Biological Diversity

ORIGINAL ARTICLE OPEN ACCESS

The Distribution Patterns of Vascular Plant Diversity in Green Spaces in Guangzhou, Southern China

Ke Liu[1,2] | Lingbo Ji[1,3] | Qinfeng Guo[4] | Hai Ren[1,2] | Hongxiao Liu[1,2]

[1]South China Botanical Garden Chinese Academy of Sciences, Guangzhou, China | [2]University of Chinese Academy of Sciences, Beijing, China | [3]Ecology and Environmental Science Research & Design Institute of Zhejiang Province, Hangzhou, China | [4]USDA—Southern Research Station, Research Triangle Park, North Carolina, USA

Correspondence: Hongxiao Liu (liuhx@scbg.ac.cn)

Received: 20 April 2025 | **Revised:** 2 August 2025 | **Accepted:** 16 August 2025

Funding: This study was funded by the Guangdong Flagship Project of Basic and Applied Basic Research (Grant No. 2023B0303050001), National Natural Science Foundation of China (42271308) and Youth Innovation Promotion Association CAS (2023363). The authors would like to thank and acknowledge colleagues at the Ecological Center of the South China Botanical Garden for their assistance with plant investigation and experiments and extend special thanks to Ji Lingbo for his help with plant identification.

Keywords: floristic | native species | park | residential green space | street greenery | subtropical | urban biodiversity

ABSTRACT

Vascular plants are a fundamental component of urban green spaces (UGSs) and their diversity determines the associated ecological benefits. This study surveys the vascular plant diversity in three types of UGSs (i.e., urban parks, residential green spaces, and street green spaces) in Guangzhou, Southern China. The distribution patterns of vascular plant diversity in UGSs were analyzed from multiple perspectives, such as native-exotic species, urbanization degree (urban-rural gradient). We recorded a total of 207 vascular plant species belonging to 172 genera and 83 families, accounting for only 5.9% of the total recorded species in the city. Shannon–Wiener index and richness of street green spaces were the lowest among the three types of UGSs. Allien and invasive species account for 8.5% and 4.6% in urban parks, 7.1% and 4.8% in residential green spaces, and 4.3% and 0% in street green spaces respectively. Shannon–Wiener index and Pielou's evenness index first decrease and then increase with the central-intermediate-outer urban gradient. Compared to the surrounding natural areas and other subtropical cities, urbanization has reduced vascular plant diversity in inner city areas, contributing to low overall diversity. Our results provide support for urban biodiversity conservation and plant species selection for UGS planting in Guangzhou.

1 | Introduction

Urban green spaces (UGSs) provide multiple important ecosystem services such as air purification, thermal regulation, flood control, and cultural services, which are crucial for the sustainable development of cities. Vascular plants, characterized by specialized xylem and phloem tissues for water and nutrient transport, are distinct from non-vascular plants in their ability to develop complex structures (e.g., trees, shrubs, and herbs) and adapt to diverse urban microhabitats. This structural complexity makes them fundamental to urban ecosystems. They form the primary productivity base of UGSs, drive material cycling, and create multi-layered habitats for urban fauna and microorganisms. Their longer lifespan and larger biomass also enhance the stability of ecosystem services, such as long-term air purification and microclimate regulation, which are critical for urban resilience. Vascular plants constitute the main component of UGSs, and their diversity is a key aspect of UGSs quality. Studies to date have shown that plant diversity enhances habitat heterogeneity, thereby providing habitats for a wide range of animals and microorganisms and serving as the foundation of urban biodiversity [1]. However, many UGSs have

https://doi.org/10.1002/bod2.70009

Highlights

- Native species dominated all urban green space (UGS) types (86.9% in parks, 91.2% in residential areas, 95.7% in street green spaces), with alien species < 10% in all. Urban parks had the highest invasive species proportion (4.6%), while street green spaces had none—parks are key invasion risk zones.
- Street green spaces had notably lower species richness and Shannon-Wiener Index than parks and residential green spaces; Simpson Diversity Index and Pielou Evenness showed no significant differences among the three.
- Along central (0–5 km) → intermediate (5–10 km) → outer (10–15 km) zones, Shannon-Wiener Index and Pielou Evenness followed a "high → low → high " trend (intermediate zone significantly lower); species richness and Simpson Diversity Index had no significant gradient differences.
- Low UGS diversity relates to urbanization (intermediate zone habitat fragmentation) and management (preferring herbs, inconsistent maintenance). Suggestions: prioritize native shrubs, strengthen park invasive monitoring, and restore intermediate zone habitat connectivity.

low vascular plant diversity, which restricts their stability to provide ecosystem services and support biodiversity.

The economic, cultural, and social development of cities influences the plant diversity of UGSs [2, 3]. Unlike natural environments in the wilderness, the composition of vegetation in UGSs is influenced by human factors, and its plant diversity is subject to management. Therefore, plant diversity in cities is affected by various natural and anthropogenic factors [4].

In recent years, some studies have found that plant diversity exhibits a unimodal increasing trend from the city center to rural areas, as human disturbances decrease [5–8]. However, some studies suggest that the city center may have higher plant diversity than suburban or rural areas due to the introduction of many alien species or because the city itself is a biodiversity hotspot. For instance, researchers found in their study of Siberian cities that the proportion of alien species decreased from 45% in urban areas to 23% in rural areas with increasing distance from the city center [9]. Another study discovered that plant diversity, woody plants, and perennial herbaceous species richness increased with urbanization in Shanghai, China, while the Shannon–Wiener index and evenness of annual herbaceous plants, exhibited the opposite trend [10]. Therefore, the spatial patterns of plant diversity in UGSs may be complex and differ across different cities. The diversity of different plant groups (woody vs. herbaceous, native vs. non-native species) may also show different trends along the urbanization gradient. Additionally, using different plant diversity indicators may yield different results [11, 12].

