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A topological classification of open-forest lawn spatial morphologies in planting design: A case study of parks in Hangzhou and Shanghai, China

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Abstract

Open-forest lawns – comprising sparse tree canopies and herbaceous ground layers – play vital ecological, esthetic, and social roles in urban green spaces, yet lack a systematic spatial typology to inform design and application. This study employs a case study approach to develop a spatial typology for open-forest lawn landscapes grounded in topological principles. It identifies three spatial archetypes – node-based, pathway-driven, and island-based – and selects 12 representative sites from urban parks in Hangzhou, Zhejiang, and Shanghai, China, for analysis. The study examines the spatial characteristics of each archetype, along with their corresponding design logic and thematic intentions. The results show that node-based spaces create a sense of ceremony through enclosed interfaces; pathway-driven spaces encourage dynamic exploration through linear infiltration; and island-based spaces rely on discrete clusters to foster diverse forms of interaction. Moreover, these three spatial forms can be layered to establish a coordinated relationship spanning design themes, spatial sequences, and planting configurations. From both theoretical and practical perspectives, the proposed typological framework offers a spatially oriented reference and guidance for open-forest lawn design.

Keywords: Open-forest lawn; Planting design; Spatial morphology; Topological classification

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1. Introduction

Open-forest lawns (疏林草坪; *shulin caoping*) are landscape types composed of sparsely distributed canopy trees (with approximately 0.4 – 0.6 in canopy density) and herbaceous ground plants (Chen *et al.*, 2008). This configuration preserves the vertical layering and ecological functions of woodlands while offering the openness of lawns and spaces conducive to human activities. These landscapes play crucial roles in enhancing biodiversity (Winkler *et al.*, 2024), regulating microclimates (Francoeur *et al.*, 2021), and conserving soil and water (Pantsyreva *et al.*, 2023). At the same time, they serve as "woodland-plus-grassland" open spaces that shape spatial rhythms of enclosure and openness, strengthen the sense of place, and enrich landscape esthetics (Chen & Wang, 2016; Poje *et al.*, 2024). Historically, 18th-century English landscape gardens were characterized by expansive lawns, naturalistic plantings, and meandering paths. In Chinese imperial gardens – such as the Shanglin Park of the Han dynasty (202 BCE – 220 CE) and the Chengde Summer Resort of the Qing dynasty (1644 – 1912) – open-forest

lawns were often designed to resemble grasslands for aristocratic hunting. With the rise of modern urbanization, traditional private gardens gradually transitioned into public parks, making open-forest lawns an indispensable component of urban green spaces and planting design. In cities, such as Hangzhou (Zhejiang province) and Shanghai – both located in China's subtropical monsoon zone, characterized by hot and humid summers – large unshaded lawns often feel uncomfortable (Booth, 1989). In contrast, open-forest lawns offer better microclimatic regulation, more seasonal variations, and improved user experience, thereby contributing to a distinct regional planting typology.

In the field of planting design, early studies in landscape architecture often borrowed theories of forest structure from ecology, leading to an overemphasis on tree species selection while overlooking overall spatial structure. Subsequently, attention shifted toward more spatially oriented approaches. Booth (1989) advocated first delimiting the location and area of large planting zones and then subdividing them to organize plant combinations. Robinson emphasized primary and supporting roles of vegetation in spatial definition, wayfinding, and focal point creation, striving to move beyond the traditional view of merely decorating the surface with plants. Leszczynski (1999) further noted that plant arrangements and spatial structures must form a cohesive whole shaped by clear design intentions. Austin (2001) advocated establishing spatial boundaries and circulation systems before plant selection. Simonds and Starke (2006) later proposed shaping places through layered planting configurations.

In recent years, Chinese scholars and designers have increasingly explored planting design from a spatial perspective. For instance, Liu (2003), the China Association of Survey and Design, Landscape Design (2003), regarded planting space as a key method of spatial division. Zhu and Chen (2007) recommended organizing open-forest lawns (and their focal or linear trees) by first distinguishing lawn and tree zones, progressing from groundcovers to shrubs and trees. Shen and Shu (2009), building on Norman K. Booth's design procedure for plant layout, criticized its basis in small courtyard design and advocated for incorporating plant spatial planting early in the functional layout of medium to large projects, supported by sections and elevations to explore plant community relationships. Li and Bao (2013) proposed first delineating vegetation spaces and strengthening their spatial connections before finalizing design themes. Li (2012) further developed a typological classification of plant-space forms, such as "L-shaped," "U-shaped," and "fuzzy," and extended this approach to planning scales using linear and clustered combinations. He also observed that lawns often serve as connective spatial elements between vegetation units. Xu (2017) focused on open-forest lawns, classifying them into inward-facing, outward-facing, and mixed types according to topography and the extent of plant-based spatial enclosure.

Overall, existing research tends to center on partial configurations or specific functions, leaving a gap in the systematic classification and fine-grained analysis of overall layout, local spatial forms, and the dynamic (experiential) dimensions of open-forest lawns. Although typological approaches to plant-space analysis can describe basic forms, they often fall short in accommodating the diversity of real-world spatial demands. Effective plant-space design requires a multidimensional understanding that accounts for plant growth dynamics, multiple spatial interpretations, and cross-scalar complexity, demands that call for more fundamental analytical tools. In practice, Western gardens often employ plants to define geometric or naturalistic spaces, whereas in China, plants are more frequently treated as the principal medium of "scene-making," with less emphasis on regional adaptability, thematic expression, and functional integration. This can lead to designs that suffer from "scenery for scenery's sake" or "flower beds for the sake of flower beds," resulting in limited functionality, weak regional relevance, inadequate integration of landscape elements, and esthetic homogeneity. Typical manifestations include lawns designed only for viewing rather than use, poorly thriving cherry trees, and arbitrarily placed flower beds – phenomena that hinder the practical application and further development of open-forest lawns in urban green spaces. Consequently, a core question arises: which spatial typology of open-forest lawns can best respond to landscape themes and site-specific requirements? Moving beyond the rigid "function-to-form" formula, this prompts a new approach to open-forest-lawn design – one that is interpretable, replicable, and adaptable.

2. Introducing topology into plant spatial morphology research

Topology, a branch of mathematics, investigates the relational attributes of space, focusing on intrinsic structural properties, such as connectivity, boundaries, and continuity, rather than geometric metrics, such as distance or angles. In architecture and urban planning, topology has moved beyond abstraction to become a powerful tool for analyzing spatial essence. From Le Corbusier's *promenade architecturale* – a continuous, transformative spatial sequence – to Bernard Tschumi's "point-line-plane" deconstruction of Parc de la Villette, topology consistently poses a fundamental question: how do spatial relationships, rather than surface forms, shape human behavior and cultural perception? This focus on

"relationality" offers a compelling cognitive framework for contemporary plant landscape research, especially in the study of open-forest lawns, which integrate natural growth patterns with human functional needs. By stripping away physical details of vegetation – such as plant species or height – this approach allows designers to focus on the underlying spatial relationships.

