Landscape Pattern Characteristics of Plant Species Diversity in Campus Courtyards from the Perspective of Functional Differentiation: A Case Study of the Courtyard at Tongzhou Campus, Renmin University of China

ZHANG Qi[1], DENG Huiwen[2*], YANG Xin[2]

(1. China Urban Construction Design & Research Institute Co., Ltd., Beijing 100120, China; 2. School of Architecture and Art, North China University of Technology, Beijing 100144, China)

Abstract This study focuses on the three courtyards located in the eastern, central, and western sections of the Tongzhou Campus of Renmin University of China. Adopting a functional differentiation perspective, the research systematically analyzes the patterns of plant diversity within courtyards characterized by distinct functional orientations. This analysis employs various plant species diversity indices, including the Patrick richness index, Simpson dominance index, Shannon–Wiener diversity index, and Pielou evenness index, alongside a classification of functional plant types, namely ornamental, ecological regulation, spatial shaping, and recreational assistance. The results indicate that the east courtyard presents the highest Patrick species richness (S=42), predominantly comprising spatial shaping and recreational assistance plants, which are well-suited for recreational and passage functions. Conversely, the central courtyard exhibits the lowest Patrick species richness (S=19), characterized by a balanced distribution of functional types, with an emphasis on public display and traffic guidance. The west courtyard demonstrates the greatest stability in the tree layer (D=0.87), featuring a combination of shade-tolerant and ornamental plants that fulfill the requirements for a tranquil and naturalistic environment. One-way analysis of variance reveals that only Patrick species richness differs significantly among the courtyards (P=0.007), whereas the diversity index does not show a significant difference. This finding suggests that functional requirements precisely regulate diversity through microhabitat heterogeneity and plant configuration strategies. This study offers both a theoretical foundation and practical guidance for the plant configuration and functional optimization of small-scale courtyards on campus.

Keywords Campus courtyard, Plant species diversity, Functional differentiation, Tongzhou Campus of Renmin University of China

DOI 10.16785/j.issn 1943-989x.2025.4.001

Urban biodiversity conservation and the optimization of small-scale landscape functions are central concerns within contemporary landscape architecture[1]. Campus green spaces, serving as primary areas for daily rest and interaction among teachers and students, must concurrently fulfill ecological and functional objectives, including biodiversity maintenance, microclimate regulation, facilitation of public activities, and provision of private rest areas[2]. The manner in which plant diversity responds to these functional demands constitutes a focal point of research at the intersection of landscape ecology and landscape architecture.

Most existing studies concentrate on the plant diversity within urban parks or large green spaces, while comparatively less attention has been given to small-scale courtyards on campuses. Furthermore, there is a notable lack of targeted analyses addressing the "functional differentiation, plant selection, and diversity configuration" in these smaller spaces. Studies have demonstrated that functional zoning and microhabitat heterogeneity are critical factors influencing the diversity of campus vegetation[3]. Nevertheless, the function-driven mechanisms governing northern campus courtyards, such as those in Beijing, require further empirical validation. In these regions, characterized by cold winters, plant selection must consider both seasonal landscape aesthetics and ecological adaptability, with functional requirements imposing more stringent constraints on diversity patterns.

The functional boundaries of the three courtyards within the Tongzhou Campus of Renmin University of China are distinctly defined. The east courtyard, centered on "recreation and passage", encompasses north-south sunken

Column introduction

The City Observer column was initiated by Yang Xin and Zhang Qi, the hosts of RLncut research station. This article examines the diverse pattern characteristics of courtyard plants at the Tongzhou Campus of Renmin University of China from the perspective of functional differentiation, providing a theoretical foundation and practical guidance for the plant configuration and functional optimization of small-scale courtyards on campus.

Yang Xin, Zhang Qi, the hosts of RLncut research station

Received: May 20, 2025 Accepted: July 23, 2025

Sponsored by 2025 Undergraduate Innovation and Entrepreneurship Training Program Project.

* Corresponding author.

courtyards and a T-shaped bridge. The central courtyard serves as a "public activity and transportation hub", situated adjacent to the dining hall and learning center, and benefits from optimal natural lighting. The west courtyard emphasizes a "tranquil and naturalistic environment", characterized by a rooftop garden and shade-tolerant vegetation. This paper examines the differentiated characteristics of function-specific courtyards with respect to plant species composition and diversity indices, and investigates how these characteristics fulfill their respective functional requirements through plant configuration.

1 Overview of the research area

1.1 Research area

The research area is situated on the northwest side of the Tongzhou Campus of Renmin University of China, adjacent to Yudaihe Street. It encompasses a total area of 3.2 hm^2, with approximately 2 hm^2 designated for landscape design. The building's inner courtyard serves as the principal part, with the east, central, and west courtyards interconnected through a pedestrian network. These courtyards are accessible from both the first floor and the B1 level. Additionally, a dedicated connecting passage is established on the B1 level between the east and central courtyards.

1.2 Description of courtyard features

The primary functions of the east courtyard are recreation and passage. It encompasses a total area of approximately 5,500 m^2, which includes 1,884 m^2 of terraces and 866 m^2 of sunken spaces. Additionally, there are two sunken courtyards located to the north and south that provide access to the B1 level. The landscaped fire escape on the first floor of the courtyard functions as a significant passageway and recreational area. Additionally, it forms a T-shaped bridge structure extending toward the east, west, and south. The bridge on the B1 level serves dual purposes as both a pavilion and a corridor, connecting the sunken courtyards to the north and south. The 5.5 m height difference between the first floor and the B1 floor of the building is employed to create a sloping and terraced composite space. This design enhances occupants' field of vision, minimizes blind spots, and effectively reduces the sense of isolation typically associated with sunken spaces. However, the sunken areas, extending from north to south, experience high humidity levels and limited natural light, with the average daily illumination on the B1 floor being less than 3 h.

