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Ethnobotanical uses and community perceptions of high-carbon sequestration tree species in the green spaces of Porto-Novo: Towards sustainable and inclusive urban planning

Godonou Etienne Romaric Adéwalé*[1], Gbesso Gbodja Houéhanou François[1], Idakou Gildas N'tibouti[1], Gbaguidi Ahonankpon Hubert Frédéric[2], Lougbegnon Olou Toussaint[3]

[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, Kétou, Benin*

[2]*Laboratoire des Géosciences et Applications (LAGEA), Université Nationale des Sciences, Technologies, Ingénierie et Mathématiques, Bénin*

[3]*Unité de Recherche en Foresterie et Conservation des Bio Resources, Laboratoire de Sciences Végétales, Horticoles et Forestières, École de Foresterie Tropicale, Université Nationale d'Agriculture, Kétou, Benin*

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Abstract

This study aims to evaluate the ethnobotanical uses and community perceptions of tree species with high carbon sequestration potential in urban green spaces in Porto-Novo, Benin, to inform sustainable and inclusive urban green space management. With a mixed-method, descriptive study with a cross-sectional design, this research was conducted in various green spaces within Porto-Novo, Republic of Benin, from July to October 2024. Twenty tree species with high carbon sequestration potential were identified through a preliminary assessment. Data were gathered from 390 residents across urban green spaces using semi-structured interviews to explore their knowledge uses and perceptions of the selected species. Quantitative indices, including Relative Frequency of Citation (RFC), Use Value (UV) and Cultural Importance Index (CII) were calculated to quantify species importance. Principal Component Analysis (PCA) was used to categorize species according to their primary uses (food, Medicinal artisanal and ornamental) and the plant parts commonly utilized (leaves, roots, fruits, bark). The study revealed high recognition and use of *Citrus limon* (93.4%), *Artocarpus altilis* (81.2%) and *Senna siamea* (75.9%) among the local population with food and medicinal uses predominating ornamental and artisanal species such as *Eucalyptus globulus* and *Tectona grandis* were valued for their aesthetic and craft applications. PCA results highlighted distinct usage clusters confirming the cultural and practical significance of each species. Protection of green spaces sustainable planting techniques and community engagement in reforestation were supported by 98% of respondents. The study emphasizes the multifunctional role of green spaces in urban resilience biodiversity and community well-being in Porto-Novo. Integrating ethnobotanical knowledge into urban planning can enhance ecological and social benefits supporting sustainable development that aligns with local needs and cultural values.

* **Corresponding Author:** Romaric Adéwalé ✉ godonouetienne@gmail.com

Introduction

In response to the growing challenges of rapid urbanization and climate change, urban green spaces are emerging as essential infrastructures for sustainable development and ecological resilience in cities. These areas play a crucial role in regulating local climate, purifying the air, and preserving biodiversity, thereby enhancing the quality of urban life (Kenney *et al.,* 2011). Particularly in West African cities like Porto-Novo, the importance of conserving and promoting plant diversity in urban spaces is paramount for addressing ecological degradation and reinforcing ecosystem services (Osseni *et al.,* 2020). Urban expansion exerts pressure on these areas, depleting local plant species diversity and raising concerns over their conservation (Godonou *et al.,* 2024).

These spaces also serve as habitats for wildlife, contributing to urban biodiversity by creating ecological corridors that facilitate species mobility and survival in urban environments (Berke *et al.,* 2008). Furthermore, they function as natural stormwater management systems enhancing water infiltration an essential benefit for flood-prone areas (Connors *et al.,* 2013). Socially and psychologically green spaces provide meeting places, relaxation areas and play zones, all of which are vital for the mental and physical well-being of urban residents. They foster enriching social interactions that strengthen community bonds and encourage more active, healthy lifestyles (Crewe *et al.,* 2016).

Porto-Novo, a city experiencing rapid growth and significant environmental challenges, finds green space integration and enhancement crucial to achieving sustainable development and urban resilience goals. In Africa, much knowledge is lost due to a lack of transmission leading to knowledge erosion that hinders resource conservation by local populations.