Despite growing global research on biodiversity patterns in urban areas, the specific vascular plant diversity patterns in different types of UGSs in central Guangzhou remain unexplored. In this study, we aim to fill this gap by examining the vascular plant diversity of three types of UGS, and their spatial patterns across different urban zones in Guangzhou. Specifically, this study addresses: (1) How does vascular plant diversity vary among different UGS types? (2) How does species composition influence vascular plant diversity? (3) What is the pattern of vascular plant diversity across urban zones? The answers to these questions aim to provide baseline data that can inform targeted strategies for biodiversity conservation and urban sustainability in Guangzhou.

2 | Methodology

2.1 | Study Site

Guangzhou is the capital of Guangdong Province and one of the largest cities in South China, serving as a major hub of fast social and economic development in recent decades. The total area of the city is 7434 km^2, with a permanent population of 18.81 million. Guangzhou is located at 22°26′-23°56′N and 112°57′-114°3′E, with the city center at 23°06′32″N and 113°15′53″E. It has a typical subtropical monsoon climate in South Asia, with prevailing southwest winds in the summer and predominantly north winds in the winter. The greenspace coverage in the urban built-up area was 45.5% [13]. For this study, we selected a central built-up area as the study site, which included 8 administrative districts (Figure 1). We selected three types of UGSs, that is, urban parks, residential green space, and street green space since these three types of UGSs account for 72% of the total UGS area in central Guangzhou. We randomly established 12 sampling plots for each type of UGS (Figure 2). Based on the distribution map of UGSs in the city, the spatial diffusion pattern of the city is determined on the OpenStreetMap (https://www.openstreetmap.org/). We selected a 15 km radius around the Guangdong Provincial Museum to capture the core urbanized area and its outward expansion gradient in all four cardinal directions. The distances from the central point are divided into three zones: 0–5 km (central area), 5–10 km (intermediate area), and 10–15 km (outer area). These selected zones (gradients) represent the outward diffusion trend during the city's urban development, illustrating the dispersion trends of population and economic density. To some extent, it reflected the distribution of human activity levels in the city. GPS positioning was used to locate all sample plots during the survey, recording coordinate data and marking the sample plot locations as reference points.

2.2 | Plant Survey

Plant community surveys were conducted annually in the months of March to July in both 2021 and 2022. All trees within the plots were measured, and the cover and frequency for shrubs and herbaceous plants were recorded, along with photographs taken to document community density. We referred to "Invasive Plants in Guangzhou" [11], the Chinese iPlant Intelligent Plant Database (http://www.iplant.cn/), and the National Specimen Resource Sharing Platform (NSII) (http://nsii.org.cn/). We used the vegetation classification system following "The Terrestrial Plant Resources in Guangzhou" [14]. The main recorded information of each plot was as follows:

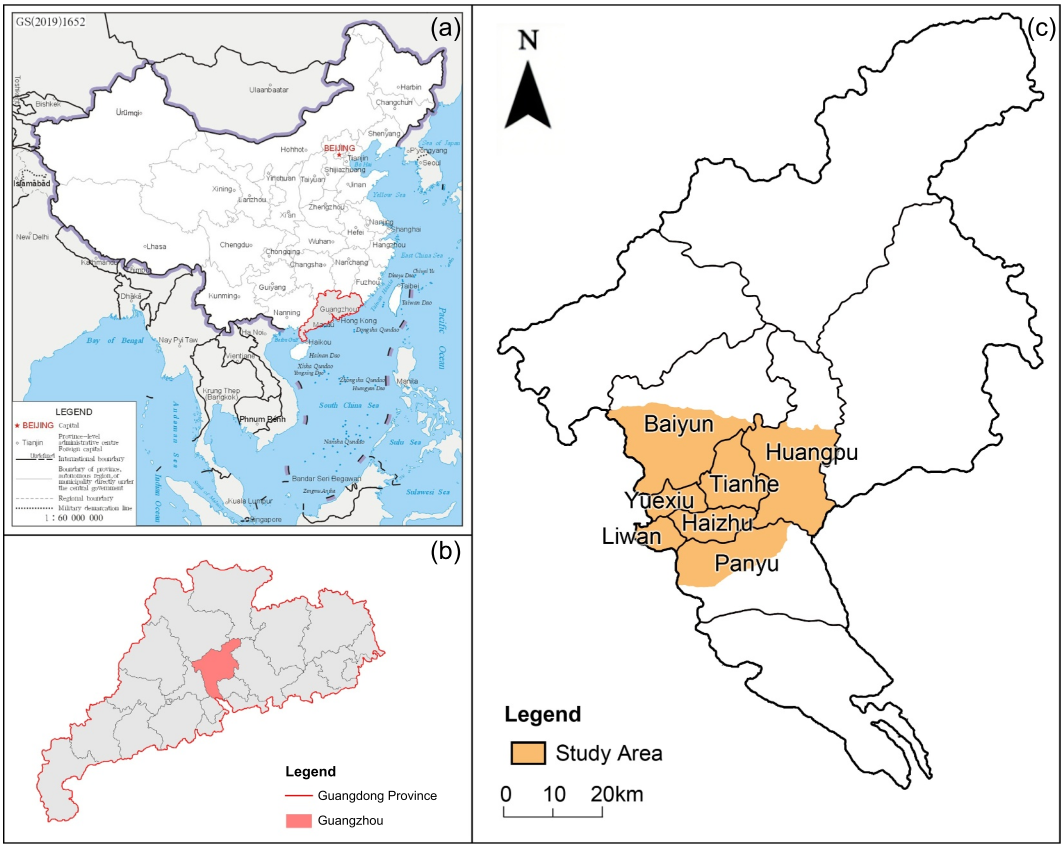

FIGURE 1 | The study area in Guangzhou, China. (a) Guangdong province, China; (b) Administrative district of Guangzhou; (c) Study area. *This map was produced based on the standard map with the map revision number GS (2019) 1823 downloaded from the website of the Ministry of Natural Resources. The boundaries of the base map have not been modified.