The central courtyard primarily functions as a public activity and transportation hub, encompassing a total area of approximately 2,077 m^2. This includes 1,594 m^2 of terraces and 483 m^2 of sunken spaces. Notably, the absence of buildings obstructing the southern side results in this courtyard receiving the most favorable lighting conditions among the three courtyards, with an average daily illumination exceeding 7 h. The central courtyard functions as a transportation hub linking the east and west courtyards and houses both the dining hall and the learning center. Consequently, it exhibits a more pronounced public character and experiences a higher level of human activity, with an average daily flow density exceeding 5 individuals/100 m^2.

The courtyard is predominantly characterized by its sloping terrain, which serves to accommodate the elevation difference between the northern and southern ends. The southern end provides access to the campus road, whereas the western and northern sides connect to the B1 level of the dining hall and learning center through ramps or stairs. Additionally, the eastern side offers direct access from the B1 level to the sunken courtyard located within the east courtyard. The courtyard features tree-lined ramps and stepped pathways that meander through the wooded area. Additionally, it includes recreational areas and small plazas beneath the trees, serving as spaces for the daily group activities of teachers and students. Consequently, the proportion of hard paving is relatively substantial, comprising approximately 30% of the area.

The primary function of the west courtyard is to establish a tranquil and naturalistic environment. It encompasses an area of approximately 3,630 m^2, which includes a rooftop garden located on the top floor of the north district dining hall, as well as a fire escape landscape belt. The sunken area occupies 543 m^2. The building introduces numerous obstructions, resulting in an average daily sunlight exposure ranging from 3 to 5 h. Consequently, the courtyard predominantly supports a shade-tolerant microenvironment characterized by minimal human disturbance, with an average daily flow density of fewer than 1 individual/100 m^2. Seating and rest areas have been established alongside the landscaped driveway in the courtyard. Together with the surrounding autumn-colored trees, shade-tolerant flowering shrubs, and ground covers, these elements create a vibrant outdoor landscape during the golden

Table 1 Courtyard plants and their functional types

Plant name	Functional type	Plant name	Functional type	Plant name	Functional type	Plant name	Functional type
Yulania×soulangeana	Ornamental	*Acer tataricum*	Ornamental	*Buxus sinica*	Spatial shaping	*Leucanthemum maximum*	Recreational assistance
Yulania biondii	Ornamental	*Hibiscus syriacus*	Ornamental	*Picea pungens*	Spatial shaping	*Rudbeckia laciniata*	Recreational assistance
Acer saccharinum	Ornamental	*Euonymus alatus*	Ornamental	*Taxus cuspidata*	Spatial shaping	*Salvia leucantha*	Recreational assistance
Ginkgo biloba	Ornamental	*Gaura lindheimeri*	Ornamental	*Lonicera maackii*	Spatial shaping	*Euonymus fortunei*	Recreational assistance
Cotinus coggygria	Ornamental	*Fraxinus chinensis*	Spatial shaping	*Callicarpa bodinieri*	Spatial shaping	*Juniperus sabina*	Ecological regulation
Weigela florida	Ornamental	*Pinus bungeana*	Spatial shaping	*Syzygium aromaticum*	Recreational assistance	*Pennisetum alopecuroides*	Ecological regulation
Physocarpus amurensis	Ornamental	*Sophora japonica*	Spatial shaping	*Abelia chinensis*	Recreational assistance	*Miscanthus sinensis*	Ecological regulation
Hydrangea macrophylla	Ornamental	*Sabina chinensis*	Spatial shaping	*Ophiopogon japonicus*	Recreational assistance	*Calamagrostis epigeios*	Ecological regulation
Koelreuteria paniculata	Ornamental	*Tilia cordata*	Spatial shaping	*Hosta plantaginea*	Recreational assistance	Cool season turfgrass	Ecological regulation
Malus 'American'	Ornamental	*Pinus tabuliformis*	Spatial shaping	*Sedum lineare*	Recreational assistance	*Kerria japonica*	Ecological regulation
Prunus × yedoensis	Ornamental	*Phyllostachys propinqua*	Spatial shaping	*Hemerocallis fulva*	Recreational assistance	*Cornus alba*	Ecological regulation
Magnolia denudata	Ornamental	*Viburnum sargentii*	Spatial shaping	*Stipa lessingiana*	Recreational assistance	*Iris tectorum*	Ecological regulation
Prunus davidiana	Ornamental	*Buxus megistophylla*	Spatial shaping	*Indocalamus tessellatus*	Recreational assistance	*Parthenocissus quinquefolia*	Ecological regulation
Euonymus maackii	Ornamental	*Yucca gloriosa*	Spatial shaping	*Carex* L.	Recreational assistance	*Lythrum salicaria*	Ecological regulation
Malus 'Radiant'	Ornamental	*Buxus sinica*	Spatial shaping	*Matteuccia struthiopteris*	Recreational assistance		

autumn season. Furthermore, the plant layers are diverse yet low-maintenance, fostering a tranquil, relaxed, natural, and rustic courtyard atmosphere. Additionally, a rooftop garden has been designed on the top floor of the north district dining hall to enhance outdoor leisure and social interaction spaces for teachers and students (Fig.1).

2 Research methods

2.1 Data collection and classification processing

2.1.1 Classification processing. Based on the distinct functions of the three courtyards, all collected plant species have been categorized into the following functional types according to their morphological characteristics and growth habits: Ornamental type[4], characterized by "spring-blooming flowers and autumn-colored leaves", primarily serving landscape display purposes; Ecological regulation type[3], comprising "water-tolerant, soil-stabilizing, and air-purifying" plants, suitable for specific microhabitats; Spatial shaping category[5], predominantly consisting of "tall trees and shade-tolerant shrubs", utilized for shading and spatial delineation; and Recreational assistance type[6], which includes "ground cover plants beneath the canopy and aromatic species", aimed at creating a comfortable recreational environment, as detailed in Table 1.

