, multiple uses, and tolerance to urban stress [28, 30, 32]. The dominance of *Azadirachta indica*, for instance, can be attributed to its strong adaptability to poor soils and semi-arid microclimates due to its deep root system and drought-resistant physiology, which make it a robust species for urban landscaping in tropical cities. In Kara, the same families predominate, but

with more indigenous species such as *Mangifera indica, Cassia siamea, Vitellaria paradoxa,* and *Khaya senegalensis*, often associated with religious spaces and natural formations. These same species have been reported in previous studies by other authors in the city of Kara [31, 36].

The higher floristic diversity observed in Lomé may be explained by its role as a coastal and port city, where a higher influx of exotic plant species has historically been introduced through trade, urban planning projects, and ornamental landscaping. This urban dynamic, combined with higher urbanisation levels and denser infrastructure, has favoured diversified planting, as confirmed by similar findings in port cities like Grand Popo [52] and Accra [53]. Furthermore, national policy efforts such as the Urban Greening Act adopted by the Togolese government in 2018 have contributed to the revitalisation of urban vegetation through reforestation campaigns, the protection of green corridors, and institutional support for city-level greening initiatives. While the implementation of this policy remains uneven between cities, it has had a more visible impact in Lomé due to stronger institutional capacity and support from urban development agencies.

Biological types are dominated by mesophanerophytes (MP) in Lomé and Kara (65-70% weighted), reflecting the predominance of medium to large trees in urban green spaces. However, Kara shows greater morphological diversity with significant proportions of nanophanerophytes (NP) and therophytes (TH), indicating a more dynamic plant mosaic that is potentially favourable to urban biodiversity.

From a phytogeographical point of view, the EVUs in Lomé are characterised by the predominance of Guineo-Congolese species (≈35% weighted) such as *Milicia excelsa* and *Nauclea diderrichii*, while Kara shows a clear influence of Sudano-Zambesian species (≈35% weighted) with species such as *Anogeissus leiocarpa* and *Vitex doniana*. According to studies by Brunel et al. [47] and Akoègninou et al. [48], these trends reveal distinct ecological affinities shaped by bioclimatic gradients.

In terms of diversity indices, Lomé generally has higher floristic diversity indices than Kara in most types of green spaces, especially in highly artificial areas, but this richness is often accompanied by low evenness, indicating a dominance of specific species. Kara, on the other hand, sometimes displays more modest diversity, but with often higher levels of evenness, reflecting greater homogeneity in species distribution, particularly in RSGS. When comparing Shannon diversity indices, Lomé's values (Ish ≈ 7.48) are relatively high compared to cities in similar humid tropical zones such as Cotonou (Ish = 2.28 [26]) and Porto-Novo (Ish = 3.64 [21]), suggesting a richer yet more uneven floristic composition These results reflect different ecological and planning dynamics between the two cities, influenced by climatic conditions, urban management practices, and the functions assigned to green spaces. Studies in other African cities such as Accra [53] and Lagos [54] have shown that the floristic diversity of urban green spaces depends not only on climate and biogeographical context, but also on urban management policies, planning standards, and the role assigned to green spaces in sustainability plans.

5. CONCLUSIONS

This in-depth comparative analysis shows significant differences in the typology and plant variety of urban green spaces between Lomé and Kara. These differences are a result of distinct biogeographical, socio-economic, and planning factors. The dominance of a few species and families, while ensuring a certain adaptation to urban conditions, raises concerns about the long-term resilience and ecological functionality of these spaces. To enhance urban sustainability, it is essential to adopt integrated management strategies that prioritize the introduction of at least 20% native species coverage in each UGS, promote floristic heterogeneity, and tailor plant selection to local ecological conditions. These strategies should also strengthen the provision of specific ecosystem services—such as thermal regulation, biodiversity support, and stormwater management—according to the typology and function of each UGS. However, this research presents certain limitations that must be acknowledged. In particular, the influence of citizen preferences and socio-cultural perceptions on the selection and distribution of plant species was not explored, even though such factors may strongly shape urban vegetation patterns and the success of greening policies. Future studies should incorporate participatory assessments to better align ecological goals with community expectations.

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