

Floristic composition and biodiversity conservation of urban green spaces in Porto-Novo, Benin- Implications for sustainable urban planning

¹Etienne Romaric Adéwalé Godonou , ^{1, §}Gbodja Houéhanou François Gbesso , ²Sedami Igor Armand Yevide , ³Ahonankpon Hubert Frédéric Gbaguidi , ²Olou Toussaint Lougbegnon 

1 Unité de Recherche Horticole et d'Aménagement des Espaces Verts, Laboratoire des Sciences Végétales, Horticoles et Forestières, École d'Horticulture et d'Aménagement des Espaces Verts, Université Nationale d'Agriculture, PO Box 43, Kétou, Benin.

2 Unité de Recherche en Foresterie et Conservation des Bio Ressources, Laboratoire de Sciences Végétales, Horticoles et Forestières, École de Foresterie Tropicale, Université Nationale d'Agriculture PO Box 43, Kétou, Benin.

3 Laboratoire des Géosciences et Applications (LAGEA), Université Nationale des Sciences, Technologies, Ingénierie et Mathématiques, Bénin.

§Corresponding author: **Gbodja Houéhanou François Gbesso**, Email : fr.gbesso@gmail.com

Abstract

In Benin, particularly in urban areas, rapid population growth has led to significant biodiversity loss in green spaces. This study analyzes the vegetation of Porto-Novo, aiming to assess the diversity of plant communities in a city undergoing rapid urbanization. A floristic inventory was conducted across 39 green spaces in the city. The results highlight the floristic composition, phytogeographic, and biological types, as well as the distribution of species within these green spaces. The study identifies 72 species belonging to 63 genera and 30 families, with the most dominant families being Moraceae (7 species), Sterculiaceae (6 species), Combretaceae (5 species), Fabaceae (5 species), and Mimosaceae (5 species). The five most frequent species are *Terminalia catappa*, with a relative frequency of 22%, followed by *Mangifera indica* (17%), *Terminalia mantaly* (17%), *Khaya senegalensis* (11%), and *Acacia auriculiformis* (11%). A comparison with the city's flora in 2015 reveals a significant decline in biodiversity, underscoring the need for conservation practices. The protection and sustainable management of urban green spaces should be integrated into urban development policies, emphasizing not only the preservation of existing spaces but also the creation of new ones. Environmental education and public awareness are crucial to the success of these initiatives

Keywords: Benin, Biodiversity loss, Phytogeography, Porto-Novo, Species richness, Sustainable management, Urban ecology

Received August 17, 2024 ; Revised September 30, 2024 ; Accepted October 2, 2024

<https://dx.doi.org/10.4314/br.v22i2.7> This is an Open Access article distributed under the terms of the Creative Commons License [CC BY-NC-ND 4.0] <http://creativecommons.org/licenses/by-nc-nd/4.0>. Journal Homepage: <https://www.bio-research.com.ng>
Publisher: Faculty of Biological Sciences, University of Nigeria, Nsukka, Nigeria.

INTRODUCTION

Urban green spaces, often referred to as urban forests, play a vital role in contemporary cities due to their multifaceted functions across various domains, including environmental, cultural, agroforestry, and technological aspects (Oueslati *et al.*, 2008 ; Ouassa & Tasso, 2010). They are indispensable for the harmonious development of cities, particularly in the context of rapid urbanization and the pressing challenges of sustainable development (Ali-Khodja, 2010).

In many African cities, including those in Benin, urban vegetation has been the focus of numerous studies due to its critical role in enhancing urban living conditions (Amontcha *et al.*, 2017). Urban trees contribute significantly to air purification by sequestering carbon dioxide, creating microclimates, restoring urban tree species, enhancing land attractiveness, and reducing flood risks (Adhikari *et al.*, 2023 ; Pendall *et al.*, 2022 ; Seastedt & Oldfather, 2021). Furthermore, they offer psychological benefits, improve the quality of life, and provide ecological and aesthetic advantages (Kenney *et al.*, 2011 ; Kouadio *et al.*, 2016).

Despite these benefits, human activities often lead to the destruction of biodiversity-rich sites, both in immediate and distant environments, driven by the need to meet various demands. Such anthropogenic actions are among the most significant contributors to the rapid changes observed in plant communities, although climate factors remain a critical determinant of species distribution (Li & Zhang, 2021 ; Diop *et al.*, 2019). The effects of climate change are particularly pronounced in the context of exponential global population growth (Bawa, 2017).

In recent years, many countries have faced environmental challenges due to precipitation deficits and human activities, resulting in the degradation of natural resources. The extent of vegetation cover degradation varies regionally, with urban areas being particularly affected by current environmental issues such as climate change and biodiversity loss (Baggnian *et al.*, 2021 ; Guihini Abakar *et al.*, 2021).

Urban green spaces are not just remnants of natural ecosystems in urban settings but are also crucial for sustainable urban planning. They mitigate the urban heat island effect, improve air quality, and provide recreational spaces for urban residents (Clergeau, 2007 ; Li & Zhang, 2021). The strategic planting of trees in urban areas has proven to be a cost-effective way to enhance urban environmental management (Choumert & Travers, 2010).

Porto-Novo, the administrative capital of Benin, is no exception to these phenomena. The allocation of space for green areas in the city is insufficient to support the thriving plant life, leading to low diversity in urban vegetation. This study, therefore, aims to analyze the floristic composition and woody vegetation diversity of urban green spaces in Porto-Novo. The results will guide stakeholders in the development of future strategic documents for the city.

Based on the observed loss of biodiversity and the dominant presence of a few species, the objective of this study is to assess the current state of floristic diversity in Porto-Novo's urban green spaces and to propose actionable strategies for the conservation and enhancement of biodiversity in the city's urban planning efforts.