2.1.2 Data processing. The primary data were organized and subjected to statistical analysis using Excel 2021, with the proportions of functional types calculated accordingly. One-way ANOVA was conducted using SPSS 26.0 to assess the significance of the effect of "courtyard function" on species richness, diversity indices, and related variables.

2.2 Calculation of diversity index

The species diversity index encompasses several measurement indices[7-9], specifically Patrick richness index (R_0), Simpson dominance index (D), Shannon−Wiener diversity index (H'), and Pielou evenness index (J). The corresponding calculation formulas for these indices are as follows:

$$R_0=S$$

$$P_i=N_i/N$$

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

$$H'=-\sum_{i=1}^{S}P_i\log_2 P_i$$

$$J=H'/\ln S$$

where S denotes the number of species; P_i represents the proportion of individuals belonging to species i relative to the total number of individuals, often calculated using relative importance values; N_i indicates the number of individuals of species i; and N signifies the total number of individuals across all species within the community.

3 Results and analysis

3.1 Diversity characteristics of plants across various courtyards

A total of 59 plant species have been collected and documented within the study area, representing 30 families and 52 genera. The Rosaceae family exhibits the greatest species diversity, comprising five species, which accounts for 8.47% of the total species recorded. This is followed by the Poaceae and Celastraceae families, each represented by four species, constituting 6.78% of the total species. The selection of plant species within the three courtyards is strategically designed to highlight the winter landscape. A substantial number of evergreen trees, including *Pinus bungeana*, *Sabina chinensis*, *Picea pungens*, and *Pinus tabuliformis*, are incorporated, resulting in an evergreen-to-deciduous tree ratio of approximately 1 : 2. Additionally, numerous evergreen shrubs and bamboo species, such as *Buxus sinica*, *Taxus cuspidata*, *Phyllostachys propinqua*, *Indocalamus tessellatus*, and *Sabina vulgaris*, are planted. Emphasis is also placed on species characterized by prolonged foliage retention and those prized for their distinctive trunks, including *Kerria japonica*, *Cornus alba*, *Carex breviculmis*, and cool season turfgrasses, to further enhance the winter aesthetic. The vegetation planted in the three courtyards is designed to emphasize the overall ecological character. Trees and shrubs constitute approximately 79% of the plantings, while non-forest understory lawns and ground cover plants comprise about 21%. Additionally, the use of native plant species exceeds 90%.

3.1.1 East courtyard (recreation and passage): Medium and high diversity of trees and recreational assistance types. According to the collected data, a total of 42 plant species are cultivated in the east courtyard, which exhibit the highest species richness among the three courtyards. The stratified diversity is characterized by "trees providing shade and herbs supporting recreational activities".

The tree layer in the east courtyard demonstrates a Patrick species richness (S) of 12, a Simpson dominance index (D) of 0.86, a Shannon-Wiener diversity index (H') of 2.18, and a Pielou evenness index (J) of 0.88. Half of the plants are spatial shaping species, while the remaining half are ornamental. The tall trees are arranged in a staggered pattern, providing continuous shade and ornamental value. This arrangement prevents uneven shading by any single tree species and effectively accommodates the needs for recreation and passage. The shrub layer exhibits a Patrick species richness (S) of 16, a Simpson dominance index (D) of 0.80, and a Shannon-Wiener diversity index (H') of 1.75. Among the shrubs, 37.5% function as spatial shaping plants, while 18.75% serve as recreational assistance plants. The pathways and recreational zones are primarily delineated by hedges, with fragrant shrubs incorporated to enhance the comfort of the environment. The herb layer exhibits a Patrick species richness (S) of 16, a Simpson dominance index (D) of 0.41, and a Shannon−Wiener diversity index (H') of 1.07. Among the plants, 56.25% serve recreational assistance purposes, while 37.5% contribute to ecological regulation. Within the courtyard, the vegetation is densely distributed, effectively covering the understory space beneath the forest canopy. Notably, water-tolerant herbaceous species are predominantly concentrated in the sunken area of the B1 layer, a location characterized by a high-humidity microenvironment conducive to their growth.

The tree layer in the east courtyard primarily consists of tall, vertically oriented tree species, including *Ginkgo biloba*, *P. tabuliformis*, and *P. bungeana*. These species are planted in a staggered arrangement along the T-shaped bridge and the landscaped fire escape, thereby creating a continuous shading structure. This configuration not only diminishes visual connectivity between the dormitory buildings but also ensures that the passage remained protected from direct sunlight. A portion of the bridge is densely planted with *G. biloba*. *Buxus megistophylla* hedges are employed to delineate the passageways and resting areas on the bridge. Ornamental grasses, including *Gaura lindheimeri* and *Pennisetum alopecuroides*, are integrated to enhance the dynamic character of the bridge's landscape, thereby supporting its function as a "gray space". The humidity in the sunken area of the east courtyard is elevated, and the light intensity is low. Consequently, plants capable of tolerating water and moisture while maintaining stable growth, such as *Iris tectorum* and *P. alopecuroides*, are selected for planting to facilitate the sunken area's function as a sponge for water collection. The evergreen *Sabina chinensis*, the autumnal foliage of *Acer tataricum*, and the vibrant leaves of *Euonymus alatus* are integrated with the flowering period of *Kerria japonica* to enrich the seasonal landscape and enhance the visual prominence of the entrance. Additionally, the overall plant height is maintained at a moderate level to avoid obstructing the view of the entrance pathway (Fig.2).