In this context, ethnobotany offers a unique perspective by documenting not only the diversity of local plants but also the traditional knowledge and practices associated with their use. Ethnobotany explores the relationship between human populations and plants, helping identify species that hold cultural and functional value for local communities. These practices, often ancient, form pillars of local resilience against environmental changes and human pressures (Dossou *et al.,* 2012). Studies in Benin and other African regions have shown that incorporating local knowledge in natural resource management not only promotes conservation but also ensures sustainable use of plant resources as evidenced by research on the Agonvè forest in Benin (Dossou *et al.,* 2012).

The main challenge of this study is the need to preserve tree species diversity within Porto-Novo's urban green spaces while incorporating local ethnobotanical knowledge. This approach is essential for biodiversity conservation and carbon sequestration and addresses the socio-economic needs of urban communities that rely on these plants for various uses (Dossou *et al.,* 2012). Ethnobotanical practices reveal that residents attribute different values to plants based on their contributions to subsistence and health needs integrating these species into daily life and highlighting the importance of their conservation.

Driven by the urgency to preserve urban green spaces and promote sustainable urban planning practices, this research aims to provide a knowledge base for managing and valuing tree species amidst growing urban pressures. By documenting the perceptions and uses of tree species by the people of Porto-Novo, this study supports the integration of ethnobotanical values into urban management policies, thereby strengthening the ecological sustainability and resilience of cities (Baggnian *et al.,* 2021).

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 (Fig. 1). It covers an area of 52 km², representing 0.05% of the national territory (Tohozin and Orekan, 2017).