MATERIALS AND METHODS

Study area

Porto-Novo is located between 6°25' and 6°30' North Latitude and between 2°34' and 2°40' East Longitude. It covers an area of 52 km², representing 0.05% of the national territory (Tohozin & Orekan, 2017). The climate is sub-equatorial, characterized by two rainy seasons and two dry seasons, with an average annual rainfall of 1300 mm and an average temperature of 27.5°C (Adam & Boko, 1993). The city's natural vegetation consists of swamp and sacred forests (Osseni *et al.*, 2020). The anthropogenic vegetation, composed of green spaces, includes a few fruit trees, kapok trees, mahogany trees, and silk-cotton trees. Porto-Novo is home to 263,616 inhabitants, spread over an area of 52 km², with a population density of 5069 inhabitants per km² (INSAE, 2015).

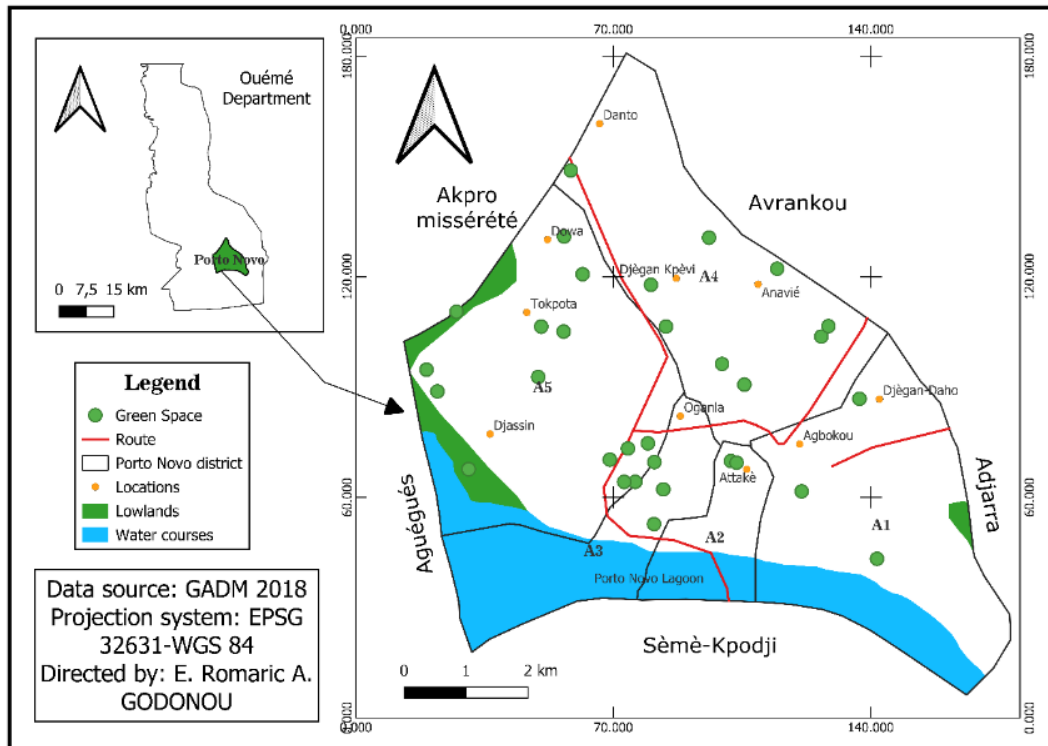


Figure 1 : Geographic location of the city of Porto-Novo and Location map of distribution of sampled green spaces

Data collection and sampling

Data collection involved a comprehensive inventory of the woody plant species within these green spaces. The methodology included both qualitative and quantitative approaches. A floristic survey was conducted using the itinerant survey method, where all species encountered along the streets and in public and private green spaces were recorded. Trees with a minimum height of 130 cm or a diameter at breast height (DBH) of 10 cm or more were included in the inventory. The geographical coordinates of each tree were recorded using a GPS device, enabling the calculation of the area of polygonal green spaces or public vegetated areas. All species were sampled and herbarium specimens were prepared for identification at the Laboratory of Applied Ecology (LEA/FSA/UAC) at University of Abomey Calavi. Identification was based on the "Flore Analytique du Bénin" by Akoègninou *et al.*, (2006).

The green spaces are classified based on their usage according to the typology proposed by Berger (2004). Seven types of green spaces have been identified. The selection criteria for these green spaces require them to be publicly accessible at all times. They can be either polygonal (vegetated public squares) or linear (paved or concrete streets where trees form

shaded rows along the lines). An exploratory visit to the city was conducted to identify green spaces that meet these criteria. The selected green spaces have at least three trees or shrubs with a diameter of at least 10 cm. Table 1 and Figure 2 provide a detailed overview of the distribution and classification of green spaces in Porto-Novo. The table lists the number of different types of green spaces, while Figure 2 visually represents this distribution across the city, highlighting the concentration of green spaces in specific areas and indicating regions with fewer green spaces, such as cemeteries and natural landscaped areas. This comprehensive representation emphasizes the diversity and spatial organization of Porto-Novo's green spaces, reflecting the city's urban planning priorities.

This study was carried out by considering 07 types of green spaces. Among these green spaces, we have public green spaces (EVPu), private green spaces (EVPr), landscaped natural green spaces (EVNA), green spaces to support public buildings (EVABP), green spaces to support social and educational establishments (EVAESE), cemeteries (Cim) and Trees of alignment (AA).

Data processing and analysis

The collected data were subjected to qualitative analysis to assess the floristic diversity. This

involved examining the species lists with details on genus, family, biological types, and phytogeographical types (TP) for each species. Species richness (S), representing the number of plant species in each green space, was calculated.

The Shannon-Wiener Diversity Index (H) was used to measure species diversity within each type of vegetation. It was calculated using the formula :

$$H = - \sum (Pi \log_2 Pi)$$

where Pi is the proportion of individuals of species i to the total number of individuals, ni is the number of individuals of species i, and N is the total number of individuals. Typically, H values range from 0 to 5.

Pielou's Evenness Index (E) was used to measure the evenness of species distribution within each population, calculated as :

$$E = \frac{H}{H_{max}}$$

where Hmax=log₂ R is the maximum theoretical diversity value for each group, and R is the total number of species recorded.

The Jaccard Similarity Index (IJ) was calculated to understand the relationships between different vegetation formations. The formula used was :

$$IJ = \frac{100 \times c}{a + b - c}$$

where a and b are the numbers of species in environments A and B, respectively, and c is the number of species common to both environments. A similarity is indicated by IJ > 50%, while dissimilarity is indicated by IJ < 50%.