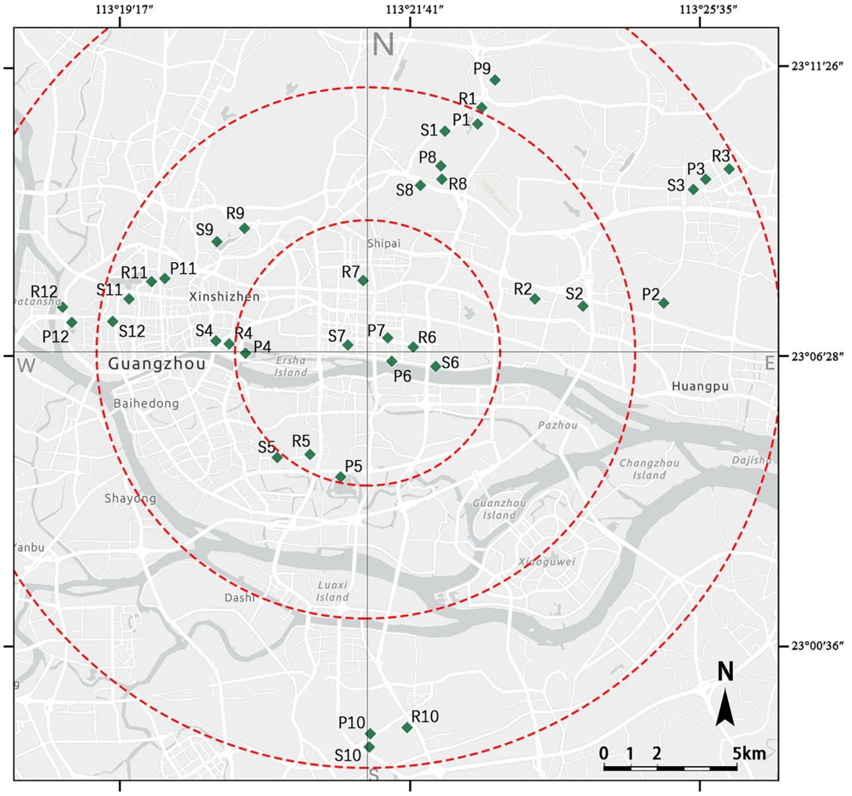

FIGURE 2 | Spatial distribution map of the sample plots in Guangzhou, China. P represents park green spaces, R represents residential green spaces, S represents street green spaces.

1. Species, number of trees, height, crown width, and DBH (Diameter at Breast Height) of the trees.
2. The species, coverage, abundance, density, and average height of shrubs and herbaceous plants.

2.3 | Species Diversity

The Importance Value of Species (IV) and alpha diversity indices were used to compare differences in vascular plant species diversity.

Importance Value (IV) is a composite index that quantifies the dominance of a species in a community by integrating three key metrics: Relative Frequency (RF, the proportion of plots where the species occurs), Relative Coverage (RC, the proportion of the total coverage occupied by the species), and Relative Abundance (RA, the proportion of the total number of individuals belonging to the species). Importance Value of Species (IV) in vascular plant communities:

$$IF = \frac{RF + RC + RA}{3} \tag{1}$$

Species Richness:

$$R = S \tag{2}$$

Shannon–Wiener Index:

$$H = \sum_{i=1}^{S} (P_i \ln P_i) \tag{3}$$

Simpson Diversity Index:

$$D = 1 - \sum_{i=1}^{S} P_i^2 \tag{4}$$

Pielou Evenness:

$$J = \frac{H}{\ln S} \tag{5}$$

In the above equations, R represents species richness, H represents Shannon–Wiener Index, D represents Simpson Diversity Index, J represents Pielou Evenness, RF is Relative Frequency, RC is Relative Coverage, RA is Relative Abundance, S is the count of species, and P_{i} represents the relative coverage of the i-species.

2.4 | Floristic Composition

According to the NSII, the Chinese Plant Atlas (https://www.iplant.cn/), "Flora of China", and the Global Biodiversity Information Facility (GBIF), the vascular plants of UGSs in Guangzhou were divided into six floristic types based on their geographical distribution. These include Tropical and Subtropical Distribution, Ubiquitous Subtropical Distribution, Tropical and Temperate Distribution, East Asia Distribution, East Asia Isle Distribution, and Worldwide, Tropical and Subtropical Origin.

2.5 | Comparison of Native and Alien Plants

Based on recent reports on species information in the South China region [15], as well as "Flora of Guangdong" and the Chinese Plant Atlas (https://www.iplant.cn/), the percentages of native species, alien species, and invasive species were calculated separately for the three types of UGSs.

2.6 | Data Analysis

One-way analysis of variance (ANOVA) was employed to quantify the differences in species diversity among different types of UGSs and urban-rural gradients. All analyses were conducted using SAS JMP 16.0.0 software.

3 | Results

3.1 | Vascular Plant Species Composition

Through surveys conducted in 2021 and 2022 in the three types of UGSs in central Guangzhou, including urban parks, residential green spaces, and street green areas, a total of 207 species of 172 genera and 83 families of vascular plants were identified. These species represented approximately 5.9%, 12.6%, and 36.0% of the total vascular plant species in Guangzhou (3508 species, 1362 genera, and 230 families) [16].