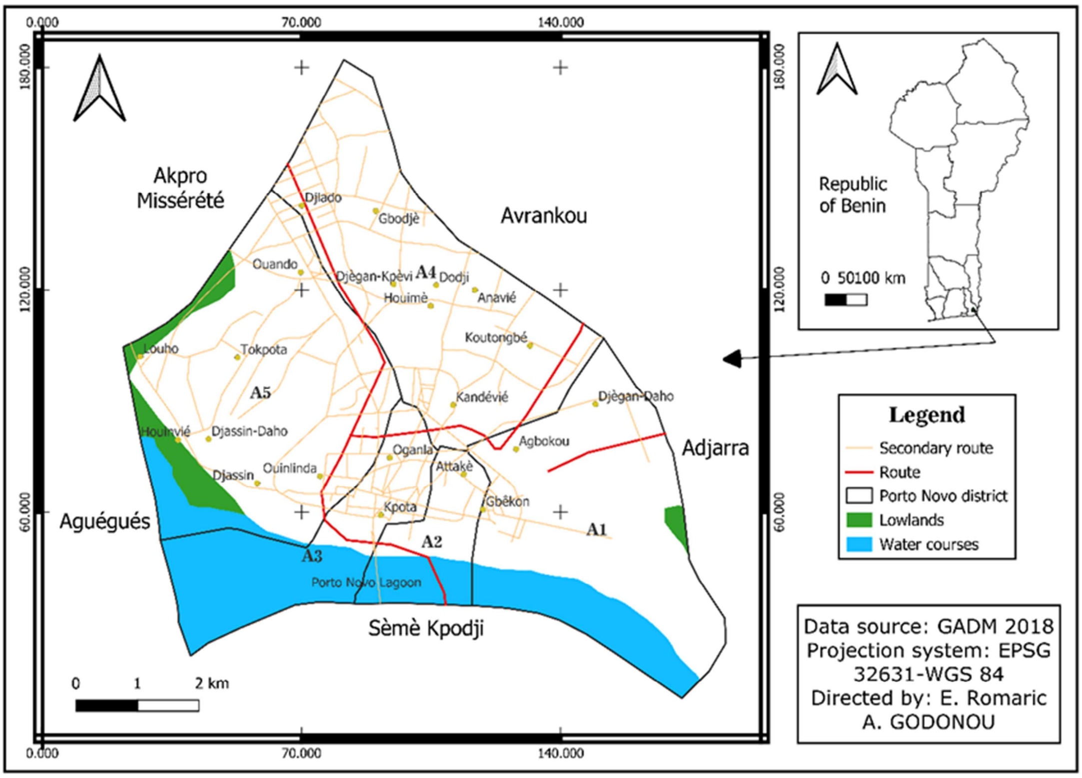

Fig. 1. Geographic location of the city of Porto-Novo

Table 1. Twenty (20) identified tree species and their carbon stocks

Species	Carbon stock in tC
Citrus limon L	0.005
Artocarpus altilis (Parkinson) Fosberg	0.035
Senna siamea (Lam.) H.S.Irwin et Barneby	0.006
Eucalyptus globulus Labill.	0.033
Dialium guineense Willd.	0.013
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	0.077
Tectona grandis L.f.	0.027
Salix babylonica L	0.024
Casuarina equisetifolia L.	0.048
Albizia lebbeck (L.) Benth.	0.107
Spondias mombin L.	0.002
Anogeissus leiocarpa (DC.) Guill. Et Perr.	0.007
Cordia gerascanthus L.	0.087
Myristica fragrans Houtt.	0.007
Triplochiton scleroxylon K. Schum.	0.087
Castilloa elastica Sessé	0.002
Hevea brasiliensis (Wild. Ex A. Juss.) Müll. Arg.	0.051
Pterocarpus santalinoides DC	0.013
Carapa procera DC	0.080
Pilocarpus racemosus Vahl	0.081

The climate is subequatorial, 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 and 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). Porto-Novo is located within the Guineo-Congolian ecological zone and experiences a subequatorial climate. This climate features two dry seasons (from mid-November to mid-March and from mid-July to August) and two rainy seasons (from mid-March to mid-July and from September to mid-November). The average annual rainfall is approximately 1.200 mm with 700 to 800 mm occurring during the major rainy season and 400 to 500 mm during the minor season (Boko, 1988). Vegetative cover development in this region is influenced by geomorphological, topographical, pedological, climatic, and hydrographic factors. The soil plays a crucial role in plant growth, acting as a reservoir that can retain varying amounts of water and essential nutrients.

Data collection methods

Identification and selection of species

The study focused on 20 tree species identified for their high carbon sequestration potential (Table 1) which were selected during a preliminary assessment.

Data collection

Data were gathered through semi-structured surveys. Interviews explored residents' knowledge and perceptions of the uses of the 20 targeted species, their role in mitigating climate change impacts and the benefits associated with urban green spaces. Respondents also shared suggestions for the sustainable management of these spaces. In total, 10 people were surveyed per green space within a 100-meter radius resulting in 390 individuals surveyed along with 4 resource persons. The data collected included social characteristics (socio-cultural group, gender, age, main occupation), types of plant species in green spaces, different plant parts used (leaves, fruits, roots, etc.) and the frequency of use of green space species.

Data processing and analysis

The data collected from residents around the green spaces in Porto-Novo were extracted using Kobocollect, and the following indices were calculated.

Relative frequency of citation (RFC)

This measures the rate of responses per species with high carbon sequestration potential as indicated or recommended by the population. It is calculated using the formula from Idakou *et al.* (2024). This index measures each species' popularity by calculating the proportion of respondents who mentioned a specific species among the 20 studied. offering insights into the integration of each species into local practices.

$$\text{FRC} = \frac{n}{N} \times 100$$

Where:

n = the number of people who mentioned a given species et N = the total number of respondents.

Use value (UV)

This was used to calculate the use value of each species by usage category following the method used by Lykke (2004) and Belem (2008). The Use Value is calculated based on the frequency and diversity of mentions for each species expressing the relative importance of each species for Porto-Novo residents according to observed uses. It is calculated as follows.

$$vu = \frac{\sum_i^n si}{n}$$

Where:

UV (spi) = the use value of a given species for a specific category.

Si = the usage score assigned by respondents.

N = the number of respondents for a given usage category.

Cultural importance index (CII)

This index represents the relative importance of each species or plant part used as indicated by each respondent (Salako *et al.,* 2019). Calculated to assess each species' cultural importance, this index considers mentions by usage category (medicinal, food, artisanal, ornamental), reflecting the symbolic and practical significance of the species in the daily lives of Porto-Novo's residents.

$$IIC = \sum_{uc=1}^{nuc} IICuc = \sum_{uc=1}^{nuc} \sum_{i=1}^{n} \frac{Suc, i}{n}$$

Where:

Suc, i = the importance score assigned by respondent i for a species or plant part c

nuc = the number of species or plant parts.

CII represents the cumulative importance of all species or plant parts and IICuc is the importance value for each species or plant part.

A correspondence analysis was conducted using R software to examine the relationship between species and usage categories, as well as between species and various plant parts used. This analysis helped identify relationships and grouped species based on their contribution to different types of uses providing a map of the ethnobotanical practices in Porto-Novo.