3.1.2 Central courtyard (public activity + transportation hub): Low species richness and functional balance. A total of 19 plant species are cultivated in the central courtyard. Although this courtyard exhibits the lowest overall diversity index, it demonstrates the most balanced proportion of functional plant types. The Patrick species richness (*S*) of the tree layer is 4, the lowest among the three courtyards, while the Shannon−Wiener diversity index (*H'*) and the Pielou evenness index (*J*) are 1.32 and 0.95, respectively, both the highest values recorded among the courtyards. Approximately 75% of the plants are ornamental species. The combination of low Patrick species richness and high Pielou evenness index facilitates the concentrated blooming of *Prunus* and *Malus spectabilis* in spring, thereby creating a distinctive floral landscape. Additionally, the absence of visual obstructions from the dining hall enhances its suitability for public display purposes. The shrub layer exhibits a Patrick species richness (*S*) of 9, a Simpson dominance index (*D*) of 0.70, and a Shannon-Wiener diversity index (*H'*) of 1.37. Ecological regulation plants account for 33.33% of the total, while ornamental plants comprise 22.22%. Extensive planting of *S. vulgaris* is implemented in the concave green space to facilitate rainwater infiltration in accordance with the sponge campus concept. Additionally, the low stature of the shrubs ensures that views of public activities remain unobstructed. The herb layer exhibits a Patrick species richness (*S*) of 6, a Simpson dominance index (*D*) of 0.67, and a Shannon-Wiener diversity index (*H'*) of 1.25. Half of the plant species serve recreational assistance functions, while the remaining half contribute to ecological regulation. *Ophiopogon japonicus* is predominantly located adjacent to the tree-lined slope, and the small square is covered with cool season turfgrass to maintain the openness of the activity area.

The entrance to the central courtyard experiences the highest pedestrian traffic and remains unobstructed. *Malus* 'American' and *Koelreuteria paniculata* are selected as ornamental trees due to their spring blossoms and autumnal foliage color changes, which contribute to a distinctive entrance landscape and fulfill the aesthetic requirements of public spaces. The evergreen *P. bungeana* provides year-round greenery, while *K. japonica* and *S. vulgaris* constitute middle and lower layer vegetation. These species not only enrich landscape landscape's stratification but also maintain clear sightlines at entrance due to their low growth. The courtyard features a small square designed for group activities and temporary rest for both teachers and students, necessitating a balance between openness and landscaping. By concentrating the planting of *Prunus × yedoensis*, a continuous floral belt can be established in spring, thereby fulfilling the landscape requirements for "public display". *K. paniculata* offers shade in the upper canopy layer, while the fragrance of *Syringa* contributes to a more comfortable resting environment. The ground is covered with *S. vulgaris* and *O. japonicus* to prevent excessive soil compaction in the plaza. *Parthenocissus quinquefolia* is employed to climb the building facade, thereby softening the rigid boundaries. This overall configuration not only maintains the openness of the activity space but also enhances the ambiance of the setting through the use of vegetation (Fig.3).

3.1.3 West courtyard (tranquil and naturalistic environment): High stability of trees and outstanding ornamental trees. A total of 30 plant species are cultivated in the west courtyard, with the tree layer exhibiting the greatest diversity. This layer is characterized by "high stability and low disturbance". Specifically, the tree layer demonstrates a Patrick species richness (*S*) of 10, a Simpson dominance index (*D*) of 0.87 (the highest among the three courtyards), a Shannon-Wiener diversity index (*H'*) of 2.13, and a Pielou evenness index (*J*) of 0.93. Notably, 60% of the species serve spatial shaping functions, while 30% are ornamental. Shade-tolerant trees are evenly distributed, and no single species dominates the community. This composition supports the maintenance of a "natural forest structure" with minimal pruning, thereby fulfilling the low-disturbance management objectives. The shrub layer exhibits a Patrick species richness (*S*) of 11, a Simpson dominance index (*D*) of 0.70, and a Shannon-Wiener diversity index (*H'*) of 1.42. Of these species, 36.36% are ornamental plants, and an equal proportion (36.36%) serves as spatial shaping plants. Shade-tolerant shrubs, together with the tree layer, form a multi-layered structure that enhances the overall greenery while preserving the tranquil and naturalistic environment. The herb layer exhibits a Patrick species richness (*S*) of 9, a Simpson dominance index (*D*) of 0.71, and a Shannon-Wiener diversity index (*H'*) of 1.50. Of these species, 55.56% function as recreational assistance plants, while 44.44% serve ecological regulation. The ornamental grasses grow naturally, creating a "golden autumn charm" landscape in conjunction with autumn-leaf trees during the golden autumn season. This natural assemblage minimizes human intervention and emphasizes the landscape's functional orientation toward a tranquil and naturalistic environment.

The west courtyard is designed to provide a "tranquil and naturalistic environment" as its primary function. By incorporating tall, shade-tolerant trees such as *P. tabuliformis* and *P. bungeana*, a stable, multi-layered shading structure is established. The addition of the autumn foliage of *Acer saccharinum* and the fragrance of *Syringa* further enhances the seasonal and sensory qualities of the pathway, thereby fostering a serene atmosphere. At the eastern entrance, the continuous planting of *G. biloba*, valued for its autumnal foliage, can enhance the distinctiveness of the entryway. *Physocarpus amurensis* and *Hosta plantaginea* exhibit shade tolerance, rendering them well-suited for shaded entrance areas. Additionally, *S. vulgaris* and *P. propinqua* establish an evergreen boundary, while *P. alopecuroides* contributes a naturalistic aesthetic. This combination not only prevents landscape monotony but also preserves the overall tranquil atmosphere of the courtyard (Fig.4).