According to the IV in ranking the species dominance in the canopy layer, the genus *Ficus* from the Moraceae family had the highest importance value. Species with IV greater than 1 were as follows: *Ficus macrocarpa* (3.64), *Terminalia myriocarpa* (1.76), *Cinnamomum burmanni* (1.73), *Ficus benjamina* (1.43), *Elaeocarpus apiculatus* (1.20), *Ficus virens* (1.07), and *Bauhinia purpurea* (1.02). In the understory, the IV, from high to low, were as follows: *Axonopus compressus* (3.85), *Cynodon dactylon* (3.10), *Schefflera arboricola* (1.24), and *Loropetalum chinense* 'rubrum' (1.00) (Table 1). The species with IV ranging from 0.80 to 1.00 included *Ophiopogon bodinieri*, *Oxalis corniculata*, *Alocasia odora*, *Liriope spicata*, and *Duranta erecta*. The remaining 135 species had a lower IV than 1.0.

The plant species in Guangzhou's UGSs belonged to five major groups: trees, shrubs, herbaceous plants, vines, and ferns. Among them, trees and herbaceous plants were the most dominant species. There were a total of 80 tree species, accounting for 38.61% of the total species richness, 27 shrub species (12.99%), and 95 herbaceous species (46.14%). The understory exhibited the lowest overall species richness, with relatively low similarity in species composition among different sites. There were only three fern species and two woody vine species. The ratio of tree to shrub to herbaceous plant species in the vascular plant community was approximately 4:1:3. The distribution of dominant species of vascular plants in UGSs in Guangzhou is relatively even.

The vertical distribution of species in vegetation communities showed distinct patterns, with more species in the canopy and herbaceous layer and fewer species in the shrub layer (Figure 3).

TABLE 1 | Species with importance value > 1 in three types of UGSs.

Canopy layer		Understory	
Species	**Importance value**	**Species**	**Importance value**
Ficus macrocarpa	3.64	*Axonopus compressus*	3.85
Terminalia myriocarpa	1.76	*Cynodon dactylon*	3.10
Cinnamomum burmanni	1.72	*Schefflera arboricola*	1.24
Ficus benjamina	1.43	*Loropetalum chinense* var. *rubrum*	1.00
Elaeocarpus apiculatus	1.20		
Ficus virens	1.07		
Bauhinia purpurea	1.02		

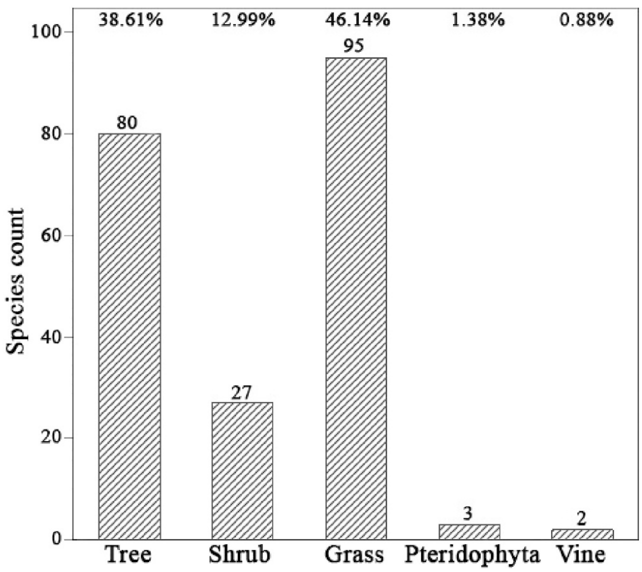

FIGURE 3 | Morphological characteristic percentage of vascular plants in Guangzhou's urban green spaces.

Additionally, among the woody vine and fern species, *Epipremnum aureum* was the sole dominant species, while the dominant species among ferns are *Cyclosorus parasiticus* and *Nephrolepis cordifolia*. In general, the number of species in woody vines and ferns was relatively low.

3.2 | Characteristics of the Vascular Plant Flora

In the UGSs of Guangzhou, there were the most species with tropical and subtropical distributions, totaling 58 species, accounting for 43% of the total. This category included trees common in South China, such as the *Ficus genus* (12 species), *Cinnamomum genus* (3 species), and *Bauhinia genus* (3 species). Next is the ubiquitous subtropical distribution, with 29 species, making up 21% of the total. There were 17 species with an East Asian distribution, accounting for 13%, 15 species with a tropical and temperate distribution (11%), 12 species with distribution in East Asian islands (9%), and only 4 species with a worldwide distribution found in tropical and subtropical regions, making up 3% of the total (Table 2).

3.3 | Native and Non-Native Species in Three Types of Urban Green Spaces in Guangzhou

Urban parks had 113 native plant species, 11 non-native species, and six invasive species. Residential green spaces had 103 native plant species, 8 non-native species, and two invasive species. Street green spaces had 45 native species, 2 non-native species, and no invasive species were found. Among these, public park green spaces had the highest number of invasive species (4.6% of the total), while street green spaces had the highest proportion of native species (95.7% of the total). The proportion of non-native species in all three types of UGSs is below 10% (Table 3).

There were a certain number of invasive alien plants in the UGSs of Guangzhou. Although native plants made up over 80% of the species in all three types of UGSs, some park green spaces and residential green spaces still had invasive species. While the proportion of alien species was relatively low, their distribution was more aggregated.

3.4 | Plant Diversity Differed Across Green Space Types

There were significant differences in species richness and Shannon–Wiener Index of vascular plants among different types of UGSs in Guangzhou. Street green spaces had significantly lower species richness and Shannon–Wiener Index compared to residential green spaces and public park green spaces. However, there was no significant difference in various diversity indices, including Simpson Diversity Index and Pielou Evenness, among the three types of UGSs (Figure 4).

3.5 | Vascular Plant Diversity Along the Urban-Rural Gradient

Different diversity indices of vascular plants exhibited differences in the direction of central → intermediate → outer area, with a pattern of high → low → high. Species richness and Simpson's diversity index did not show significant differences along the urban-rural gradient. However, Shannon–Wiener Index and Pielou's evenness index exhibited significant differences along the gradient, both showing significantly lower values in the intermediate zone compared to the central and outer area (Figure 5).