At the urban scale, topology is often used in space syntax to analyze street-network connectivity, revealing how street vitality correlates with social density. It is also applied to optimize the nested spatial logic of commercial, residential, and green spaces through topological functional zoning. The essence of these practices lies in treating the city as a "relational network," employing topological attributes to diagnose spatial issues. A similar analytical framework can be applied to plant landscape design. Plant communities, boundaries, paths, and other elements in open forest lawns exhibit topological similarities to urban blocks, squares, and streets. In both contexts, the meaning of place is conveyed through spatial relationships. Accordingly, applying topological principles to the study of open-forest-lawn plant morphology demands attention to internal spatial relationships and vegetation–environment interactions, rather than solely to geometric distributions or visual impressions. It should be noted that this study does not directly employ space syntax as an analytical tool. Rather, it draws on its core concept – that spatial relationships take precedence over geometric form – as the theoretical underpinning of topological thinking. This supports the construction of relational networks and classification logic for plant spatial structures.

Conventional plant landscape design often places considerable emphasis on the outward arrangement of plants – for example, the configuration of lawns and trees or the management of sightlines between different plantings. While these methods can be effective, they tend to overlook the dynamic changes in space and the deeper impact of plant growth on spatial experience. This underscores the importance of investigating plant spatial design from the perspective of spatial morphology. Topological analysis – by focusing on the relationships and interactions among spatial elements – enables designers to better comprehend both the potential and limitations of plant-dominated environments. For instance, open-forest lawns, a topological viewpoint enables designers not only to assess the spatial distribution of grass and trees, but also to elucidate the connectivity and boundaries among plant communities, thereby offering deeper insights into the fluidity and transitional qualities of spaces. Such analysis can foster dual integration of diverse functions and esthetics.

Moreover, topology provides a more flexible and adaptable design methodology, enabling designers to better address spatial changes resulting from the natural growth of plant communities in open-forest lawns. By reserving ample flexibility and adaptability in the early design stages, one can maintain thematic clarity and ensure a high-quality user experience over time. Finally, the introduction of topology can help overcome limitations of the single-function focus often found in traditional plant landscape design, where the focus might be limited to recreation, esthetic appeal, or ecological value. By emphasizing spatial layering and multidimensionality, topology facilitates the integration and transition of various functional demands, creating spaces with greater interactivity and experiential richness. In short, incorporating topology into the analysis and classification of spatial morphology helps transcend the constraints of conventional shape-based thinking, enabling more flexible, interactive, and multi-layered spatial configurations that continuously accommodate user emotions and spatial experiences.

2.1. Subjects, methods, and objectives

This study examines the spatial morphology of open-forest lawns in Hangzhou's West Lake area and representative urban parks in Shanghai, aiming to dissect their topological relationship networks and the multiscalar interactions between site conditions and cultural themes.

Two primary considerations guided case selection:

(i) From the perspective of regional culture: Hangzhou's West Lake park cluster uses open-forest lawns to link historical landscape sites (e.g., Liulang Wenying Park and Huagang Guanyu Park), reflecting the narrative traditions, such as the centripetal organization of classical Chinese gardens. In contrast, Shanghai – pioneering China's modern urban parks (e.g., Fangta Garden, Chenshan Botanical Garden) – showcases how open-forest-lawn design has evolved into a multifaceted contemporary model.

(ii) From a spatial-topological perspective: the 12 selected cases (Table 1) all meet basic criteria, including a tree canopy density between 0.4 and 0.6, continuous herbaceous coverage, and a minimum area of 1,000 sqm. Each case clearly exhibits one of three topological spatial types – node-based, pathway-driven, or island-based – ensuring typological representativeness and comparability. Based on the relationship between vegetative "solids" and spatial "void," the cases are categorized as node-based space, pathway-driven space, and island-based space (Figure 1).

The primary methodology is a case study approach, centered on analyzing topological relationships. Through on-site fieldwork and the translation of field drawings into analytical diagrams, we extracted key elements, such as

Table 1. Summary of research cases

Dimensions	No.	Name	Space type	Area (approximately)
>10,000 sqm	C1	Rock and Herb Garden	Island-based	13,500 sqm
	L1	Waterfront lawn	Node-based (semi-enclosed)	12,000 sqm
	H1	Snow cedar lawn	Island-based	10,780 sqm
	F1	South lawn	Node-based (semi-enclosed)	10,100 sqm
3,000 – 10,000 sqm	T1	Xiaoyao slope	Node-based (semi-enclosed)	7,750 sqm
	T2	Wangshan lawn	Node-based	6,730 sqm
	T3	Fuchen pond	Node-based	5,800 sqm
	H2	Cangshan Pavilion lawn	Node-based	5,200 sqm
	C2	Dry creek	Pathway-driven	5,100 sqm
	H3	South entrance lawn	Pathway-driven	3,670 sqm
<3,000 sqm	H5	Mimosa-London plane lawn	Node-based	2,000 sqm

Note: Case codes are derived from the first letter of each park name plus a serial number: "H" stands for Huagang Guanyu Park (Hangzhou); "T" stands for Taiziwan Park (Hangzhou); "L" stands for Liulang Wenying Park (Hangzhou); "F" stands for Fangta Garden (Shanghai); and "C" stands for Shanghai Chenshan Botanical Garden (Shanghai).
Data source: Google Earth.

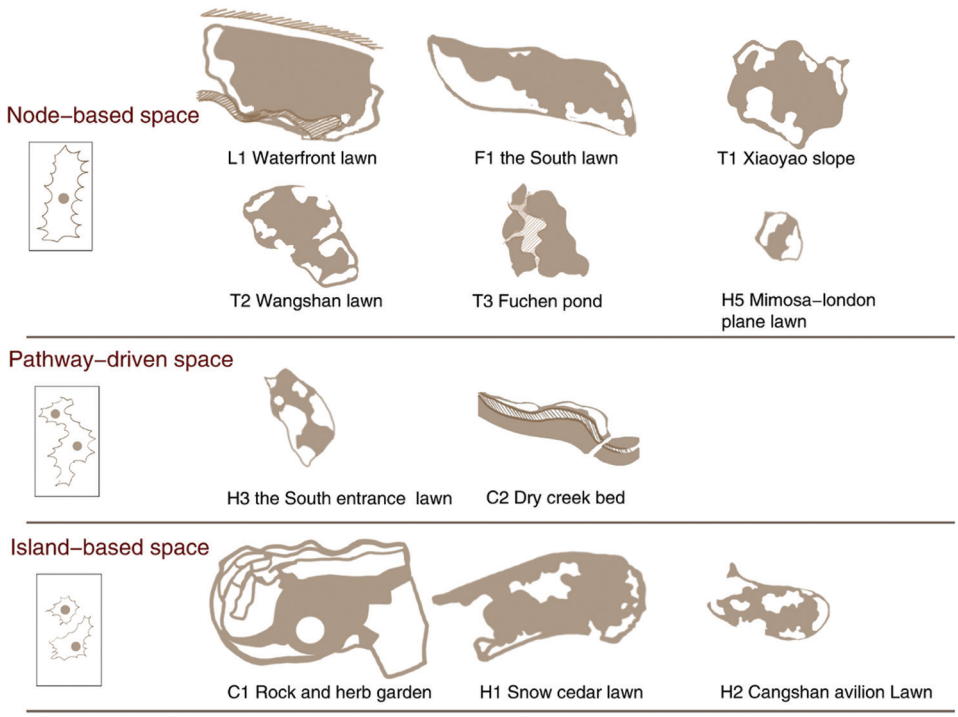

Figure 1. Spatial types of research cases
Source: Drawings by the authors.

forest edges, view corridors, and pedestrian circulation routes, to delineate the topological properties of the plant-solid and spatial-void relationship.