3.2 Validation analysis of functional differentiation

3.2.1 Verification of functional proportion. The proportional distribution of functional plants directly reflects the ecological response of the courtyard. Analysis of the compiled data indicates that the proportions of functional plants in the east, central, and west courtyards exhibit distinct function-oriented characteristics.

In the east courtyard, functional plants are distributed as follows: recreational assistance plants and spatial shaping plants each constitute 28%, ecological regulation plants represent 19%, and ornamental plants account for 25%. Notably, recreational assistance plants are predominantly found in the herb layer, comprising 56.25%, whereas spatial shaping plants are primarily concentrated in the tree layer, accounting for 50%. From the perspective of functional requirements, the landscaped fire passage on the first floor of the east courtyard forms a T-shaped bridge, serving as the primary circulation space. Additionally, a rest and communication area is established beneath the canopy. Consequently, tall trees should be planted to enclose the shaded area, thereby providing a comfortable resting environment and effectively addressing the issue of sun exposure during passage. The

Fig.1 Courtyard landscape

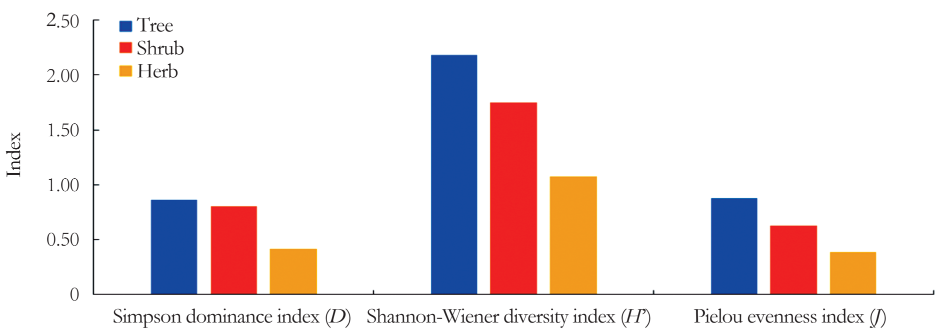

Fig.2 Plant diversity index of the east courtyard

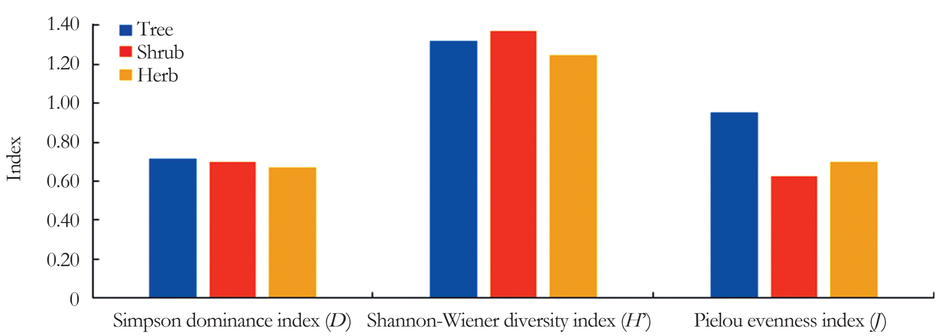

Fig.3 Plant diversity index of the central courtyard

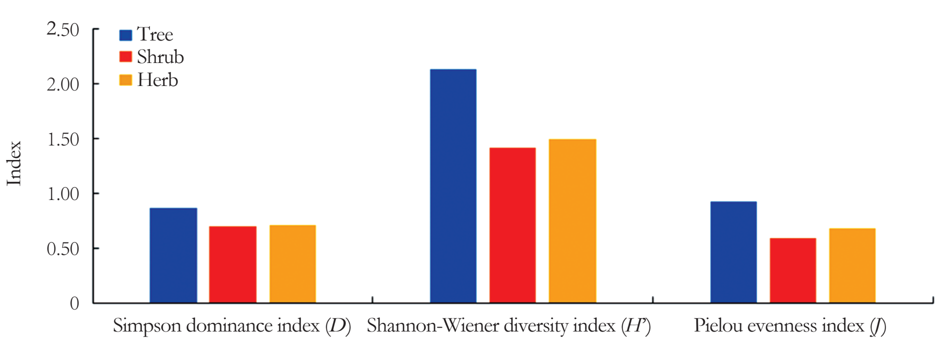

Fig.4 Plant diversity index of the west courtyard

herb layer is predominantly composed of recreational assistance plants, which densely cover the open spaces beneath the forest canopy. In combination with the shade-tolerant *Matteuccia struthiopteris*, this layer creates a cool and comfortable environment that fulfills the comfort requirements of teachers and students for leisure and communication beneath the forest canopy. From the perspective of micro-environmental adaptation, the humidity in the north-south sunken area of the B1 floor of the east courtyard is elevated, and the average daily sunlight duration is limited. Consequently, ecological regulation plants constitute 19% of the vegetation and are predominantly concentrated in the sunken area. This distribution not only facilitates adaptation to the high-humidity environment but also supports the rainwater infiltration requirements of the sponge campus, thereby enhancing the functional adaptability related to passage, recreation, and ecological regulation.

The central courtyard exhibits the most balanced distribution of functional plants, with ornamental plants comprising 32%, spatial shaping plants 21%, recreational assistance plants 21%, and ecological regulation plants 26%. The absence of a clearly dominant type underscores the courtyard's strong public character and multifunctional attributes. From the perspective of public display requirements, the south side of the central courtyard remains unobstructed and benefits from optimal lighting conditions. Consequently, 75% of the tree layer consists of ornamental plants. Although species diversity is limited to four, the high proportion of ornamental plants allows *M. spectabilis* to form a continuous floral belt in spring. When observed from the dining hall and the learning center, visual blind spots are present, effectively fulfilling the recognizable landscape criteria for public displays. From the perspective of traffic diversion requirements, the courtyard features tree-lined ramps and small activity squares. Spatial shaping plants constitute 21% of the vegetation, primarily consisting of low-growing trees. This design approach not only preserves unobstructed sightlines along the passageways but also offers localized shading for the ramps, thereby achieving a balance between open activity spaces and the need for temporary shade.