Results

Recognition of high-carbon sequestration tree species

This study identified twenty tree species with high carbon sequestration potential in Porto-Novo. Among these, several species are well-known to the local population and play an important role in their daily lives. *Citrus limon* (93.4%), *Artocarpus altilis* (81.2%), *Senna siamea* (75.9%) and *Eucalyptus globulus* (70.8%) stand out due to their high Relative Frequency of Citation (RFC), highlighting their integration into local practices and knowledge. These species are often favored for their multiple uses and visibility within urban green spaces. In contrast, species like *Carapa procera* (3.3%) and *Pilocarpus racemosus* (1.8%) are far less recognized and significantly underutilized by the population (Table 2). These low recognition rates may be attributed to factors such as their rarity in urban spaces or their perceived lesser utility among residents.

Table 2. Relative citation frequency of studied species

SL	Species	FRC (%)
1	*Citrus limon* L	93.4
2	*Artocarpus altilis* (Parkinson) Fosberg	81.2
3	*Senna siamea* (Lam.) H.S.Irwin et Barneby	75.9
4	*Eucalyptus globulus* Labill.	70.8
5	*Dialium guineense* Willd.	69.0
6	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	64.7
7	*Tectona grandis* L.f.	64.2
8	*Salix babylonica* L	51.3
9	*Casuarina equisetifolia* L.	32.0
10	*Albizia lebbeck* (L.) Benth.	24.1
11	*Spondias mombin* L.	23.9
12	*Anogeissus leiocarpa* (DC.) Guill. Et Perr.	19.5
13	*Cordia gerascanthus* L.	17.5
14	*Myristica fragrans* Houtt.	17.3
15	*Triplochiton scleroxylon* K. Schum.	9.6
16	*Castilloa elastica* Sessé	9.4
17	*Hevea brasiliensis* (Wild. Ex A. Juss.) Müll. Arg.	9.1
18	*Pterocarpus santalinoides* DC	3.8
19	*Carapa procera* DC	3.3
20	*Pilocarpus racemosus* Vahl	1.8

Ethnobotanical uses and categories of utilization

This study identified four main usage categories for tree species with high carbon sequestration potential: food, artisanal, ornamental, and medicinal. Fig. 2 and 3 illustrate the cultural significance of these species according to their uses. Fig. 2 shows the distribution across usage categories highlighting the prominence of food and artisanal uses compared to other categories. Fig. 3 displays the Cultural Importance Index (CII) for each species with specific details on plants like *Citrus limon* and *Dialium guineense*, which stand out due to their frequent and diverse applications. These figures enhance understanding of the integration of these species into the daily lives of Porto-Novo residents, underscoring the diversity of uses and highlighting the plants with the highest cultural value. This analysis of usage categories helps to identify priority species for conservation and promotion in the sustainable development of urban green spaces.