Combined with literature reviews, expert interviews, and field observations (Figure 2), this study clarifies how topological structures mediate the translation of thematic intentions into spatial form, validating the rationale for the proposed typological classification. Furthermore, it explores how optimizing spatial layout enhances the landscape experience.

The goal of this study is to establish an analytical framework that synchronizes "thematic intent–spatial

Figure 2. Field trips and expert guidance. (A) Graduate students from the Department of Landscape Architecture, China Academy of Art, visiting Shanghai Chenshan Botanical Garden. (B) Shen Chaodong, College of Agriculture and Biotechnology, Zhejiang University, explaining plantscape principles to graduate students (including Professor Qingqing Yu) at Liulang Wenying Park.
Source: Photos by Qingqing Yu (2024).

typology–plant configurations," thereby transcending the conventional linear model of "form follows function." In doing so, we seek to provide a planning methodology for open-forest-lawn design grounded in the fundamental nature of spatial relationships.

2.2. A topological classification of open-forest and grassland spatial morphologies

2.2.1. Node-based space

Node-based open-forest lawns resemble "nodes" in a topological sense. Such spaces typically form highly enclosed or semi-enclosed circular structures, marked by clear spatial boundaries. By leveraging plant height, density, and planting configurations, the surrounding vegetation encloses the central lawn, creating a centripetal interface. The visual focal point converges at the center, where a primary element is placed to convey design themes and site-specific meaning. From a topological perspective, these spaces arise when a void is encircled by vegetative "solid," forming an inward-looking core characterized by strong territoriality and ceremonial overtones. Physically and psychologically, the design highlights privacy and site demarcation, centered on fostering a sense of focus. Such spaces often serve as the primary carriers of commemorative or ceremonial activities. Accordingly, the plant palette typically features dense-canopied, structurally cohesive species (e.g., camphor [*Camphora officinarum*] or ginkgo) to establish a robust enclosing interface. In semi-enclosed spaces, species with airy canopies or low shrubs can define softer or more permeable boundaries. At the center, a solitary tree or built structure typically acts as a "topological anchor," intensifying the sense of order in the "people–nature–culture" relationship through absolute enclosure and rigorous spatial control.

2.2.2. Pathway-driven space

Pathway-driven open-forest lawns feature a topological structure of linear permeability as their core characteristic, emphasizing spatial connectivity and fluidity. Rows of trees or bands of shrubs form dynamic guiding axes, while naturally curved forest edges and topographic undulations create a sequential progression of "guidance–infiltration–extension." Rather than relying on physical barriers, spatial boundaries are maintained through gradual changes in planting density (e.g., transitions from sparsely planted trees to dense woodlands) and sightline transparency (e.g., "framed views" created by spacing between tree trunks). This engenders an open and continuous environment that invites free exploration. By capitalizing on topological connectivity, such spaces stimulate behavior and guide people's movement, crafting a narrative experience of "exploration and discovery." The composition of plant communities, variations in foliage density, and terrain elevation changes together produce visual cues reminiscent of the Chinese garden concept of "winding paths leading to secluded spots," wherein partial concealment and subsequent revelation of views add layers of richness. Similarly, ecological corridors employ linear spaces to link different plant communities, creating a progressive sense of cognition. In such environments, meandering paths or watercourses often serve as structural guidance, gradually drawing visitors into the heart of the landscape. Functionally, pathway-driven spaces often interconnect primary and secondary routes within a park, enhancing accessibility while adding a sense of exploratory pleasure. At a larger scale, they can act as ecological corridors that strengthen habitat connectivity. Planting configurations should follow a linear topological logic: major canopy trees with tall trunks and broad crowns can be staggered along a dynamic axis to yield an asymmetrical guiding effect; mid-layer shrubs may be pruned to control density and adjust visual permeability; and groundcovers can emphasize linear visual rhythm by incorporating staggered-bloom perennials, using color and texture changes to hint at movement. Ultimately, the essence of pathway-driven design lies in replacing purely geometric boundaries with topological relationships. Across "subtle guidance" through plant forms and planting patterns, designers reconcile free-form exploration with ecological functionality.

2.2.3. Island-based space

Island-based open-forest lawns can be considered collections of "isolated points" in topological terms. By distributing plant clusters or lawn mounds to form multiple "islands," the design creates a spatial experience of abundance and variety. This type of space exhibits a "figure–ground reversal": the discrete focal points of vegetation and the continuous "background" of lawn together compose the figure–ground relationship. Boundaries are often dissolved through the penetrable sightlines between clusters, meaning the space relies neither on solid enclosure nor on

linear guidance. Instead, it harnesses the interplay among plant clusters to animate the environment. Each "island" may function independently as a visual or functional focal point, or be linked through pathways, sightlines, or adjacent clusters to enrich spatial interest and interaction.

Visitor experience in island-based spaces often entails a "jumping" pattern of sightlines and freely chosen paths, encouraging a multidirectional, open-ended mode of activity. One can find solitude for reflection or socialize in small groups. The layered nature of the environment offers explorers ample opportunities for cognitive and emotional engagement. Functionally, island-based spaces enjoy a high degree of topological flexibility, accommodating diverse needs, such as social gatherings, ecological displays, and cultural interpretation. By adjusting the size, distribution, and planting composition of each "island," the design can support picnics, reading, children's play, and other varied uses. Often, each island features one or two distinctive or symbolically meaningful tree species, paired with evergreen shrubs to stabilize its core form; groundcovers employ color gradations or textural differences to visually link each cluster. The core design challenge lies in balancing the topological relationship between "discrete" and "connected." Through careful consideration of site context and user needs, the design can preserve each cluster's individuality while weaving a network of sightlines and circulation paths. This creates a rich, interactive layout that enhances both the site's dynamism and the emotional resonance between people and place.

3. Combined spatial typologies for open-forest lawns

3.1. Node-based space

The essence of node-based open-forest lawns lies in establishing a topological coupling between the vegetative enclosure interface and a central gravitational focal point. Its defining topological characteristics are the synergy between a ring-shaped enclosure and inward-directed focal energy. From any single vantage point within such a space, the entire spatial configuration can typically be perceived: the vegetation forms a dynamically closed ring around a void, creating a domain imbued with a sense of ceremony. Meanwhile, a central focal element (such as a solitary tree, a small structure, or a topographic high point) acts as the "topological anchor," concentrating the spirit of the site at its core. This type of space offers advantages, including a high degree of enclosure, strong territoriality, and relative independence, making it well suited for thematic attractions (e.g., festivals, cultural ceremonies, or tranquil meditation) where specific atmospheres need to be conveyed by varying levels of enclosure. Its limitation lies in the easily perceived boundaries; if not carefully designed, the space may feel monotonous or predictable, evoking a "nothing left to discover" sentiment. Below, we illustrate how to capitalize on the strengths and address potential shortcomings in planning such spaces, using real-world examples.