The Shapiro-Wilk normality test was performed to determine if the distribution was normal. In case where it was not, the Kruskal-Wallis test was used as an alternative to analysis of variance (ANOVA) to determine if the woody green spaces originated from the same population. The biological types of the inventoried species were determined according to Raunkiaer's (1934) definitions as applied by Djègo & Sinsin (2006), which primarily consider bud position and individual size. Phytogeographical types (TP), based on major chronological subdivisions established for Africa (White, 1986), were also determined.

Bio-Research Vol.22 No.2 pp.2383-2395 (2024)

RESULTS

Floristic composition of urban green spaces in Porto-Novo

The data reveals that the Moraceae family is the most dominant, accounting for 9.72% of the total species, followed closely by Sterculiaceae at 8.33%. Other significant families include Combretaceae, Fabaceae, and Mimosaceae, each contributing five species. This dominance by a few families indicates a certain homogeneity in the urban flora, which could be the result of selective planting practices favoring fast-growing and resilient species typical of these families. The relatively high presence of these families also suggests that they are well-adapted to the urban environment, providing important ecological functions such as shading and air purification. The less represented families, though fewer in species, contribute to the overall diversity and ecological balance of these green spaces. Understanding this distribution is essential for guiding future planting and conservation strategies to ensure a balanced and resilient urban ecosystem.

Biological and phytogeographical types of species

Figure 2A and 2B present the distribution of biological and phytogeographic types of species found in the urban green spaces of Porto-Novo. Figure 2A illustrates that mesophanerophytes dominate, particularly in natural landscaped green spaces, where they constitute 60.44% of the recorded species. This dominance highlights the importance of these green spaces in maintaining medium-sized tree species that are crucial for urban biodiversity. Figure 2B shows that tropical species are predominant, making up 43.66% of the flora, followed by Afro-Malagasy and pantropical species, which together account for a significant portion of the species diversity. The presence of these phytogeographic types underscores the rich tropical heritage of Porto-Novo's urban flora and the role these green spaces play in conserving species from diverse biogeographic origins. This distribution highlights the critical importance of natural landscaped areas for biodiversity conservation and the need to prioritize their protection and expansion in urban planning.

Frequency distribution of plant species

Figure 3 illustrates the rank-frequency distribution of plant species within the urban green spaces of Porto-Novo, revealing an exponential pattern where a small number of species are highly frequent across all sites, while the majority of species are much less common. The most frequent species, such as *Terminalia catappa*, *Mangifera indica*, and *Terminalia mantaly*, dominate the urban landscape, reflecting their adaptability and widespread use in urban planting schemes. This pattern indicates a skewed distribution, where a few species are heavily relied upon, potentially leading to reduced overall biodiversity and increased vulnerability to pests or diseases affecting those dominant species. The reliance on a narrow range of species highlights the need for diversifying urban plantings to enhance ecological resilience and ensure the sustainability of urban green spaces.

Distribution of species by status (native and non-native species)

The floristic inventory distinguished between native and non-native within the green spaces of Porto-Novo. Of the 72 recorded woody species, the distribution is as follows: 41.67% native species, reflecting the region's natural heritage, and 58.33% non-native species introduced into the city's urban fabric. This proportion indicates a predominance of non-native species introductions within the urban environment, a trend observed in many developing cities aiming to diversify and enrich their urban vegetation. Native species such as *Xylopia aethiopica*, *Newbouldia laevis*, and *Milicia excelsa* form essential components of the local flora, contributing to the conservation of biological heritage and the stability of ecosystem services. However, non-native species like *Mangifera indica* and *Eucalyptus globulus* are also abundantly present, reflecting the historical and contemporary interactions between natural environments and anthropogenic influences (Figure 6).

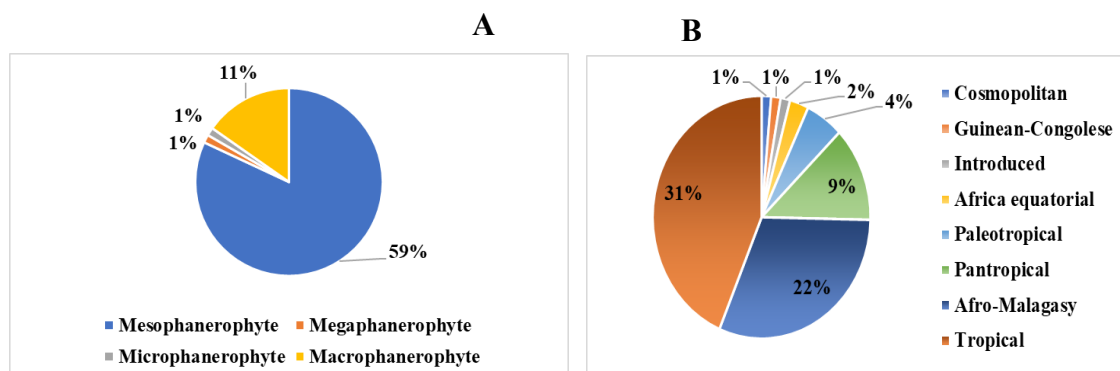


Figure 2 : Biological (A) and Phytogeographic (B) types

Specific diversity of urban green spaces in Porto-Novo

Figure 4 highlights the variation in species richness across different urban green spaces in Porto-Novo. The highest diversity is observed in green spaces accompanying social and educational establishments (EVAESE), averaging 14 species, likely due to deliberate planting and diverse management practices. In contrast, cemeteries show the lowest diversity with only 2 species on average, reflecting limited space and a focus on specific, low-maintenance plants. Other green spaces, such as public parks and private gardens, display intermediate levels of species richness. This

Bio-Research Vol.22 No.2 pp.2383-2395 (2024)

variation underscores the importance of tailored management strategies in enhancing biodiversity across different urban contexts.