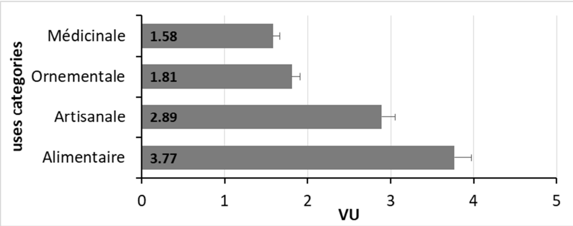

Fig. 2. Use value of use categories

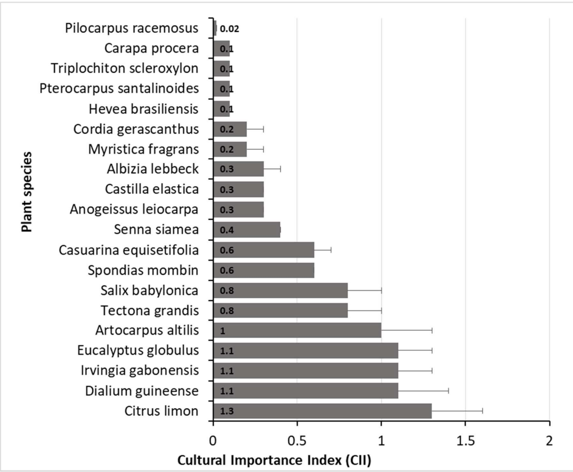

Fig. 3. Cultural importance index of species

Factorial analysis of usage categories

Fig. 4 displays species groupings by usage category providing a graphical interpretation of trends identified on axes F1 and F3. Species associated with ornamental and artisanal uses, such as *Eucalyptus globulus* (E4), *Salix babylonica* (E8), and *Tectona grandis* (E12) form a distinct group. Their positioning on the graph confirms their popularity for urban beautification and as sources of materials for artisanal crafts. The food group, represented by species like *Citrus limon* (E6), *Dialium guineense* (E9), and *Irvingia gabonensis* (E11), stands out on axis F3. These species are highly valued for their contributions to nutrition making them priority choices for conservation due to their nutritional importance. The factorial analysis and the graphic representation, thus offer a clearer understanding of the ethnobotanical preferences and practices of residents, guiding recommendations for the planning and management of urban green spaces based on dominant usage categories. These insights provide concrete directions for sustainable management that align with the cultural and practical needs of the community.

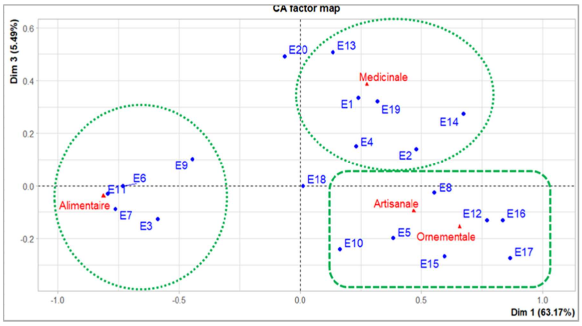

Fig. 4. Factor analysis between usage categories and different species on the F1 and F3 axes.

Plant parts used in species

Fig. 5. presents the various parts of tree species with high carbon sequestration potential that are used in different ways, each holding unique importance in local practices. This figure highlights how distinct plant parts contribute to the ethnobotanical value of these species, showcasing their diverse applications within the community.

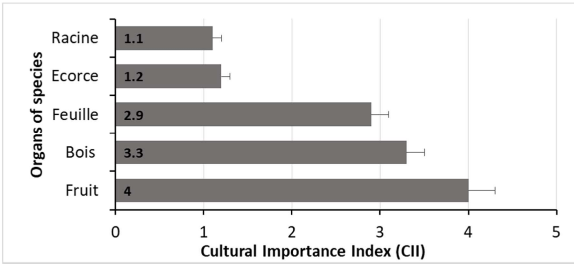

Fig. 5. Importance of the organs used

Distribution of plant part uses by species

Fig. 6. illustrates the distribution of uses for various plant parts by species, revealing specific usage trends for each part. The factorial analysis between plant parts and different species shows a strong association of *Eucalyptus globulus* (E4) and *Irvingia gabonensis* (E6) with the use of their roots and bark, primarily for medicinal purposes, affirming their importance in traditional healthcare practices. Species clustered around fruit use, such as *Citrus limon* (E6) and *Dialium guineense* (E9) clearly stand out, highlighting their essential roles in local food and economy. Finally, species like *Tectona grandis* (E12) and *Triplochiton scleroxylon* (E15) associated with wood use, underscore their importance as sources of materials for artisanal crafts and construction.

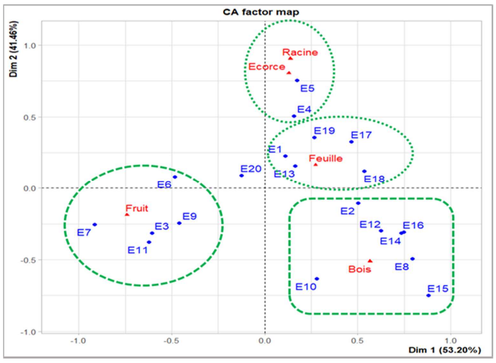

Fig. 6. Factorial analysis between species parts and different species on axes F1 and F3

These results help to identify key species for each type of use strengthening recommendations for the conservation and promotion of these species in urban green space planning. This approach supports sustainable resource utilization while meeting the practical needs of residents.