3.1.1. Dynamic circular enclosure

The territorial quality of node-based spaces stems from the ring-shaped topological structure formed by vegetation around the lawn. This structure is not a perfect geometric circle; rather, it emerges from differentiated configurations of tree height, canopy density, and planting style, creating a dynamic interplay of solid and void (Liu, 1990). Among the multiple open lawn areas and diverse water features in the park, Wangshan lawn (T2) stands out. The space has three main entrances, each relatively narrow and located at a corner. This configuration draws diagonal sightlines across the lawn, intuitively amplifying spatial depth (Figure 3).

To avoid having entrances directly face one another and to partially obscure the lawn's perimeter, the boundary is strategically raised or extended in some segments. At one corner, for instance, a gentle mound conceals part of a landmark (landscape installation) – a Dutch windmill – thereby enhancing spatial layering (Figure 3). Across the

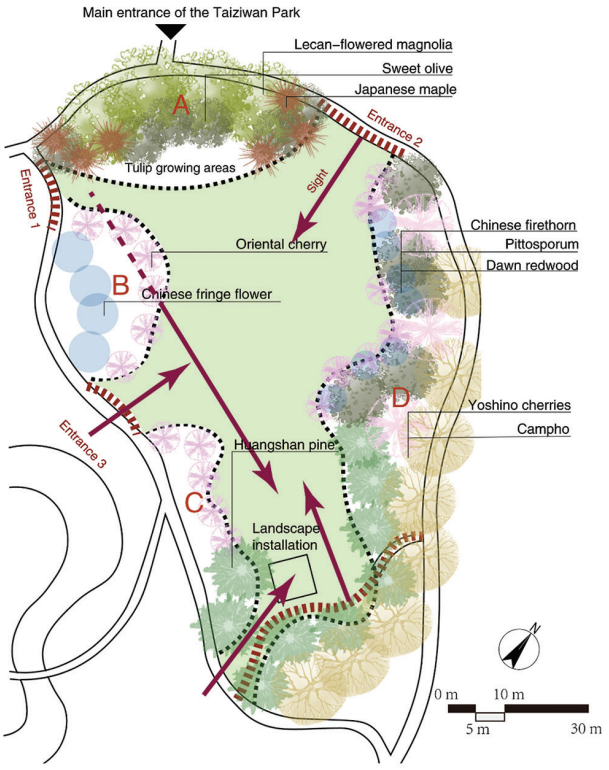

Figure 3. Sketch map of Wangshan lawn space
Source: Map by the authors.

site, varying degrees of enclosure are created by different tree-and-shrub groupings, each creating a distinct balance between visual screening and openness:

- Group A, positioned near the main entrance, employs the form of "trees + shrubs + herbaceous plants." Lecan-flowered magnolia (*Magnolia chapensis*), sweet olive (*Osmanthus fragrans*), Japanese maple (*Acer palmatum*), Chinese firethorn (*Pyracantha fortuneana*), violet cress (*Orychophragmus violaceus*), mondo grass (*Ophiopogon japonicus*), and tulips (*Tulipa gesneriana*) are planted in groups within the lawn. This cluster offers a relatively robust visual partition, enhancing the sense of seclusion.
- Group D, adopting a similar planting structure, includes taller species, such as dawn redwood (*Metasequoia glyptostroboides*) and pine (*Pinus bungeana* and *Pinus hwangshanensis*) to define the skyline, supplemented by numerous Yoshino cherries (*Prunus* × *yedoensis*) for seasonal highlights, thus creating a feeling of verticality. Viewed from Entrance 1, between Groups A and B, these plantings layer with distant hills, deepening the sense of continuity (Figure 4).
- Group B is located near the intersection of the garden path and also serves as a secondary entrance. Therefore, strong spatial separation is unnecessary. To allow visual connectivity, the design adopts the form of "small trees + shrubs," using oriental cherry (*Prunus serrulate*) and Chinese fringe flower (*Loropetalum chinense*) in a relatively sparse layout. This results in a moderate spatial separation effect. Visitors can see the lawn through the nearby gaps, while the distant view reveals a rich plant backdrop where the lawn connects with the northeast mountains.
- Group C, located next to a longer walking path, features more widely spaced trees (oriental cherry + pine). After passing through the relatively shaded area near Group D, visitors gradually transition to the lawn entrance, with the views becoming progressively clearer.

Figure 4. Sight from Entrance 1 of Wangshan lawn
Source: Photo by the authors (2025).

Therefore, within the enclosed space, different plant groupings generate varied spatial separation effects (Figure 5).

The same logic is evident in Taiziwan Park's Xiaoyao slope (T1). The south and west sides are densely planted with cherry trees and camphor trees to form a solid enclosure, while the eastern edge uses the extended branches of soapnuts (*Sapindus Saponaria*) to form a virtual boundary (Figure 6). In doing so, the design capitalizes on a 4 m elevation change from south (higher) to north (lower), gently guiding visitors' sightlines toward the western broadleaf forest and a nearby European chapel. This interplay between open and closed edges, combined with the topographic slope, effectively incorporates borrowed scenery and accentuates the overall sense of depth.

The Fuchen pond (T3) area further illustrates how partial views of distant hills – Jiuyao Hill, Nanping Hill, and Nangaofeng Peak – can ease an otherwise tightly enclosed space and evoke a more natural ambience. By drawing the planting boundary slightly back from the pond and leaving a smooth lawn slope to meet the water's edge, the design softens human-made interventions and highlights the "wild" esthetic theme. In terms of overall layout, the skyline and forest edge appear both refreshing and natural. The distant view is dominated by members of the magnolia family, such as the lecan-flowered magnolia, which echo the surrounding mountains. The middle layer features cherry trees, purple-leaf plums, and Japanese maples, while the lower layer contains hydrangeas and pyracanthas. The ground cover is densely planted with perennial flowers and aquatic wetland plants in accordance with the terrain slope. The lawn is primarily composed of cool-season grass species, such as creeping bentgrass (*Agrostis stolonifera*), bluegrass (*Poa pratensis*), and purple-leaf plum (*Prunus cerasifera*), while certain areas are planted with Bermudagrass (*Cynodon dactylon*) to form warm-season turf. These two types complement each other, collectively contributing – along with the surrounding plant communities – to a visually rich, seasonally dynamic landscape (Figure 7).