Vascular plant communities in three types of UGSs were distinctly stratified. Species diversity in the canopy layer was higher in all UGSs types, but the similarity in species composition among different UGSs was low. Some residential green spaces and street green spaces show higher similarity in the shrub and herbaceous layers. *Loropetalum Chinense* 'rubrum'

TABLE 2 | Floristic divisions of Guangzhou's vascular plants.

Distribution area	Species	Percentage (%)
Tropical and subtropical	58	43
Ubiquitous subtropical	29	21
East Asia	17	13
Tropical and temperate	15	11
East Asia Isle	12	9
Worldwide, tropical and subtropical origin	4	3

TABLE 3 | The percentage of native species, alien species and invasive species in Guangzhou's three types of urban green spaces.

	Park		Residential		Street	
Type	Species	Percentage (%)	Species	Percentage (%)	Species	Percentage (%)
Native species	113	86.9	103	91.2	45	95.7
Alien species	11	8.5	8	7.1	2	4.3
Invasive species	6	4.6	2	1.8	0	0.0

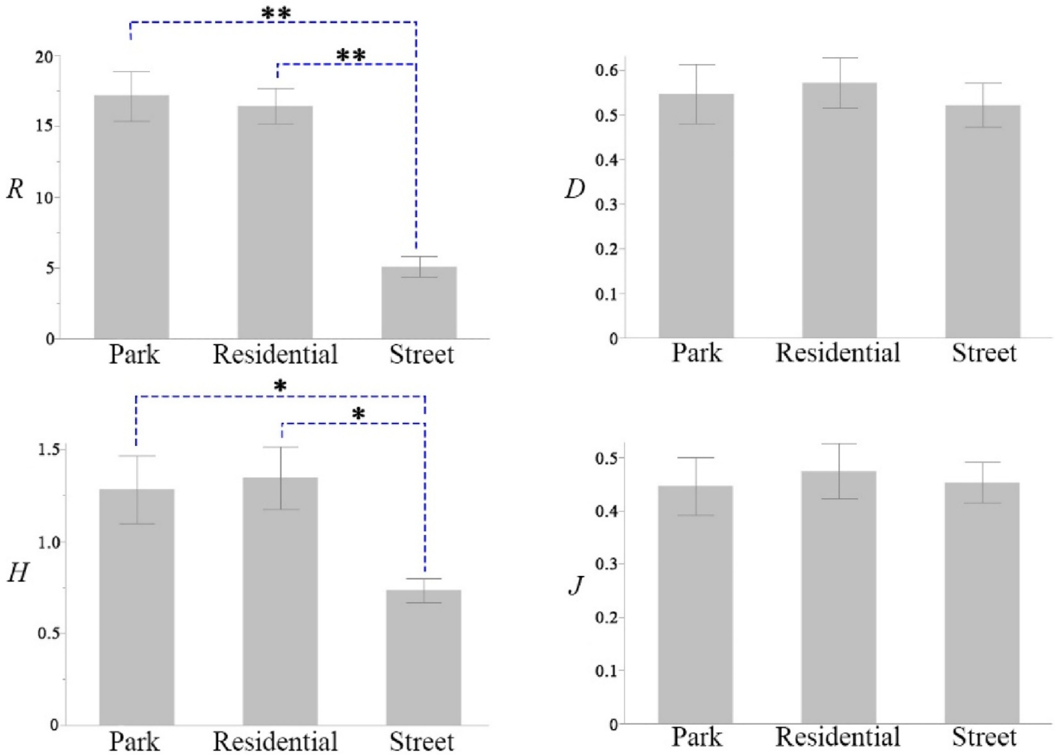

FIGURE 4 | ANOVA results of vascular plant diversity in three types of urban green spaces. R = Species Richness, D = Simpson Diversity Index, H = Shannon–Wiener Index, J = Pielou Evenness; "*" in the figure represents a significant difference between groups ($p < 0.05$), "**" represents a highly significant difference ($p < 0.01$), and unmarked indicates no significant correlation.

was the most common ornamental shrub species in most plots, while the distribution of other species was less consistent.

4 | Discussion

Our study reveals three core patterns in the vascular plant diversity of Guangzhou's UGSs: the dominant role of native species across all green space types, the highest abundance of invasive species in urban parks, a non-linear urban-rural diversity gradient with a trough in intermediate zones, and a structural imbalance characterized by herbaceous dominance over shrubs. These findings are interconnected and reflect the interplay between urbanization processes and vegetation management, which we discuss below with a focus on their ecological implications and links to our empirical data.

Native species accounted for over 85% of vascular plants in all three UGS types, significantly higher than in many other cities. e.g., there are 48.6% native herbaceous species in Chongqing's