Recommendations for green space development

To promote sustainable management of urban green spaces in Porto-Novo, several specific practices have been proposed, taking into account both ecological and social needs along with high recommendation frequencies. Foremost is a strict protection policy, supported by 98.73% of respondents, aimed at preserving areas rich in species with high carbon sequestration potential, thereby ensuring their continued environmental contributions. This measure is complemented by the adoption of sustainable planting techniques (RFC of 98.47%) that encourage the growth of tree species suited to local conditions.

Additionally, educational programs to raise awareness of the ecological importance of these species are suggested with a frequency of 98.22%. This educational aspect, paired with community involvement in reforestation and tree maintenance programs (RFC of 97.96%), enhances resident engagement and supports the sustainability of reforestation initiatives.

Moreover, the creation of diverse urban parks that integrate both local and exotic species is endorsed by 97,71% of respondents to strengthen biodiversity and improve air quality in urban areas. In parallel, the planting of tree hedges along roads and residential areas, recommended by 97.46%; serves as a natural barrier against pollution while adding green aesthetics to neighborhoods. Lastly, the establishment of recreational green spaces (RFC of 97,21%) is suggested to provide relaxation zones for city dwellers, thereby contributing to an improved quality of life (Fig. 7).

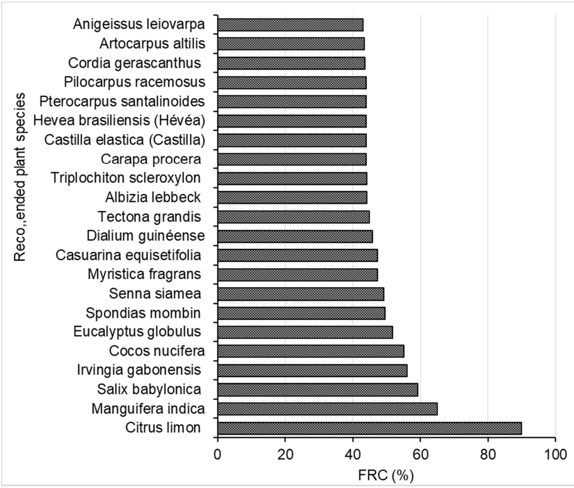

Fig. 7. Recommended plant species

Together, these structured recommendations address community expectations while strengthening the sustainability and ecological resilience of Porto-Novo's green spaces.

Discussion

The analysis of this study's results on the ethnobotanical uses of high-carbon sequestration tree species in Porto-Novo's green spaces highlights the multifunctional importance of these plants in the lives of urban residents.

Recognition of high-value tree species

The results reveal a high level of recognition for certain tree species among the Porto-Novo community, notably *Citrus limon*, *Artocarpus altilis*, *Senna siamea*, and *Eucalyptus globulus*.

This recognition, measured through the Relative Frequency of Citation (RFC), underscores the importance of these species in local practices due to their versatility for medicinal food, artisanal, and ornamental uses. This finding aligns with the research of Dossou *et al.* (2012) in the Agonvè forest in Benin, where species like *Dialium guineense* and *Raphia hookeri* are highly valued for their multiple uses, especially in pharmacology and food production. Such observations affirm the importance of maintaining plant diversity in urban spaces as they offer resilience and support to the daily needs of communities.

Use value and cultural importance of tree species

The Use Value (UV) and Cultural Importance Index (CII) calculated for each species show significant variability depending on their usage by residents. For example, *Citrus limon* and *Dialium guineense* have high values due to their diverse functions ranging from medicinal applications to nutritional needs. In West Africa, species with high use values are often prioritized in conservation efforts, as they meet fundamental community needs as seen in ethnobotanical studies in Niger and Côte d'Ivoire, where tree species play a central role in healthcare and nutrition (Béné *et al.*, 2026). This highlights the importance of ethnobotanical practices in ensuring the sustainability of urban plant species a crucial aspect of sustainable urban resource management, as noted by researchers like Kenney *et al.* (2011).

Associations between uses and sustainable urban planning

The factorial analysis grouped species according to usage categories providing key insights for green space development. Species like *Eucalyptus globulus*, *Salix babylonica*, and *Tectona grandis* were found to be particularly suitable for ornamental and artisanal uses, making them ideal for aesthetic enhancements in public areas. These findings align with the work of Baggnian *et al.* (2021), who demonstrate that urban green spaces integrating local species can enhance cultural belonging while improving biodiversity. Additionally, the prominence of food species, such as *Irvingia gabonensis* and *Spondias mombin*, reflects their potential for local food security, especially in communities with limited resource access. This aligns with studies in Cameroon, which show that these species are essential for local nutrition and should be protected under urban management policies.