In the west courtyard, functional plants are distributed as follows: spatial shaping plants constitute 33%, ornamental plants 27%, recreational assistance plants 23%, and ecological regulation plants 17%. Notably, spatial shaping plants are predominantly found in the tree layer, accounting for 60%, whereas ornamental plants are primarily located in both the tree layer (30%) and the shrub layer (36%). From the perspective of minimal human disturbance, the west courtyard is enclosed by numerous buildings that provide shading, resulting in an average daily sunlight exposure of 3–5 h and a low level of human interference. Approximately 60% of the tree layer comprises spatial shaping plants, predominantly shade-tolerant tree species, with a Simpson dominance index of 0.87, the highest among the three courtyards studied. The absence of dominance by any single species contributes to the establishment of a stable ecological framework. Furthermore, shade-tolerant trees are able to preserve their natural form without the need for frequent pruning, thereby minimizing disruptions to the tranquil atmosphere caused by human maintenance activities. From the perspective of the demand for naturalistic landscapes, ornamental plants constitute 27% of the vegetation, with the tree layer primarily composed of species exhibiting autumn-colored foliage. The rooftop garden incorporates ornamental grasses, which, together with the autumn leaves, create a distinctive autumnal landscape. This design not only satisfies the natural aesthetic preferences for naturalistic landscapes but also minimizes the need for frequent plant replacement, thereby reducing maintenance costs. From the perspective of the need for quiet rest, recreational assistance plants are arranged around the resting area adjacent to the fire escape. The low-growing ground cover does not obstruct the view and is appropriate for low-traffic, slow-paced stopover scenarios (Fig.5).

3.2.2 One-way analysis of variance. The results of a one-way analysis of variance conducted using SPSS indicate that only Patrick species richness (*S*) exhibits significant differences among the three courtyards (F=12.395, P=0.007<0.05). Post hoc analyses reveals significant differences between the east and west courtyards (P=0.032), as well as between the east and central courtyards (P=0.003). No significant difference is observed between the central and west courtyards (P=0.072). Additionally, no significant differences are found in the Simpson dominance index (D), Shannon-Wiener diversity index (H'), or Pielou evenness index (J) (P>0.05).

This result demonstrates precise control over "function-diversity" in small-scale courtyards. From the perspective of microhabitats, the east courtyard exhibits greater diversity in microhabitat types, including terraces, sunken areas, and gray spaces beneath T-shaped bridges. These three distinct microhabitat types possess a higher capacity to accommodate species[3]. The terrace receives abundant sunlight, making it conducive to light-demanding tree species such as *P. bungeana* and *Fraxinus chinensis*. In contrast, the sunken area, characterized by high humidity and low light levels, is suitable for water-tolerant herbaceous plants, including *Miscanthus sinensis* and *Calamagrostis epigeios*. Beneath the bridge, where light is extremely limited and human traffic is dense, shade-tolerant shrubs such as *B. sinica* and *I. tessellatus* are most appropriate. These three distinct microhabitats correspond respectively to the ecological niches of "trees, herbs, and shrubs"[10], collectively supporting a total of 44 plant species. The central courtyard comprises only two types of microhabitats: the southern slope and the vicinity of the dining hall. Additionally, the area is characterized by a high proportion of hard pavement (approximately 30%), which supports only ornamental plants, including 19 species predominantly represented by *M. spectabilis*. The west courtyard contains two distinct microhabitats: the rooftop garden, characterized by high light exposure and a shallow soil layer, and the area adjacent to the fire escape, which is semi-shaded. These areas primarily support shade-tolerant trees and ornamental grasses. The "niche diversity" of the three microhabitat types in the east courtyard is significantly greater than that of the two microhabitat types in the west and central courtyards. Consequently, Patrick species richness (*S*) differs significantly, with the east courtyard exhibiting higher values than the west and central courtyards, which are approximately equal (Fig.6, Tables 2–3).

4 Conclusions and discussion

4.1 Conclusions

This study focuses on three courtyards with functional differentiation located in the eastern, central, and western areas of the Tongzhou Campus of Renmin University of China. By integrating data on plant diversity indices with an analysis of the courtyards' functional orientation, the research reveals that the plant diversity

Table 2 ANOVA test results

Dependent variable		Sum of square	Degree of freedom	Mean square	F	Significance
Shannon-Wiener diversity index	Inter-group	0.261	2	0.130	0.834	0.479
	Inner-group	0.939	6	0.156		
	Total	1.200	8			
Patrick species richness	Inter-group	104.667	2	52.333	12.395	0.007
	Inner-group	25.333	6	4.222		
	Total	130	8			
Pielou evenness index	Inter-group	0.027	2	0.013	0.332	0.730
	Inner-group	0.240	6	0.040		
	Total	0.267	8			