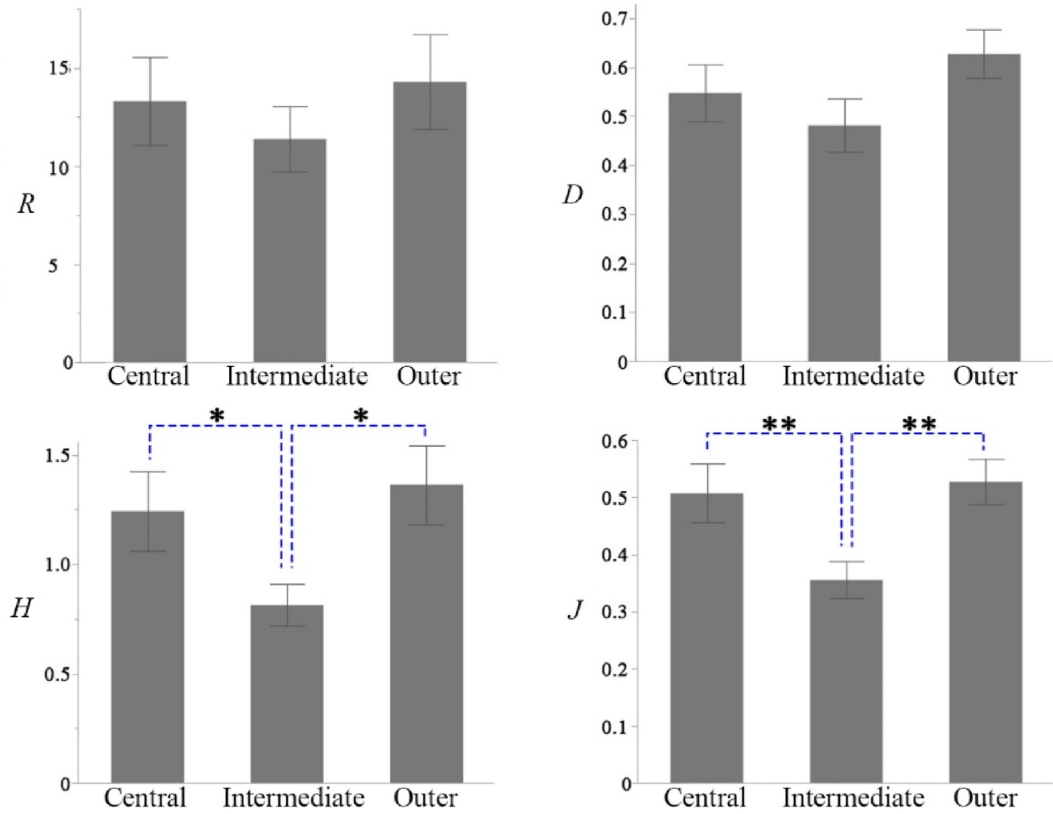

FIGURE 5 | ANOVA result of vascular plant diversity in the central (0–5 km), intermediate (5–10 km), outer (10–15 km) area of Guangzhou's built-up area. R = Species Richness, D = Simpson Diversity Index, H = Shannon–Wiener Index, J = Pielou Evenness; "*" in the figure represents a significant difference between groups ($p < 0.05$), "**" represents a highly significant difference ($p < 0.01$), and unmarked indicates no significant correlation.

urban parks [17] and 17.7% native woody species in Spanish urban parks [18]. This dominance likely stems from Guangzhou's subtropical climate, which favors local adaptation of native flora (e.g., *Ficus* spp. and *Cinnamomum burmanni*), and management practices that prioritize native species for landscaping. Such a pattern reinforces the resilience of urban ecosystems, as native species have co-evolved with local biotic and abiotic conditions, supporting stable ecosystem services like microclimate regulation and habitat provision [18]. However, this does not eliminate invasive risks: urban parks, despite their high native species proportion, harbored the most invasive species (4.6% of total species), which can be attributed to two factors. First, parks have higher rates of intentional introduction of ornamental non-natives and more frequent plant renewal compared to residential or street green spaces [19, 20]. Second, passive dispersal via soil or landscaping materials may further facilitate invasive establishment in parks, where disturbed habitats are common. This coexistence of native dominance and invasive presence highlights the need for targeted monitoring in high-risk areas like parks [10].

Despite their low proportion (4.6% in parks, 1.8% in residential areas), invasive species in Guangzhou's UGSs pose long-term ecological risks. Invasive herbs (e.g., *Bidens Pilosa*) compete with native understory species (e.g., *Ophiopogon bodinieri*) for resources, potentially reducing native abundance. Invasive vines like *Merremia boisiana* can overgrow native trees, altering canopy structure and disrupting habitat for fauna dependent on native species. Parks, as hotspots of invasive presence, face additional challenges: frequent ornamental introductions and plant renewal accelerate invasion, while passive dispersal spreads invasive propagules to other UGSs. These risks necessitate stricter screening of non-native ornamentals and targeted monitoring in parks, where management resources should prioritize eradicating early-stage invasions to protect native community integrity.

The non-linear urban-rural diversity pattern, where higher diversity is observed in the central and outer zones, but a marked decline occurs in the intermediate zone, likely results from distinct anthropogenic pressures and ecological conditions across the gradient. In the central zone (0–5 km from the city center), the high management intensity, as noted in a study on urban green space management in New York which emphasized regular maintenance and species renewal strategies in city center areas, directly contributes to maintaining species richness [21]. Additionally, the well-developed green infrastructure in the central zone, similar to the mature green spaces described in studies about urban green infrastructure development, supports stable plant communities, thus leading to relatively high diversity [22].

In the outer zone (10–15 km), the lower urbanization pressure allows for the preservation of more semi-natural vegetation remnants. As research on urban-rural gradients and plant diversity has pointed out, these semi-natural habitats, with reduced human disturbance, can support balanced species evenness, as native species adapted to local conditions can thrive without intense competition from introduced species [23].

However, the intermediate zone (5–10 km) functions as a "transition stress zone" during rapid urbanization. This area experiences compounded disturbances. Ongoing infrastructure expansion, as is common during the urbanization process as demonstrated in numerous urban development case studies [24], fragments natural habitats into smaller, isolated patches, disrupting plant dispersal, and colonization. Edge effects, which are well-documented in ecological studies on habitat fragmentation [25], such as altered light, temperature, and soil nutrient levels at the boundaries of these fragmented patches, further reduce the suitability of habitats for many species, lowering evenness. Moreover, management practices in the intermediate zone are often inconsistent, as seen in research on urban green space management across different zones [26], failing to maintain stable plant communities. This combination of habitat loss, edge effects, and uncoordinated management drives the observed diversity trough in the intermediate zone.