Conservation status

The analysis reveals a significant proportion of species categorized as either "Least Concern" or "Not Evaluated," reflecting the current stability or lack of data regarding their populations. However, a notable percentage of species are classified under various threat categories, including "Vulnerable," "Endangered," and "Critically Endangered." This distribution emphasizes the need for urgent conservation measures to protect at-risk species within the urban landscape. The

presence of threatened species in these spaces highlights the critical role that urban green areas play in biodiversity conservation, serving as

refuges for species that may be declining elsewhere due to habitat loss and other anthropogenic pressures.

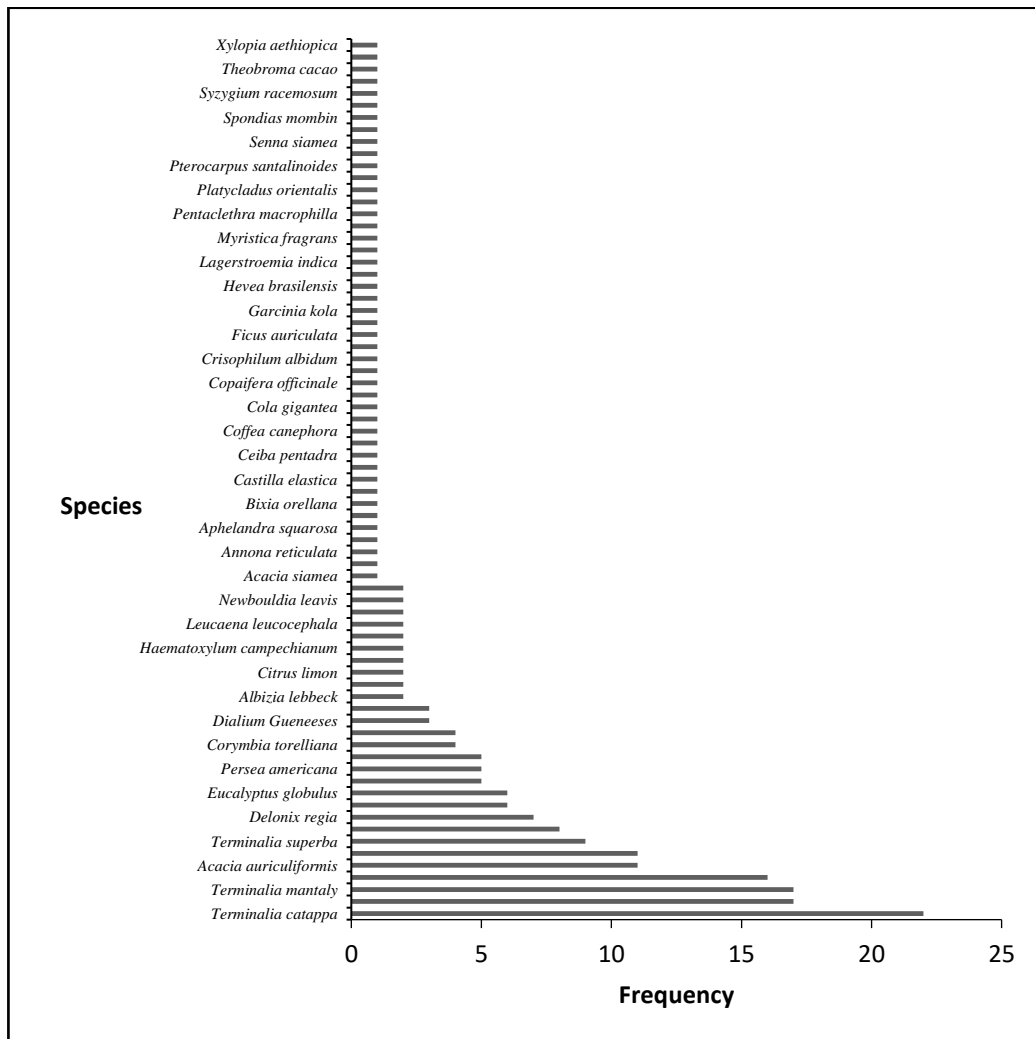


Figure 3 : Rank-Frequency distribution of species

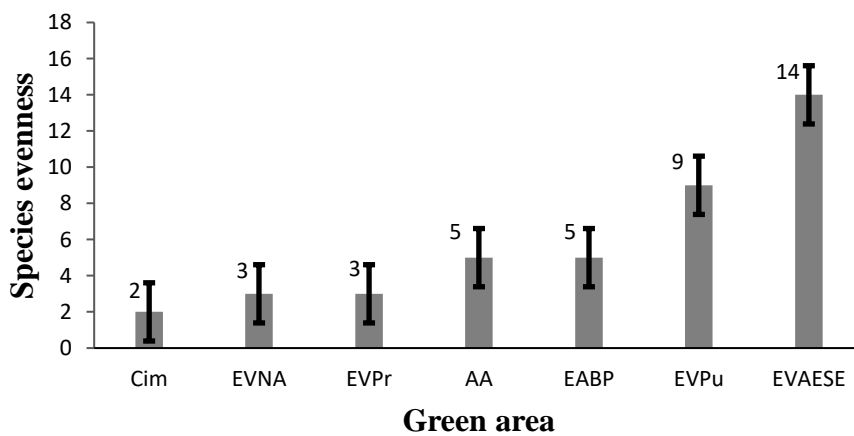


Figure 4 : Specific wealth of green spaces

Shannon diversity index and Pielou fairness of green spaces

The analysis of Table 1 shows significant variations in the Shannon Diversity Index and Pielou’s Evenness Index across different types of urban green spaces in Porto-Novo. Green spaces accompanying social and educational establishments (EVAESE) exhibit the highest species diversity, with an index of 3.64 bits, indicating a rich variety of plant species and a relatively even distribution, likely due to diverse and intentional management practices. In contrast, cemeteries have the lowest diversity, with an index of 0.48 bits, reflecting limited species variety and uneven distribution, where a few species dominate. These findings highlight the importance of tailored management strategies to enhance biodiversity in less diverse areas like cemeteries, thereby contributing to greater ecological resilience across the city.