The Mimosa-London Plane lawn (H5) in Huagang Guanyu Park also enhances the interest of the enclosed space through the richness and interaction of plantings. The terrain descends from north to south, with camphor trees and olive trees forming a strong northern backdrop, accompanied by magnolias and cherry blossoms. The spatial composition allows for seasonal interest year-round, and the overall scale is pleasant. Behind the London plane (*Platanus orientalis*) trees is a cedar (*Cedrus deodara*) forest. In the southern part of the space are cherry blossoms,

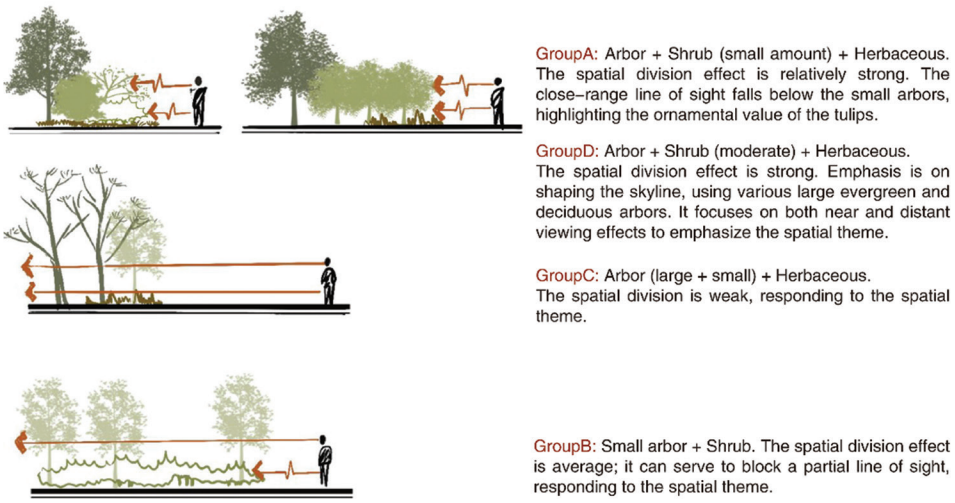

Figure 5. Analysis of landscaping nodes and space separation effects
Source: Diagram by the authors.

Figure 6. Rich plant borders at Xiaoyao slope
Source: Photo by the authors (2025).

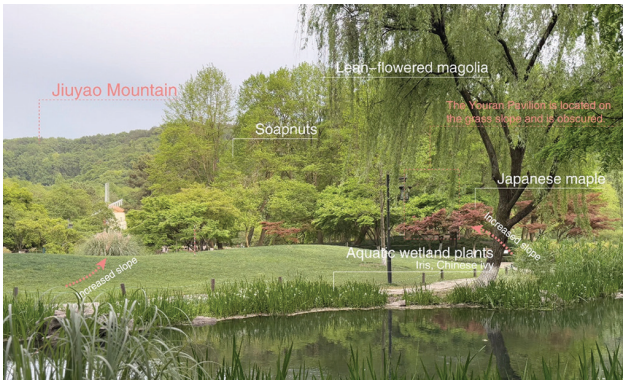

Figure 7. Seasonal planting composition around the lawn at Fuchen pond
Source: Photo by the authors (2025).

while various spring-flowering shrubs occupy the northern section. To the west of the mimosa (*Albizia julibrissin*) is a Chinese sweetgum (*Acer buergerianum*) forest. In spring, cherry blossoms bloom in the south and flowering shrubs in the north. In summer, the focal points become the blooming mimosa. In late autumn, the fallen mimosa leaves reveal a striking contrast between the red foliage of the Chinese sweetgum forest and the yellow leaves of the London planes, extending from east to west. In winter, in front of the cedar forest, the white-green trunks of nine London planes stand out cleanly, without appearing bare or shabby (Figure 8). It is worth noting that the topological integrity of plant enclosures does not rely on a single tree species, but is instead achieved through the composition of heterogeneous plant communities. In the early days, the Mimosa-London Plane lawn in Huagang Guanyu Park was designed with five freely planted mimosas as the central landscape elements to construct a centripetal form. Over time, the expanding canopy of the nine London planes opposite the main landscape trees gradually enclosed the space in reverse, becoming the dominant structural force and demonstrating the ability of plant growth to dynamically reshape the topological structure.

3.1.2. The narrative anchoring role of the gravitational core

A central focal element acts as a "topological gravitational core," serving both as the visual epicenter and a carrier of cultural meaning. Its positioning and form should align with the overarching logic of "view corridors–pathway design–thematic significance." As visitors enter, often at an oblique angle, the winding path and gradually intensifying enclosure direct their sightlines toward the center, while the focal element's symbolic undertones are translated into a tangible spatial presence through these topological relationships. In Wangshan lawn (T2), for instance, the landscape installation imitating a Dutch windmill is raised

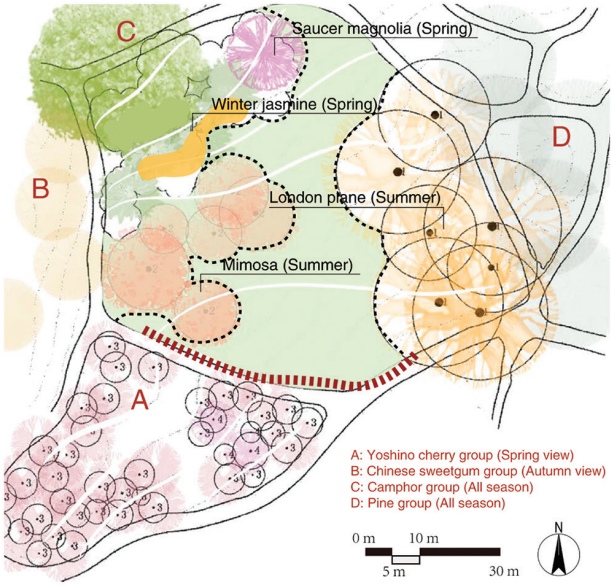

Figure 8. Schematic map of the four-season landscape of the London Plane lawn
Source: Map by the authors.

on a gentle 3% slope and viewed diagonally, heightening its spatial dominance. It functions as the cultural anchor around which seasonal tulip displays revolve. In Fuchen pond, the layout demonstrates a concentric topological relationship: the pavilion on the north-side slope constitutes a vantage point emphasizing the lawn's gentle gradient (or "green carpet") as a means of strengthening enclosure. Fuchen pond itself expands at the juncture of two waterways, with its banks shaped as natural slopes that merge into the water's edge. By setting the planting boundaries farther back and leaving a broad expanse of lawn rolling gently into the pond, the design softens the transition between artificial and natural elements, enabling the "wildness" theme to emerge through a centripetal spatial relationship.

Xiaoyao slope (T1), also in Taiziwan Park, provides another example. Drawing inspiration from 18th-century English naturalistic landscapes, it capitalizes on the roughly 4 m elevation change (south high, north low; west high, east low). Decorative cherry blossoms and soapnuts dominate the high ground in the southern part, showcasing vibrant colors in spring and fall, while a broadleaf forest on the west side delineates the skyline and visually converges with distant hills. Nearby, a European-style chapel complements the romantic ambience, reinforced by the arching branches of Yoshino cherry trees. This arrangement merges topography, planting, and architecture into a coherent thematic focus.