Our analysis also highlights a structural imbalance in UGS vegetation: herbaceous species (46.14%) dominated over shrubs (12.99%), with a tree-shrub-herb ratio of approximately 4:1:3. This pattern, consistent across UGS types, may limit ecosystem multifunctionality. Multi-layered vegetation enhances microclimate regulation, soil stabilization, and habitat complexity [27, 28], but the scarcity of shrubs in Guangzhou's UGSs reduces these benefits. This imbalance likely reflects management practices: shrubs require more pruning than herbs, leading to preferential planting of herbaceous species in street and residential green spaces. To improve ecological resilience, future landscaping could integrate more native shrubs to strengthen vertical structure.

In summary, Guangzhou's UGS vascular plant diversity is shaped by a unique combination of climate adaptation favoring natives, urbanization dynamics, and management practices influencing invasive presence and vegetation structure. These interconnected patterns provide a basis for targeted strategies: prioritizing native shrubs to balance vegetation structure, enhancing monitoring of invasive species in parks, and restoring connectivity in intermediate urban-rural zones [29]. Such measures can help maintain the ecological benefits of UGSs amid ongoing urbanization.

5 | Conclusions

Relying on the field survey, this study demonstrates that Guangzhou's UGSs exhibit exceptional dominance of native plant species. This reflects the region's emphasis on leveraging locally adapted flora to bolster ecosystem resilience. However, the persistent threat of invasive species—particularly from *Poaceae* and *Asteraceae* families—in park green spaces underscores vulnerabilities tied to intentional ornamental introductions, rapid plant turnover, and passive dispersal pathways.

Our findings align with global evidence that invasive species disrupt ecological stability, necessitating stricter biosecurity protocols and reduced reliance on non-native ornamentals. Spatial analysis reveals a critical bottleneck in plant diversity within intermediate urban–rural zones, where habitat fragmentation and edge effects drive biodiversity declines. Prioritizing habitat connectivity and ecological restoration in these transitional areas is imperative to counteract urban biodiversity loss. Furthermore, the structural imbalance in Guangzhou's UGSs dominated by herbaceous layers with sparse shrub cover, highlights opportunities to adopt multi-layered vegetation designs. Integrating trees, shrubs, and ground cover could enhance microclimate regulation, soil stability, and ecosystem multifunctionality while mitigating disturbance impacts.

Guangzhou's unique biodiversity patterns, shaped by localized management practices and urban development history, emphasize the importance of context-specific strategies in urban management. While native species conservation remains foundational, adaptive measures—such as phased invasive species eradication, community-based monitoring, and restoration of degraded transitional zones—must be scaled to balance ecological integrity with urban expansion pressures. By embedding ecological principles into urban planning frameworks, Guangzhou can serve as a model for sustainable urbanization in biodiversity-rich subtropical regions.

Author Contributions

Ke Liu: investigation, formal analysis, writing – original draft, writing – review and editing, methodology, software, data curation. **Lingbo Ji:** data curation, investigation. **Qinfeng Guo:** writing – review and editing. **Hai Ren:** conceptualization, supervision, funding acquisition, resources, writing – review and editing. **Hongxiao Liu:** writing – review and editing, supervision.

Acknowledgments

This study was funded by the Guangdong Flagship Project of Basic and Applied Basic Research (Grant No. 2023B0303050001), National Natural Science Foundation of China (42271308) and Youth Innovation Promotion Association CAS (2023363). The authors would like to thank and acknowledge colleagues at the Ecological Center of the South China Botanical Garden for their assistance with plant investigation and experiments and extend special thanks to Ji Lingbo for his help with plant identification.

Ethics Statement

The data used in this study were collected according to relevant ethical guidelines and regulations, and there were no interventions or interactions with living organisms.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Z. Baruch, C. Liddicoat, C. Cando-Dumancela, et al., "Increased Plant Species Richness Associates With Greater Soil Bacterial Diversity in

Urban Green Spaces," *Environmental Research* 196 (2020): 110425, https://doi.org/10.1016/j.envres.2020.110425.

2. D. U. Hooper, F. S. Chapin, J. J. Ewel, et al., "Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge," *Ecological Monographs* 75, no. 1 (2005): 3–35, https://doi.org/10.1890/04-0922.

3. R. Fuller, K. Irvine, P. Devine-Wright, P. H. Warren, and K. J. Gaston, "Psychological Benefits of Greenspace Increase With Biodiversity," *Biology Letters* 3 (2007): 390–394, https://doi.org/10.1098/rsbl.2007.0149.

4. R. Andrade, J. Franklin, K. L. Larson, et al., "Predicting the Assembly of Novel Communities in Urban Ecosystems," *Landscape Ecology* 36 (2020): 1–15, https://doi.org/10.1007/s10980-020-01142-1o.

5. S. L. Collins, K. N. Suding, E. E. Cleland, et al., "Rank Clocks and Plant Community Dynamics," *Ecology* 89, no. 12 (2008): 3534–3541, https://doi.org/10.1890/07-1646.1.

6. S. T. A. Pickett, M. L. Cadenasso, J. M. Grove, et al., "Beyond Urban Legends: An Emerging Framework of Urban Ecology, as Illustrated by the Baltimore ecosystem Study," *BioScience* 58, no. 2 (2008): 139–150, https://doi.org/10.1641/B580208.

7. G. Aragón, L. Abuja, R. Belinchón, and I. Martínez, "Edge Type Determines the Intensity of Forest Edge Effect on Epiphytic Communities," *European Journal of Forest Research* 134, no. 3 (2015): 443–451, https://doi.org/10.1007/s10342-015-0863-5.

8. Y. Huang, H. Ren, J. Wang, et al., "Relationships Between Vegetation and Soil Seed Banks Along a Center to Edge Gradient on a Tropical Coral Island," *Ecological Indicators* 117 (2020): 106689, https://doi.org/10.1016/j.ecolind.2020.106689.