Floristic similarity of green spaces

Table 2 presents the Jaccard Similarity Coefficient, which measures the similarity in species composition between different types of urban green spaces in Porto-Novo. The results indicate varying degrees of similarity, with some green spaces sharing a significant portion of their species, while others show more distinct compositions. Green spaces accompanying social and educational establishments (EVAESE) tend to have higher similarity coefficients with other spaces, suggesting common species across these areas, possibly due to similar planting practices or environmental conditions. In contrast, cemeteries often show lower similarity coefficients, reflecting their unique or less diverse species composition compared to other green spaces. This analysis highlights the interconnectedness or distinctiveness of the species communities in different urban green spaces and provides insights into how plant species are distributed across the city. The results underscore the potential for increasing diversity in spaces with lower similarity, thereby enhancing overall urban biodiversity.

Table 1 : Shannon diversity index and Pielou's evenness index by green space type

Type of green space	Shannon diversity index (bits)	Pielou equitability
EVAESE (green spaces accompanying social establishments)	3.64	0.96
AA (Alignment Trees)	2.12	0.91
EVPu (Public green spaces)	3.07	0.97
EVNA (Natural landscaped green spaces)	1.05	0.66
EABP (Green spaces accompanying public buildings)	2.08	0.90
EVPr (Private green spaces)	1.18	0.75
Cim (Cemeteries)	0.48	0.48

Table 2 : Jaccard similarity coefficient

	EVPu	EVPr	EVNA	AA	Cim	EVABP
EVPr	10					
EVNA	3.27	2.27				
AA	28.57	12.5	8.79			
Cim	9.09	20	9.3	17.64		
EVABP	50	8.33	10.2	35	25	
EVAESE	33.33	6.25	14.03	50	9.09	34.37

The correlogram uses color intensity to indicate the strength and direction of correlations, with darker shades representing stronger relationships, either positive or negative. The analysis shows a strong positive correlation between species richness and the Shannon Diversity Index, suggesting that as the number of species in a green space increases, the diversity also rises. This is consistent with ecological theory, where more species generally contribute to a more complex and resilient ecosystem.

Conversely, there is a negative correlation between the dominance of a single species (as indicated by low Pielou's Evenness Index) and overall biodiversity, highlighting the impact of species dominance on reducing diversity. High dominance values correspond to lower species evenness, which can weaken the ecological stability of urban green spaces.

Figure 5 presents a correspondence analysis (CA) graph that illustrates the relationship between different types of urban green spaces in Porto-Novo and the species found within them, plotted on Axes 1 and 2. This graphical representation helps identify associations between specific species and particular green space types, revealing patterns of species distribution and habitat preference. The analysis on Axis 1 separates green spaces based on their species composition, with certain types of green spaces clustering together due to shared species. For example, green spaces accompanying social and educational establishments (EVAESE) are closely associated with species that prefer managed, semi-natural environments, reflecting the diverse and structured plantings typically found in these areas. Axis 2 further differentiates the species by highlighting those that are more prevalent in less managed or more natural green spaces, such as natural landscaped areas (EVNA). These spaces show a strong association with native species and those adapted to less disturbed environments, indicating their role in preserving local biodiversity. The correspondence analysis also shows that cemeteries (Cim) are positioned further from other green spaces on the plot, indicating a unique species composition that is less similar to other types of urban green spaces. This could be due to the specific cultural or functional roles of cemeteries, which might influence the selection and management of plant species.

Overall, Figure 10 provides a clear visual representation of how species are distributed across different green space types in Porto-Novo, highlighting the unique ecological roles that each space plays in the urban landscape. This information is crucial for urban planners and conservationists aiming to enhance biodiversity through targeted management of these green spaces.

Figure 6 extends the correspondence analysis by plotting the relationship between urban green space types and species on Axes 2 and 3. This additional perspective provides further insights into the nuances of species distribution and habitat specialization within Porto-Novo's urban green spaces. Axis 2, as observed previously, continues to highlight species that are more prevalent in natural and semi-natural green spaces, such as those in natural landscaped areas (EVNA). These species are often native and adapted to less disturbed environments, emphasizing the role of these green spaces in conserving indigenous biodiversity. Axis 3, however, introduces a new dimension of differentiation, capturing subtler ecological variations that might not be evident on the first two axes. For instance, this axis may reveal distinctions between species that prefer slightly different environmental conditions within similar types of green spaces. It could also highlight species that are less common but highly specialized, contributing to the unique ecological character of certain spaces, such as those associated with green spaces accompanying public buildings (EVABP) or alignment trees (AA). The combined analysis on Axes 2 and 3 may also show a clearer separation of cemeteries (Cim) from other green spaces, reinforcing their distinct ecological identity within the urban fabric of Porto-Novo. This separation could be linked to the specific management practices and environmental conditions of cemeteries, which differ significantly from other urban green spaces.

In summary, Figure 11 provides a deeper understanding of the ecological dynamics in Porto-Novo's urban green spaces by exploring species distribution across different environmental gradients represented by Axes 2 and 3. This analysis is crucial for identifying specific conservation needs and opportunities for enhancing biodiversity in these urban areas.

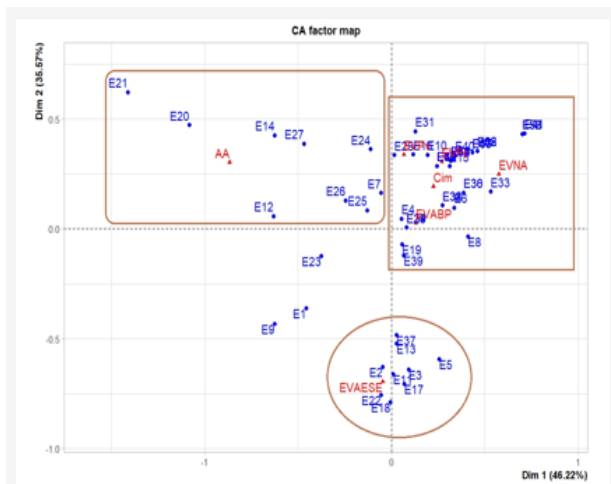


Figure 5 : Correspondence analysis graph of green space types and species on axes 1 and 2