Importance of plant parts in local practices

The diversity of plant parts used, such as leaves, Bark, Fruits, and roots, reveals the importance of various plant parts in pharmacology and food. For example, the leaves of *Vitex doniana* and the roots of *Eucalyptus globulus* are frequently used in medicinal preparations. A practice observed in many regions of Africa. Research on the Agonvè swamp forest also confirms that each plant part can be valued for specific uses, underscoring the importance of these resources for traditional healthcare. This multifaceted use highlights the need to preserve tree species not only for their aesthetic value but also for their contributions to the health and subsistence of communities.

Perspectives for sustainable and inclusive green space development

Respondents' recommendations for sustainable management practices, particularly strict protection of green spaces, highlight a growing ecological awareness. The adoption of sustainable planting techniques, along with the proposed educational programs. represents a proactive approach to involving communities in green space preservation. The strong resident support for reforestation and education initiatives, as also observed in other African urban contexts, reflects an increased appreciation for the ecological and social benefits of tree species. According to Godonou *et al.* (2024). This participatory approach can play a key role in protecting urban ecosystems from anthropogenic pressures and the effects of climate change.

Strengths and weaknesses of the methodology

The methodology used in this study presents notable strengths as well as some limitations impacting the quality of the results obtained. On one hand, the quantitative approach, using ethnobotanical indices such as Use Value (UV) and Cultural Importance Index (CII), is a major asset that allows quantification of species importance to the community (Dossou *et *al.,* 2012). This type of evaluation, also used in similar studies, provides a relevant hierarchy of species and facilitates conservation priorities (Codjia *et al.,* 2007). Additionally, the methodology values traditional knowledge by documenting local perceptions and uses which is essential for sustainable and culturally respectful management practices as highlighted in the Agonvè swamp forest study (Dossou *et al.,* 2012). The use of Principal Component Analysis (PCA) is another methodological strength, as it allows for species grouping based on uses and enables tailored development recommendations (Baggnian *et al.,* 2021).

However, this methodology has certain weaknesses. Heavy reliance on participants' memories may introduce biases affecting the accuracy of information on uses (Dossou *et al.,* 2012). Moreover, the lack of direct measurement of anthropogenic pressure on species limits understanding of the impact of human exploitation, as also noted in the Agonvè study. Finally, focusing the sampling exclusively on Porto-Novo without interregional comparisons reduces the generalizability of the results to other urban contexts (Codjia *et al.,* 2007).

Overall, this study highlights the importance of tree species for the ecological and social resilience of urban environments, particularly in Porto-Novo. By integrating these species into green space management policies, decision-makers could not only enhance urban biodiversity and carbon sequestration but also meet residents' cultural and economic needs, thus linking ecological conservation to local values. The ethnobotanical knowledge gathered provides a solid foundation for developing sustainable development strategies that align with local practices, supporting a more inclusive and holistic approach to plant resource management. These findings demonstrate that ensuring respectful and sustainable use of natural resources requires an approach that values cultural practices and meets the socio-economic needs of local communities. By combining ecological conservation with the preservation of traditional knowledge, urban managers can better meet community expectations while contributing to the sustainable development of Porto-Novo.

Conclusion

This study highlights the significant multifunctional roles of urban green spaces in Porto-Novo, particularly focusing on tree species with high carbon sequestration potential. Key findings indicate that certain species, such as *Citrus limon*, *Artocarpus altilis*, and *Eucalyptus globulus*, are highly valued by the local community for diverse uses, including medicinal, food, artisanal, and ornamental purposes. The calculated ethnobotanical indices (RFC, UV, CII) reveal the strong cultural and practical importance of these species, suggesting that their conservation is essential for community well-being and environmental resilience.

Furthermore, the support for sustainable management practices, such as strict protection of green spaces and community engagement in reforestation, reflects a growing ecological awareness. These insights underscore the importance of incorporating local knowledge and preferences into urban planning to maximize both ecological and social benefits. By aligning conservation efforts with cultural values, this study provides a foundation for more inclusive and sustainable green space management in Porto-Novo.

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