9. T. Vakhlamova, H. P. Rusterholz, Y. Kanibolotskaya, and B. Baur, "Changes in Plant Diversity along an Urban–Rural Gradient in an Expanding City in Kazakhstan, Western Siberia," *Landscape and Urban Planning* 132 (2014): 111–120, https://doi.org/10.1016/j.landurbplan.2014.08.014.

10. M. Wang, J. Li, S. Kuang, et al., "Plant Diversity along the Urban–Rural Gradient and its Relationship With Urbanization Degree in Shanghai, China," *Forests* 11, no. 2 (2020): 171, https://doi.org/10.3390/f11020171.

11. M. J. McDonnell, A. K. Hahs, J. M. Grove, et al., "Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas," *Annual Review of Ecology Evolution and Systematics* 32, no. 1 (2001): 127–157, https://doi.org/10.1146/annurev.ecolsys.32.081501.114012.

12. N. B. Grimm, S. H. Faeth, N. E. Golubiewski, et al., "Global Change and the Ecology of Cities," *Science* 319, no. 5864 (2008): 756–760, https://doi.org/10.1126/science.1150195.

13. Guangzhou Statistical Yearbook, *Parks, Gardens and Green Areas in Urban Districts* (Guangzhou Statistical Bureau, 2020): [In Chinese], 9.

14. R. J. Wang, *The Terrestrial Plant Resources in Guangzhou* (Guangdong Science Publishing House, 2010): [In Chinese].

15. R. J. Wang, *Guangzhou Invasive Plants* (Guangdong Science Publishing House, 2019): [In Chinese].

16. Y. N. Guo, G. T. Wang, and D. Liang, "Investigation and Analysis of Plant Diversity in Guangzhou," *Journal of Tropical and Subreopical Botany* 29 (2021): 229–243, https://doi.org/10.11926/jtsb.4241.

17. S. W. Hu, C. Jin, R. Y. Liao, et al., "Herbaceous Ornamental Plants With Conspicuous Aesthetic Traits Contribute to Plant Invasion Risk in Subtropical Urban Parks," *Journal of Environmental Management* 347 (2023): 119059, https://doi.org/10.1016/j.jenvman.2023.119059.

18. M. A. Goddard, A. J. Dougill, and T. G. Benton, "Scaling Up From Gardens: Biodiversity Conservation in Urban Environments," *Trends in Ecology & Evolution* 25, no. 2 (2010): 90–98, https://doi.org/10.1016/j.tree.2009.07.016.

19. Ł. Dylewski, W. Banaszak-Cibicka, Ł. Maćkowiak, and M. K. Dyderski, "How Do Urbanization and Alien Species Affect the Plant Taxonomic, Functional, and Phylogenetic Diversity in Different Types of Urban Green Areas?," *Environmental Science and Pollution Research* 30, no. 40 (2023): 92390–92403, https://doi.org/10.1007/s11356-023-28808-y.

20. D. J. Zhao, Q. M. Yang, M. Q. Sun, et al., "Urbanization and Greenspace Effect on Plant Biodiversity Variations in Beijing, China," *Urban Forestry and Urban Greening* 89 (2023): 12811, https://doi.org/10.1016/j.ufug.2023.128119.

21. T. McPhearson, Z. A. Hamstead, and P. Kremer, "Urban Ecosystem Services for Resilience Planning and Management in New York City," *Ambio* 43, no. 4 (2014): 502–515, https://doi.org/10.1007/s13280-014-0509-8.

22. L. van der Walt, S. S. Cilliers, M. J. Du Toit, and K. Kellner, "Conservation of Fragmented Grasslands as Part of the Urban Green Infrastructure: How Important Are Species Diversity, Functional Diversity and Landscape Functionality?," *Urban Ecosystems* 18, no. 1 (2014): 87–113, https://doi.org/10.1007/s11252-014-0393-9.

23. M. L. McKinney, "Effects of Urbanization on Species Richness: A Review of Plants and Animals," *Urban Ecosystems* 11, no. 2 (2008): 161–176, https://doi.org/10.1007/s11252-007-0045-4.

24. S. Angel, J. Parent, D. L. Civco, A. T. Blei, and D. Potere, "The Dimensions of Global Urban Expansion: Estimates and Projections for All Countries, 2000–2050," *Progress in Planning* 75, no. 2 (2011): 53–107, https://doi.org/10.1016/j.progress.2011.04.001.

25. C. Murcia, "Edge Effects in Fragmented Forests: Implications for Conservation," *Trends in Ecology & Evolution* 10, no. 2 (1995): 58–62, https://doi.org/10.1016/s0169-5347(00)88977-6.

26. S. F. Wang and H. Zhang, "Tree Composition and Diversity in Relation to Urban Park History in Hong Kong, China," *Urban Forestry and Urban Greening* 67 (2022): 127430, https://doi.org/10.1016/j.ufug.2021.127430.

27. X. L. Cheng, J. P. Cubino, K. Balfour, et al., "Drivers of Spontaneous and Cultivated Species Diversity in Tropical Cities: A Case Study From Zhanjiang, China," *Urban Forestry and Urban Greening* 67 (2022): 127428, https://doi.org/10.1016/j.ufug.2021.127428.

28. Q. C. Lin, Y. Q. Cen, M. Xu, D.-D. Jiang, and J. Zhang, "Effects of Urban Green Space Habitats on Ectomycorrhizal Fungal Diversity and Implications for Urban Tree Management," *Scientific Reports* 14, no. 1 (2024): 25369, https://doi.org/10.1038/s41598-024-74448-8.

29. S. Paudel and S. L. States, "Urban Green Spaces and Sustainability: Exploring the Ecosystem Services and Disservices of Grassy Lawns Versus Floral Meadows," *Urban Forestry and Urban Greening* 84 (2023): 127932, https://doi.org/10.1016/j.ufug.2023.127932.