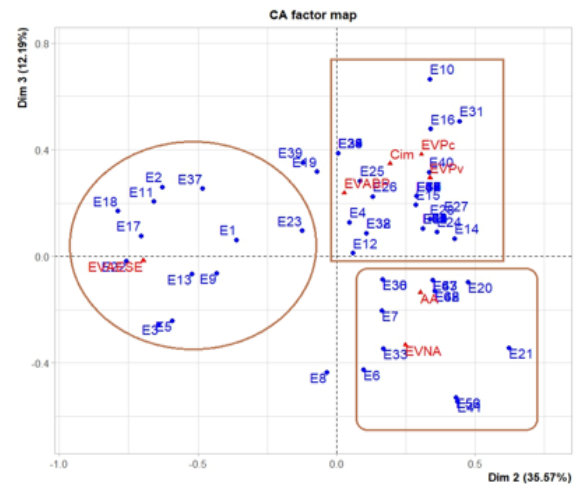


Figure 6 : Correspondence analysis graph of green space types and species on axes 2 and 3

DISCUSSION

The analysis of Porto-Novo's urban green spaces reveals a floristic composition dominated by a few plant families, particularly Moraceae, Sterculiaceae, Combretaceae, Fabaceae, and Mimosaceae. This dominance can be attributed to the adaptability of these families to urban environments, characterized by their resilience and fast-growing nature. Similar patterns have been observed in other tropical cities, where certain species are favored due to their ability to thrive under urban conditions (Zhang *et al.*, 2021 ; Li *et al.*, 2020).

The presence of a significant proportion of exotic species (58.33%) highlights the influence of urbanization and globalization on the local flora. The introduction of non-native species, such as *Mangifera indica* and *Eucalyptus globulus*, is often driven by their aesthetic value, fast growth, and economic importance. However, this trend raises concerns about the potential displacement of native species and the homogenization of urban flora, which could reduce the ecological resilience of these environments (McKinney, 2008 ; Aronson *et al.*, 2014).

In contrast, native species like *Xylopia aethiopica*, *Newbouldia laevis*, and *Milicia excelsa* represent the local natural heritage and play crucial roles in maintaining the ecological integrity of urban green spaces. These species are often better adapted to the local climate and soil conditions, and their conservation is essential for sustaining the ecological functions of urban ecosystems (Müller *et al.*, 2013 ; Kowarik *et al.*, 2020).

Bio-Research Vol.22 No.2 pp.2383-2395 (2024)

The Shannon Diversity Index and Pielou's Evenness Index reveal significant variations in species diversity and distribution across different types of green spaces in Porto-Novo. The highest diversity was observed in green spaces accompanying social and educational establishments (EVAESE), with a Shannon Index value of 3.64 bits, indicating a rich and evenly distributed plant community. This high diversity can be linked to deliberate planting practices aimed at creating aesthetically pleasing and ecologically functional spaces, which are often designed to serve educational purposes as well (Kong *et al.*, 2010).

Conversely, cemeteries exhibited the lowest diversity, with a Shannon Index value of 0.48 bits, reflecting a limited range of species and a dominance of a few hardy, low-maintenance plants. This pattern is consistent with other studies on urban green spaces, where cemeteries often show lower biodiversity due to their specific cultural and maintenance practices (Jim, 2011 ; Davoren *et al.*, 2020).

The correspondence analysis further supports these findings, showing distinct clusters of species associated with different types of green spaces. Green spaces like the EVAESE are closely linked with a variety of species, while cemeteries and natural landscaped areas (EVNA) show more specialized species compositions. This differentiation highlights the role of specific green spaces in supporting various aspects of urban biodiversity, from generalist species in managed areas to more specialized, native species in less disturbed environments (Gaston *et al.*, 2013 ; Nagendra *et al.*, 2013).

The Jaccard Similarity Coefficient analysis reinforces the idea of connectivity and uniqueness among the green spaces. The higher similarity between spaces like EVAESE and public green spaces (EVPu) suggests that these areas share common species, possibly due to similar environmental conditions and human interventions. On the other hand, the lower similarity of cemeteries compared to other green spaces indicates a more isolated species community, which may reflect their distinct ecological niche within the urban matrix (Guirado *et al.*, 2006 ; Chen *et al.*, 2021).

The limitations of this study include species identification, which relies on herbarium specimens and existing references, potentially overlooking rare or newly introduced species. Additionally, seasonal variations were not considered, although these could significantly impact floristic diversity. The influence of human activities, particularly the introduction of exotic species, also limits the assessment of native biodiversity. Furthermore, the study focuses solely on flora, without including fauna, which plays a crucial role in ecological interactions. While recommendations are made for urban green space management, the long-term effects of urbanization and climate change on the resilience of these ecosystems were not fully explored, highlighting the need for further research to ensure the sustainability of conservation efforts.

The findings of this study have important implications for urban planning and biodiversity conservation in Porto-Novo. The dominance of a few families and the high proportion of exotic species suggest a need for more careful selection of plant species in urban planning. To enhance ecological resilience, it is crucial to prioritize the conservation and integration of native species, which are better suited to the local environment and play a vital role in maintaining ecosystem services (Aronson *et al.*, 2017 ; Beninde *et al.*, 2015).

The varying levels of species diversity across different green spaces highlight the importance of tailored management strategies. For example, increasing structural and species diversity in less diverse areas like cemeteries could improve their ecological function and resilience. Additionally, the connectivity between different green spaces should be strengthened to facilitate species dispersal and genetic exchange, which are critical for sustaining urban biodiversity over the long term (Taylor *et al.*, 2019 ; Shwartz *et al.*, 2013).

Finally, the study underscores the need for integrating biodiversity conservation into urban development policies. As urbanization continues to expand, the preservation and enhancement of green spaces should be seen as a key component of sustainable city planning. This includes not only the protection of existing green spaces but also the creation of new ones that are designed to support a wide range of species and ecological functions (Elmqvist *et al.*, 2015 ; Tzoulas *et al.*, 2007).