Table 3 Post hoc test results

Dependent variable	(I) 1=West courtyard 2=Central courtyard 3=East courtyard	(J) 1=West courtyard 2=Central courtyard 3=East courtyard	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
						Lower limit	Upper limit
Shannon-Wiener diversity index	1	2	0.367 26	0.322 93	0.299	−0.422 9	1.157 4
		3	0.012 38	0.322 93	0.971	−0.777 8	0.802 6
	2	1	−0.367 26	0.322 93	0.299	−1.157 4	0.422 9
		3	−0.354 88	0.322 93	0.314	−1.145 1	0.435 3
	3	1	−0.012 38	0.322 93	0.971	−0.802 6	0.777 8
		2	0.354 88	0.322 93	0.314	−0.435 3	1.145 1
Patrick species richness	1	2	3.667	1.678	0.072	−0.44	7.77
		3	−4.667*	1.678	0.032	−8.77	−0.56
	2	1	−3.667	1.678	0.072	−7.77	0.44
		3	−8.333*	1.678	0.003	−12.44	−4.23
	3	1	4.667*	1.678	0.032	0.56	8.77
		2	8.333*	1.678	0.003	4.23	12.44
Pielou evenness index	1	2	−0.025 85	0.163 37	0.879	−0.425 6	0.373 9
		3	0.100 17	0.163 37	0.562	−0.299 6	0.499 9
	2	1	0.025 85	0.163 37	0.879	−0.373 9	0.425 6
		3	0.126 02	0.163 37	0.470	−0.273 7	0.525 8
	3	1	−0.100 17	0.163 37	0.562	−0.499 9	0.299 6
		2	−0.126 02	0.163 37	0.470	−0.525 8	0.273 7

Note: The significance level for the difference in means is set at 0.05.

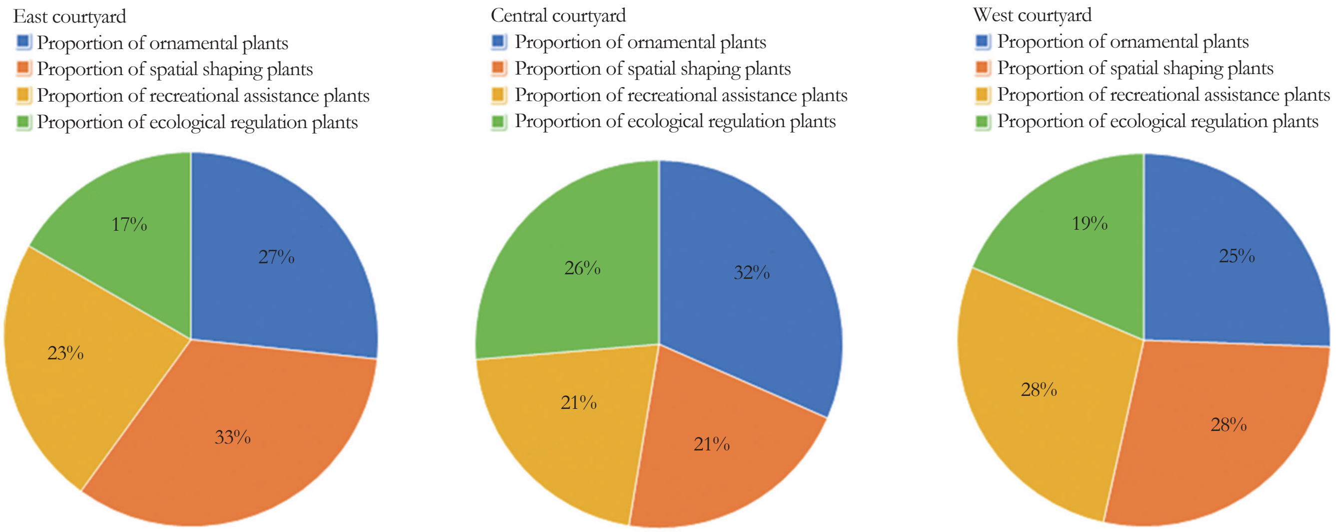

Fig.5 Proportion of functional plants in the three courtyards

Fig.6 Diversity of plant landscapes in the courtyard

patterns in these courtyards exhibit pronounced function-driven characteristics and closely align with adaptations to the micro-environment. The east courtyard exhibits a relatively high Shannon-Wiener diversity index (*H'*=2.18) and Simpson dominance index (*D*=0.86) within the tree layer, facilitating continuous passage and shading through the presence of 12 spatial shaping tree species. Conversely, the herb layer demonstrates a lower Pielou evenness index (*J*=0.39), which is appropriate for the functional zoning of ecological regulation and rest beneath the canopy within the sunken area, attributable to the concentrated distribution of water-tolerant herbaceous plants and recreational assistance ground covers. The central courtyard establishes a distinctive landscape for public display by clustering four ornamental tree species characterized by the lowest Patrick species richness (*S*=4) and Shannon-Wiener diversity index (*H'*=1.32), alongside the highest Pielou evenness index (*J*=0.95), while maintaining unobstructed visibility for pedestrian and vehicular movement. The west courtyard, characterized by the highest Simpson dominance index (*D*=0.87) within the tree layer, establishes a stable community composed predominantly of shade-tolerant trees arranged uniformly. This configuration satisfies the requirements for a low-disturbance, tranquil, and naturalistic environment. One-way analysis of variance reveals that only Patrick species richness differs significantly among the courtyards, whereas no significant differences are observed in other diversity indices. This finding reflects the differential regulation of plant diversity driven by functional requirements. The east courtyard, characterized by the greatest variety of microhabitats, exhibits a higher capacity to support species diversity, while all three courtyards adjust their functional attributes by modulating parameters such as dominance and evenness.

4.2 Discussion

This article examines the relationship between the functions and plant diversity of small-scale campus landscapes, specifically the east, central, and west courtyards of the Tongzhou Campus of Renmin University of China. The findings offer valuable reference strategies for plant configuration in similar courtyards and provide practical insights.