Semi-enclosed lawns can also utilize an analogous anchoring mechanism. In Liulang Wenying Park, along the southern shore of West Lake, Hangzhou, a semi-enclosed waterfront lawn (L1) fosters both openness and enclosure by slightly raising its terrain (2 – 5% slope), forming a spacious vista that maintains a sense of privacy. Tall trees define the skyline on three sides, while willows along the lakefront echo the theme of "Orioles Singing in the Willows," one of the Ten Scenic Views of West Lake. This setup offers a sense of security and intimacy, encouraging relaxation and social enjoyment (Figure 9).

Fangta Garden's south lawn (F1) showcases this narrative-anchoring strategy in a more pronounced form. The lawn's axis faces a Song dynasty (960 – 1279) pagoda across a central lake. This semi-enclosed space delivers a powerful sense of directed view, making the pagoda the focal point. The lawn gently slopes downward (south to north), with camphor trees in the distance framing the skyline and interweaving forest edges with waterside vegetation. A partial ring of trees screens out adjacent urban noise, preserving calm and delineating the space for leisurely activities. Meanwhile, the tall pagoda stands as a cultural emblem, evoking the esthetic sensibility of the Song era (Figure 10).

The essence of node-based open-forest lawns lies in the dialectical interplay between enclosure and openness, which cannot be seen merely as a rejection of nature. With the introduction of topology, "enclosure" ceases to be defined by fixed physical boundaries; rather, it is shaped through the layered distribution of plant communities and the interplay between solid and void, thereby regulating the dynamic relationship between interior and exterior. This approach creates a spatial experience that ensures privacy without descending into monotony. In plant landscape design, node-based layouts can employ the following strategies to highlight strengths and mitigate weaknesses:

(i) The designer's task is to adjust plant density, morphology, and visual permeability to establish a sense of territory and privacy, while maintaining dialogue with the external environment and fulfilling multiple functional needs. When thematic intentions call for different atmospheres – such as grand events, commemorative ceremonies, or private meditation – designers can respond by fine-tuning the degree of enclosure, the placement of entrances, and seasonal configurations of plantings. This avoids boundaries dominated by a single species or uniform planting, allowing a flexible shift between "highly enclosed" and "semi-enclosed" spaces, and thereby endowing open-forest lawns with more diverse functional and esthetic value.

(ii) Emphasize topological coordination among multiple elements by introducing garden features – such as

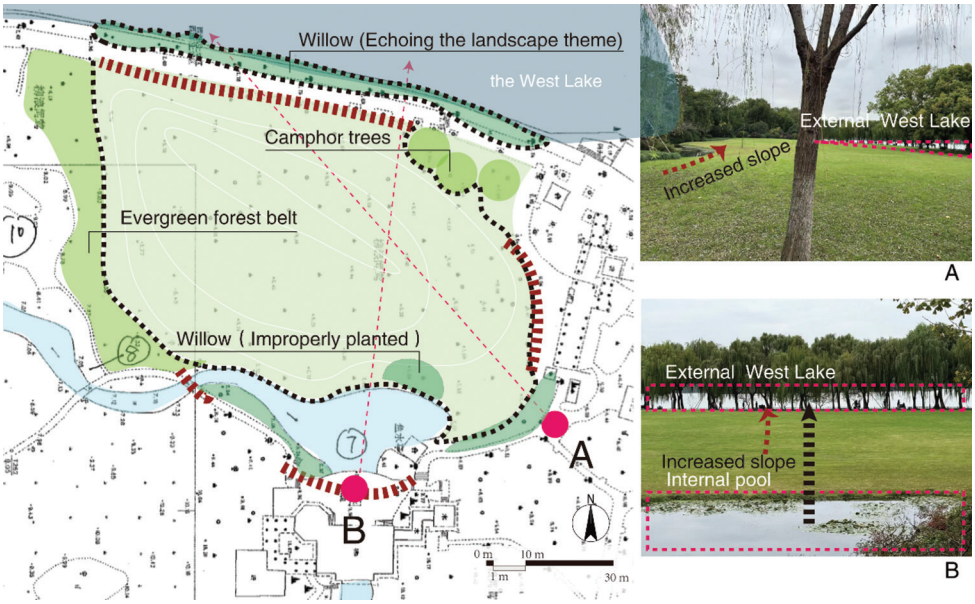

Figure 9. Semi-enclosed waterfront lawn in Liulang Wenying Park
Source: Map by the authors; Photos by the authors (2024).

Figure 10. Fangta Garden's south lawn
Source: Map by the authors; Photos by the authors (2024).

landforms, water bodies, borrowed scenery, and built structures – that jointly enrich the spatial interface and boundary. For instance, undulating terrain uses slopes and contour lines to guide sightlines; water features create reflective surfaces that dissolve rigid boundaries; and borrowed scenery can visually extend the space, enhancing the complexity of the enclosing edge.

(iii) The gravitational pull of the central element should not be confined to formal esthetics; rather, it must be deeply integrated with site context and functional requirements, translating thematic concepts into topological relationships. This gravitational pull not only creates a visual focal point that draws visitors' attention, but also weaves cultural symbols into the spatial network, functioning as the hub that orchestrates spatial experience and effectively mitigates feelings of over-enclosure. By incorporating seasonal variations in focal plantings and dynamically adjusting the visual centerpiece to respond to changing needs, designers can achieve a "fixed topological structure with variable meaning." This design method enables node-based spaces to transcend single functional identities, generating diverse cultural and emotional expressions across time and context.

3.2. Pathway-driven space

The essence of pathway-type open-forest lawns lies in reconstructing the connectivity and fluidity of linear space through the topological relationships of plant communities. The central dilemma is that overly emphasizing geometric axes may render the spatial experience mechanical, whereas a fully naturalistic, unordered layout might dilute its narrative clarity. The introduction of topology transforms this dilemma into a dynamic equilibrium, identifying the core of pathway-driven spaces as the relationship between "edges" and "axes." Gradual variations in plant density, curvilinear terrain, and the phased concealment and revelation of view corridors collectively extend what would otherwise be a limited space, creating a dynamic experience that requires visitors to "gain insight as they move along."

3.2.1. Topological expansion from the small to the large

Pathway spaces are typically elongated in form, using clear axial lines and connectivity to convey depth. Especially in smaller sites, the design of pathways leverages extensions and turns to shift visual perception from local segments to an integrated whole, forming a topological structure in which "the small reveals the large." By applying the principle of "spatial folding," such an approach transforms the detailed experience of a small area into deeper insights into the entire space, thereby externalizing its latent spatial potential.

Take the south entrance lawn of Huagang Guanyu Park as an example. The overall space features an autumn foliage theme, with a lawn area of approximately 3,700 sqm and a planted landscape area of about 2,000 sqm. Although not especially large, the interlocking of lawn and plantings enhances the sense of flow and openness. Across a T-shaped spatial axis, combined with a tree belt and three "tree islands," the design creates winding forest edges of varying density. This interplay of "contraction and expansion" lends the site greater depth and a tranquil ambience. Given the modest scale, only a few solitary ornamental trees are used; instead, clusters of autumn-colored species serve as visual anchors, functioning both as focal points and contributors to broader vistas. Meanwhile, the interweaving of multiple sightlines and axes yields a layered spatial experience in which no single viewpoint provides a complete panorama. A circular path around the lawn offers diverse vantage points, allowing visitors to appreciate its profound setting from different angles.