CONCLUSION

This study provides a detailed analysis of the floristic composition, diversity, and ecological significance of urban green spaces in Porto-Novo, revealing key patterns and trends that have important implications for urban planning and biodiversity conservation. The findings highlight a floristic composition dominated by a few resilient plant families, with a significant presence of exotic species. While these species contribute to the rapid greening of urban areas, the predominance of non-native plants raises concerns about the potential displacement of native flora and the overall ecological resilience of the city's green spaces.

The diversity analysis shows that green spaces associated with social and educational establishments (EVAESE) are the most biodiverse, offering a balanced and rich environment that supports a wide range of species. In contrast, cemeteries exhibit the lowest levels of diversity, reflecting a more limited ecological function. These findings underscore the need for targeted management strategies to enhance the biodiversity of less diverse spaces and ensure the ecological integrity of all urban green spaces.

Moreover, the correspondence and similarity analyses reveal important insights into the distribution patterns of species across different green spaces, emphasizing the distinct ecological roles that these spaces play within the urban fabric. The results suggest that while some green spaces share common species due to similar management practices, others, like cemeteries, host unique species communities that require specific conservation efforts.

In conclusion, the study underscores the critical importance of integrating biodiversity conservation into urban planning. As Porto-Novo continues to grow and develop, maintaining and enhancing the biodiversity of its green spaces should be a priority. This involves not only protecting existing green spaces but

also designing new ones that are ecologically diverse and resilient. By prioritizing the conservation of native species and promoting ecological connectivity between different green spaces, Porto-Novo can ensure that its urban environment remains vibrant, resilient, and capable of supporting both human well-being and biodiversity.

Conflict of Interest

The authors have no conflict of interest to declare.

Acknowledgment

The authors are grateful to Ogoubiyi Marietta and Kodjo Hermione for assisting in data collection.

Author contributions

ERAG, GHFG and SIAY : Conceptualization, data collection, data analysis, article writing and its correction ; GHFG and SIAY : Supervision, editing and validation before submission ; OTL and AHFG : Supervision and validation. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

- Adam, S.K. et Boko M. (1993) Bénin. Les éditions du Flamboyant, Cotonou, 6.
- Adhikari, S., Struwig, M., & Siebert, S. (2023). Identifie les arbres communs et les plantes herbacées pour atténuer la pollution par les particules dans une région minière semi-aride d'Afrique du Sud. *Climat*, **11** (9).
- Ali-Khodja A. (2010). Aménagement urbain : la problématique de l'espace vert public dans la ville de Constantine. Département d'Architecture et d'Urbanisme. Université Mentouri Constantine.
- Akoègninou, A., Van der Burg, W., & Van der Maesen, L. J. G. (2006). *Flore analytique du Bénin*. Backhuys Publishers.
- Amontcha, A. A. M., Djego, J. G., Lougbegnon, T. O., & Sinsin, B. A. (2017). Typologie et répartition des espaces verts publics dans le grand Nokoué (Sud Bénin). *European Scientific Journal*, **13** (21), 79-97.
- Aronson, M.F.J., La Sorte, F.A., Nilon, C.H., Katti, M., Goddard, M.A., Lepczyk, C.A., ... et Dobbs, C. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society B*. **281** (1780), 20133330. DOI: 10.1098/rspb.2013.3330.
- Aronson, M.F.J., Pataki, D.E., Blythe, J.N., Pincetl, S., Gillespie, T.W., Whitlow, T.H., ... et Wentz, E.A. (2017). Urbanization and the future of biodiversity in the 21st century. *Emerging Topics in Life Sciences*, **1** (3), 250-256. DOI: 10.1042/ETLS20170016.
- Bagnian, I., Sanda Seydou, N., & Adam, T. (2021). Floristic diversity and vulnerability of woody vegetation in the Illela department, Tahoua region, Niger. *Journal of Environmental Science, Toxicology and Food Technology*, **15** (9), 15-27. <https://doi.org/10.9790/2402-1509031527>
- Bawa A. (2017). Mutations des périphéries urbaines au sud du Togo : des espaces ruraux à l'épreuve du peuplement et de la marchandisation des terres. Sciences de la Terre. Université Montpellier.
- Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters*, **18** (6), 581-592. DOI: 10.1111/ele.12427.
- Berger, M. (2004). Les périurbains de Paris. De la ville dense à la métropole éclatée? Paris, Ed. du CNRS, coll. Espaces et milieux. 317. <https://doi.org/DOI:10.4000/books.editionscnrs.9397>
- Chen, W.Y., Jia, B.S., & Yu, T.Y. (2021). Urban green space planning for biodiversity conservation: A systematic review. *Urban Forestry & Urban Greening*, **64**, 127271. DOI: 10.1016/j.ufug.2021.127271.
- Clergeau, P. (2007). Une écologie du paysage urbain. *Phytosociologie de la végétation de sous-bois et impact écologique des plantations forestières sur la diversité floristique au sud et au centre du Bénin*. Thèse de Doctorat Unique, Abomey calavi. 362.
- Choumert, J. (2010). La capitalisation immobilière des espaces verts dans la ville d'Angers. *Revue économique*, **61** (5), 821-836.
- Djègo, J., & Sinsin, B. (2006). Impact des espèces exotiques plantées sur la diversité spécifique des phytocénoses de leur sous-bois. *Systematics and Geography of Plants*, 191-209.
- Elmqvist, T., Setälä, H., Handel, S.N., van der Ploeg, S., Aronson, J., Blignaut, J.N., ... et de Groot, R. (2015). Benefits of restoring ecosystem services in urban