In recreational and accessible courtyards, such as the east courtyard, priority should be given to the arrangement of spatial shaping tree species, including *P. bungeana* and *F. chinensis*, to establish a shading layer and maintain continuous pathways. The herb layer should be designed in accordance with micro-environmental zoning. In sunken, high-humidity areas, water-tolerant plants such as *M. sinensis* and *C. epigeios* are recommended. Beneath the tree canopy, recreational assistance ground covers, such as *O. japonicus* and *H. plantaginea*, should be densely planted to align with functional zoning requirements while also fulfilling sponge objectives.

For public activity courtyards, such as the central courtyard, it is recommended to select 2−3 types of ornamental trees, such as *Prunus* and *M. spectabilis*, to create a distinctive landscape characterized by a high degree of evenness in distribution. The incorporation of ecological shrubs, including *S. vulgaris*, alongside cool season turfgrasses, can effectively balance rainwater infiltration and maintain the openness of the activity area. This approach helps prevent the disruption of visual traffic flow caused by an excessive diversity of species.

For tranquil and naturalistic courtyards, such as the west courtyard, it is recommended to prioritize the selection of highly stable and

(To be continued in P16)

6 Conclusions and prospects

Although the existing large number of old communities in the city appear dilapidated in appearance, they are actually full of vitality. Their streets and courtyards are of pleasant scale, with high living convenience and strong spatial vitality. Compared to newly built high-rise residential areas, neighborhood relationships are more harmonious. Therefore, adapting old communities to the needs of modern lifestyles through rational design and renewal has become a key proposition.

From the practice of community micro-renewal, it is recognized that the value of pocket parks is particularly prominent: it is characterized by "flexibility and diversity, not limited by area and function", and has become the core path to reshape the public environment of communities. This update mode not only continues the logic of "inserting every opportunity", and parks grow in the fragmented spaces of the community; but also emphasizes multi-party collaboration, with residents' proposals as the starting point, designers leading the design, and communities participating in the creation. Meanwhile, details design that is suitable for aging and activity is embedded. By incorporating public space modules such as community gardening, rehabilitation and fitness, and children's playgrounds that meet the needs of the times, the iteration of community public activity spaces is completed. Of particular importance is that pocket park has incorporated a mechanism for residents to jointly maintain and construct on top of its original advantages: it is no longer an isolated landscape, but has become a "communication center" and "emotional bond" for the community. It not only activates community vitality and deepens neighborhood relationships, but also cultivates more resilient "vitality nodes" for the city by upgrading public spaces.

References

[1] Wang, Z. F., Yuan, Y. M. & Zhang, F. (2021). Construction of ecological intelligent pocket park in urban micro-renewal: Innovative road pocket park design. *Inner Mongolia Forestry Investigation and Design*, *44*(5), 53-57.

[2] Song, R. C., Zhang, X. N. (2018). The application strategy with pocket park in the micro-renewal of public space in urban old community. *Architecture & Culture*, (11), 139-141.

[3] Wang, Y. P., Zeng, Y. L. & Zang, S. Q. (2024). Be a good urban steward and building a "heart to heart bridge" of public service: Documentary of Macheng urban management law enforcement work. *China Construction*, (12), 13-14.

[4] He, Q. *Research on the renewal model of traditional urban communities in mountain areas guided by park communities: A case study of Chongqing Guihuayuan Community*//Proceedings of the 2021 China Urban Planning Annual Conference. 2021, 199-211.

[5] Li, Z. L. (2025). *Research on landscape renewal design of old residential areas based on the concept of age friendly* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[6] Li, Q. *Innovative integration of ecological sustainability and aesthetics in modern park landscape design*//Proceedings of the 3rd Academic Exchange Conference on Engineering Technology and Digital Intelligence Empowering County Economy and Urban-Rural Integration Development in 2025. 2025, 234-235.

****

(Continued from P7)

shade-tolerant tree species, including *P. bungeana* and *Tilia cordata*. These trees can be complemented with ornamental grasses, such as *M. sinensis*. This strategy considers both the seasonal naturalistic appeal and the need for low maintenance, thereby minimizing disturbances to the tranquil environment caused by human activity.

References

[1] Li, Z. G., Zhang, B. S. & Zhai, X. et al. (2010). Insect diversity in different habitats in Guangzhou of China. *Chinese Journal of Ecology*, *29*(2), 357-362.

[2] Justice, M., Anesu, K. & Monicah, M. et al. (2019). The role of urban schools in biodiversity conservation across an urban landscape. *Urban Forestry & Urban Greening*, *43*, 126370.

[3] Liang, X. Y., You, G. X. & Zhu, S. et al. (2023). Spontaneous vegetation species diversity and distribution in heterogeneous habitats of university campus green spaces of Harbin. *Chinese Landscape Architecture*, *39*(12), 138-144.

[4] Forestry Bureau of Hunan Province. (2025). *Meaning and classification of flowers*. Retrieved from http://lyj.hunan.gov.cn/lyj/tslm_71206/lykp/syjs/202102/t20210218_14495337.html.

[5] Che, S. Q., Zheng, L. R. (2004). Spatial classification of garden plants (I). *Landscape Architecture Academic Journal*, (7), 20-21.

[6] Pan, G. X. (2011). Landscaping form of garden plants in the square rest area. *Jilin Agriculture*, (4), 261.

[7] Dong, M. (1997). *Investigation, observation and analysis of Terrestrial biological communities*. Beijing: China Standards Press.

[8] Jiang, J. (2009). Reviews of the research on the species diversity of biotic community. *Sci-Tech Information Development & Economy*, *19*(27), 131-133.

[9] Chen, T. G., Zhang, J. T. (1999). A comparison of fifteen species diversity indices. *Henan Science*, *17*(A06), 55-57, 71.

[10] Wu, M. J., Qiu, J. & Zheng, F. et al. (2024). Study on shrub species diversity and niche of wild fruit forest in Xinjiang. *Arid Zone Research*, *41*(12), 2094-2109.