Moving counterclockwise, one first perceives the far-reaching lawn framed by trees on both sides, then enters the semi-concealed "illusory scene" beneath the forest canopy (Group B). Gradually, framed views among the trees (Groups BC and CD) guide attention toward a large *Pterocarya* tree – complete with a resting spot beneath it – which functions as the climactic spectacle. This area is only partially visible through the Groups BC corridor and fully revealed between Groups CD, exemplifying a "changing scenery with each step" sequence that highlights the interplay between primary axes and shifting sightlines in a pathway-type space (Figure 11). Another expression of "the small revealing the large" runs parallel to the main axis, akin to a continuous "handscroll" in traditional Chinese landscape painting. In the winding dry creek at Shanghai Chenshan Botanical Garden, visitors can walk along the dry creek bed (C2) or view it in its entirety from the banks. Various grasses (Gramineae) and stones are arranged in a naturalistic fashion, and at each triangular turn, larger plant specimens – such as *Miscanthus* spp., *Cortaderia selloana* (pampas grass), *Miscanthus floridulus*, and various reed species, reaching 1.5 – 2.5 m in height – are planted in an asymmetrical layout. In this way, a mere 200 m of linear space evokes a lush autumnal scene (Figure 12). Through topological guidance and integrated planning, pathway-type spaces provide visitors with a multifaceted visual experience and emotional connection.

3.2.2. The implicit logic of dynamic guidance

Traditional pathway design often focuses solely on whether to use straight lines or curves to direct pedestrian flow. Yet topology reminds us that the true significance of a pathway lies in how it helps people comprehend and perceive the

Figure 11. South entrance lawn of Huagang Guanyu Park
Source: Map by the authors.

spatial logic of the entire site. Through carefully structured plant configurations, one can subtly guide user behavior and shape a compelling pathway-type environment.

Take the south entrance lawn (H3) of Huagang Guanyu Park as an example. As the first entry point, its deep, tranquil ambience immediately instills a sense of calm in visitors. At Viewpoint Group A, situated near Nanshan Road, vegetation is arranged in a linear strip to partition the space. The upper canopy primarily comprises soapnuts and Chinese wingnuts (*Pterocarya stenoptera*), while the mid-layer features Japanese maple and sweet olive. The ground layer includes mondo grass, Chinese violet cress, spotted laurel (*Aucuba japonica*), kurume azalea (*Rhododendron obtusum*), and other species. This "tree–shrub–groundcover" community follows a natural, curvilinear boundary that effectively highlights seasonal variation. *Pterocarya* and *Acer truncatum* – both species

Figure 12. Dry creek in Shanghai Chenshan Botanical Garden
Source: Photos by the authors (2024).

known for their autumn foliage – are strategically placed at turning points along the planted edge. As focal elements of different clusters, they reinforce the autumnal theme; their asymmetrical layout creates an interwoven, visually resonant effect. At the same time, their tall trunks and broad crowns become topological tools for spatial guidance. *Acer truncatum*'s branches extend toward the lawn center, while *Pterocarya*'s tall, expansive form redirects the sightline. Together, they generate an "explore–focus–re-explore" behavioral logic that continuously entices visitors with the promise of further spatial discovery, whether they are entering the lawn or observing from a fixed position.

In designing planting schemes for pathway-type spaces, landscape architects should avoid relying exclusively on geometric axes or embracing entirely unstructured, naturalistic curves. Instead, they should adapt the "landscape sequence" and "planting scheme" to suit their thematic intentions, ensuring the space is both directive and exploratory. If the theme emphasizes natural wildness, naturalistic plantings and curved pathways can foster a "sense of discovery." If the goal is to highlight an ordered, human-made esthetic, symmetry and axial lines can be reinforced in both walkway alignment and vegetative partitions. Generally, the defining feature of pathway-type spaces is the "shifting field of view during movement." Designers can integrate topography, water features, and bridges to enrich the spatial layers along the path. By varying plant density, they can guide how visitors move and where they look, allowing them to discover new scenes in a continuous state of "flow." This approach creates a dynamic spatial experience of "exploration–focus–renewed exploration," effectively fulfilling the design's thematic goals and providing a systematic basis for subsequent plant composition and detailed design.

3.3. Island-type space

Island-type open-forest lawns feature a dispersed-cluster topological structure as their core trait. Essentially, they emphasize a figure–ground reversal between plant clusters and the lawn substrate. Unlike node-based spaces that focus inward or pathway-based spaces that rely on linear guidance, island-type layouts use discrete plant groupings to form multi-focal networks within a continuous lawn "ocean," creating an "island–sea" topological relationship. Each plant cluster serves as a standalone functional anchor while connecting to others through sightlines and pathways, ultimately forming an interactive spatial system that balances elasticity with stability. The main challenge in island-type design arises from constructing an overall sense of wholeness out of dispersed clusters. If the plant groups are placed too far apart, the space risks becoming fragmented and thematically diluted; if the clusters are too dense, they lose individual distinctiveness, reducing the effectiveness of focal points along major sightlines. In such cases, the design risks reverting to a node-based or "backside" space.

3.3.1. Cultural symbols and topological negotiation

A prominent example of how cultural symbols guide the interplay between "discretion and connectivity" can be found in the Rock and Herb Garden at Chenshan Botanical Garden. Originally part of a former quarry, now repurposed into a garden, the central circular lawn (C1) serves as a void substrate, while four heterogeneous "islands" (a xeric plant zone, an herb garden, a rock-plant zone, and a shaded garden) surrounding it form a topological mapping. Each "island" establishes a defining thematic character through topological homology between constructed rock textures and the morphological traits of plantings:

- The western xeric zone uses thorny shrubs and chunky sandstone to create sharp boundaries.
- The northeastern rock zone leverages the mountain slope to assemble layered rock bands with permeable edges.
- The southeastern shaded garden uses rock paving to form a diffuse boundary.