- areas. *Current Opinion in Environmental Sustainability*, **14**: 101-108. DOI: 10.1016/j.cosust.2015.05.001.
- Gaston, K.J., Warren, P.H., Thompson, K., & Smith, R.M. (2013). Urban domestic gardens (IV): The extent of the resource and its associated features. *Biodiversity and Conservation*, **14**, 3327-3340. DOI: 10.1007/s10531-004-9513-9.
- Guirado, M., Pino, J., & Rodà, F. (2006). Comparing the role of site disturbance and landscape properties on understory species richness in fragmented periurban Mediterranean forests. *Landscape Ecology*, **21** (5), 715-727. DOI: 10.1007/s10980-005-5229-5.
- Guihini Abakar, M., Saleh Mahamat, M., Diallo, A., Mekila, M., & Guisse, A. (2021). Floristic composition and structure of woody stands on two sites along the Great Green Wall route in Chad. *Journal of Animal & Plant Sciences*, **49** (1), 8774-8784. <https://doi.org/10.35759/JAnmPISci.v49-1.2>
- INSAE, R. (2015). Que retenir des effectifs de population en 2013. Direction des études démographiques. Cotonou: ministère du Développement et du Plan du Bénin.
- Jim, C.Y. (2011). Urban cemeteries as green space: Alternative models of sustainability. *GeoJournal*, **76**, 317-322. DOI: 10.1007/s10708-010-9364-5.
- Kabanyegeye, H., Ndayishimiye, J., Hakizimana, P., Masharabu, T., Malaisse, F., & Bogaert, J. (2022). Diversité floristique et statut de conservation des espaces verts de la ville de Bujumbura (Burundi). *Revue Internationale de Géologie, de Géographie et d'Écologie Tropicales (Geo-Eco-Trop.)*, **46** (1), 15-28.
- Kenney, W. A., Van Wassenaer, P. J., & Satel, A. L. (2011). Criteria and indicators for strategic urban forest planning and management. *Arboriculture & Urban Forestry (AUF)*, **37** (3), 108-117.
- Kong, F., Yin, H., Nakagoshi, N., & Zong, Y. (2010). Urban green space network development for biodiversity conservation: Identification based on graph theory and gravity modeling. *Landscape and Urban Planning*, **95** (1-2), 16-27. DOI: 10.1016/j.landurbplan.2009.11.001.
- Kouadio, Y. J. C., Vroh, B. T. A., BI, Z. B. G., Yao, C. Y. A., & N'guessan, K. E. (2016). Évaluation de la diversité et estimation de la biomasse des arbres d'alignement des communes du Plateau et de Cocody (Abidjan-Côte d'Ivoire). *Journal of Applied Biosciences*, **97**, 9141-9151.
- Kowarik, I., von der Lippe, M., & Knapp, S. (2020). Biodiversity functions in urban landscapes: An overview. *Journal of Vegetation Science*, **31** (3), 295-309. DOI: 10.1111/jvs.12835.
- Li, J., Wang, H., Wang, H., Yin, R., Liang, H., Song, D., & He, H. (2020). The impact of urbanization on plant diversity in urban green spaces: A case study in a city on the North China Plain. *Urban Forestry & Urban Greening*, **53**, 126708. DOI: 10.1016/j.ufug.2020.126708.
- Li, K., & Zhang, G. (2021). Diversité des espèces et schéma de répartition des arbres patrimoniaux dans la province du Jiangsu à urbanisation rapide. *Forêts Chine*, **12**, 1543.
- McKinney, M.L. (2008). Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems*, **11**, 161-176. DOI: 10.1007/s11252-007-0045-4.
- Müller, N., Ignatieva, M., Nilon, C.H., Werner, P., & Zipperer, W.C. (2013). Patterns and trends in urban biodiversity and landscape design. In: Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., McDonald, R.I., et al. (eds). *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*. Springer, Dordrecht, 123-174.
- Nagendra, H. Richard, L. Joao H. Rob, H. G. J. Tarantino, C. Maria, A. Paola, M. (2013). Remote sensing for conservation monitoring : Assessing protected areas, habitat extent, habitat condition, species diversity and threats. *Ecological Indicators*, **33**, 45-59.
- Osseni, A. A., Tohozin, C. A. B., Toko Mouhamadou, (2020). Analyse de la distribution spatiale et de la répartition des avantages socio-écologique de espaces verts dns la ville de Porto Novo au Bénin. *Conférence.*, 33-49.
- Oueslati, W., Madariaga, N., & Salani, J. (2008). Evaluation contingente d'aménités paysagères liées à un espace vert urbain. Une application au cas du parc Balzac de la ville d'Angers. *Revue d'Etude en Agriculture et Environnement*, **87**, 77-99.
- Pendall, E., Hewitt, A., Boer, M., Carrillo, Y., Glenn, T. N., & Griebel, A. M. J. (2022). Résilience remarquable de la structure forestière et de la biodiversité suite à un incendie dans la brousse périurbaine de Sydney, en Australie. *Climat*, **10**, 86.

- Raunkiaer, C. (1934). *The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer*. The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer.
- Seastedt, T., & Oldfather, M. (2021). Changement climatique, processus écosystémiques et réponses à la diversité biologique en haute altitude communautés. *Climat*, **9**, 87.
- Shwartz, A. Muratet, A. Simon, L. Julliard, R. (2013). Local and management variables outweigh landscape effects in enhancing the diversity of different taxa in a big metropolis. *Biological Conservation*, **157** (2013), 285–292. <http://dx.doi.org/10.1016/j.biocon.2012.09.009>.
- Taylor, L., & Hochuli, D.F. (2019). Urban ecology research: Strengthening the foundations for the study of ecology in the built environment. *Austral Ecology*, **44** (4), 617-622. DOI: 10.1111/aec.12735.
- Tohazin C.A.B. et Orekan O.A.V. (2017). Analyse par la télédétection et le SIG de l'extension urbaine de Porto Novo au Bénin. *Afrique science*.
- Tourey, S., Boukpepsi, T., Djagnikpo, Kpedenou, K., & Tchamie, T. K. T. (2020). Diversité et importance de la flore ligneuse de la ville de Sokodé (Centre-Togo). *VertigO*, **20** (3).
- Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using green infrastructure: A literature review. *Landscape and Urban Planning*, **81** (3), 167-178. DOI: 10.1016/j.landurbplan.2007.02.001.
- White, F. (1986). *La végétation de l'Afrique: mémoire accompagnant la carte de végétation de l'Afrique Unesco/AETFAT/UNSO*. **20**. IRD Editions.
- Zhang, L., Zhou, W., Qian, Y., Li, W., & Han, L. (2021). Urbanization and plant species diversity in urban green spaces: Implications for ecosystem services. *Journal of Environmental Management*, **290**, 112602. DOI: 10.1016/j.jenvman.2021.112602.