These differentiated material strategies preserve each island's autonomy, while an annular sight corridor and meandering pathways subtly connect the "dispersed" and the "linked." Visitors' initial sightlines are drawn toward the distant quarry park to the west; proceeding clockwise, they gradually experience shifts in elevation among the surrounding cliff walls and assorted vegetation islands. Eventually, they reach a resting bench at the far end, where looking upward reveals a vivid color contrast between the central "green knoll" and the surrounding rocky walls – a visual reminder of environmental conservation (Figure 13) (Hu *et al.,* 2017). Indeed, in many settings where cultural meaning or symbolic significance is embedded, a layered sequence of spatial encounters deepens the visitor

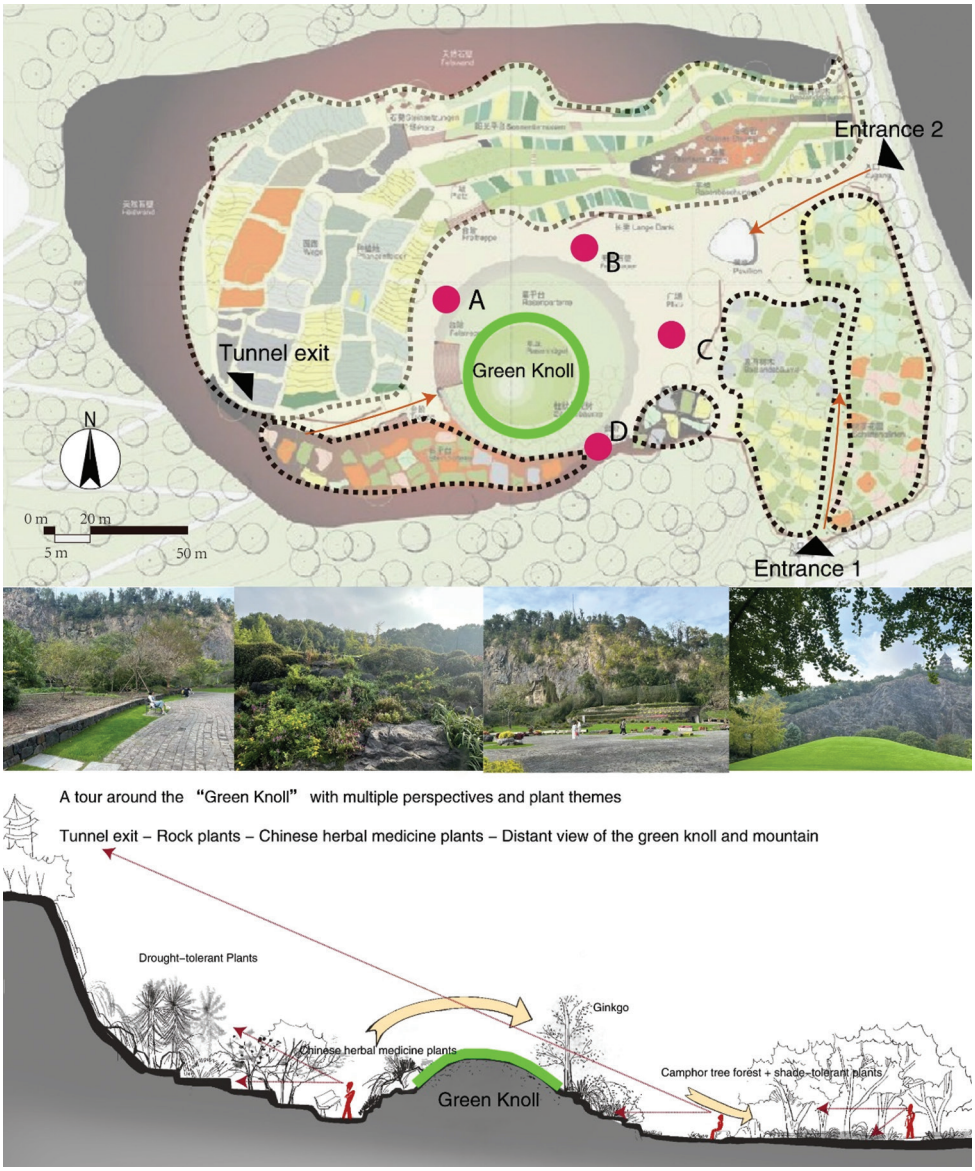

Figure 13. The "Green Knoll" and surrounding quarry walls
Source: Map by the authors; Photos by the authors (2024).

experience. Step by step, the interplay of changing scenery enriches both the esthetic and spiritual dimensions of the sites.

3.3.2. Imbalance in the figure–ground relationship

The design of the central circular lawn (C1) reveals a potential issue in island-type spaces: an imbalance in the topological relationship between the plant "islands" (the "figure") and the lawn substrate (the "ground"). When the plant clusters dominate as the figure, the continuity of the lawn void may be disrupted, fragmenting the activity space. Conversely, when the lawn substrate is overly emphasized, the discrete focal points may lose their visual appeal. The single, geometric figure–ground arrangement of the central circular lawn hampers behavioral guidance (preventing deeper educational tours), and the symmetric, regulated lawn boundary reduces spatial directionality. In the western section, Groups A and B, though seemingly connected in form, fail to achieve visual linkage due to limited sightline permeability. In addition, insufficient pathway accessibility leads to low visitor engagement, exposing a topological imbalance between spatial discreteness and functional reach.

From a topological perspective, island-type spaces require the designer not only to pursue cultural symbolism and visual diversity in scattered clusters but also to build hidden connections through "view permeability" and

"pathway association" (i.e., carefully orchestrating the relationship between routes and sightlines) to ensure adequate interaction and linkage among clusters. This is essential for achieving effective educational functions and enhancing the spirit of the site.

The Cangshan Pavilion lawn (H2) at Huagang Park exemplifies the viability of this approach. With the Cangshan Pavilion ruins as its center, the main cluster and surrounding secondary clusters form a multi-tiered topological network. As visitors follow the circular perimeter path of the lawn, sightlines pass between clusters, creating dynamic framed views (Figure 14). The main cluster remains within the field of vision as a cultural anchor, while the secondary clusters reinforce overall spatial coherence through seasonal color changes, such as *Liquidambar* or *Acer truncatum* in autumn. This asymmetrical, scattered layout preserves each node's individual narrative, while the guiding effect of sightlines establishes hidden topological linkages, maintaining a dynamic equilibrium between discreteness and connectivity. In practice, the Cangshan Pavilion ruins serve as the cultural foundation of the main cluster, complemented by plants rich in classical-garden ambience, such as bamboo, camellias, Japanese maple, saucer magnolia (*Yulania* × *soulangeana*) – planted at the center of the lawn. The main cluster, functioning as the cultural anchor, remains in the visual field and combines with the surrounding secondary clusters to form a multi-level topological network. As visitors progress along the circular path, shifting viewpoints cause their sightlines to continuously alternate among obstacle view, prospect, and neighbor view. Meanwhile, a nearby cluster can alter the viewer's line of sight at specific points. As shown in Figure 15, on the path from Point A to Point D – <100 m long – sightlines shift direction four times, creating multiple short-range scenic changes that significantly enrich the experience. In this way, the secondary clusters dispersed around the lawn remain relatively independent, each with its own plant composition and esthetic function. Yet through interlocking sightlines, they maintain a hidden topological relationship with the main cluster, aligning with the site's theme and sustaining a dynamic balance between dispersal and connection.

To reconcile the inherent tension in island-type space design between fragmentation and overall unity, designers must acknowledge that site context and its multiple layers of information are indispensable. No landscape exists in isolation. The following strategies may help coordinate and optimize spatial layout to achieve a balance between function and esthetics:

(i) Establish effective linkages among discrete clusters: appropriate pathways and carefully selected theme-related plantings can strengthen subtle visual and behavioral ties among islands, encouraging deeper visitor engagement and enriching the sense of place.

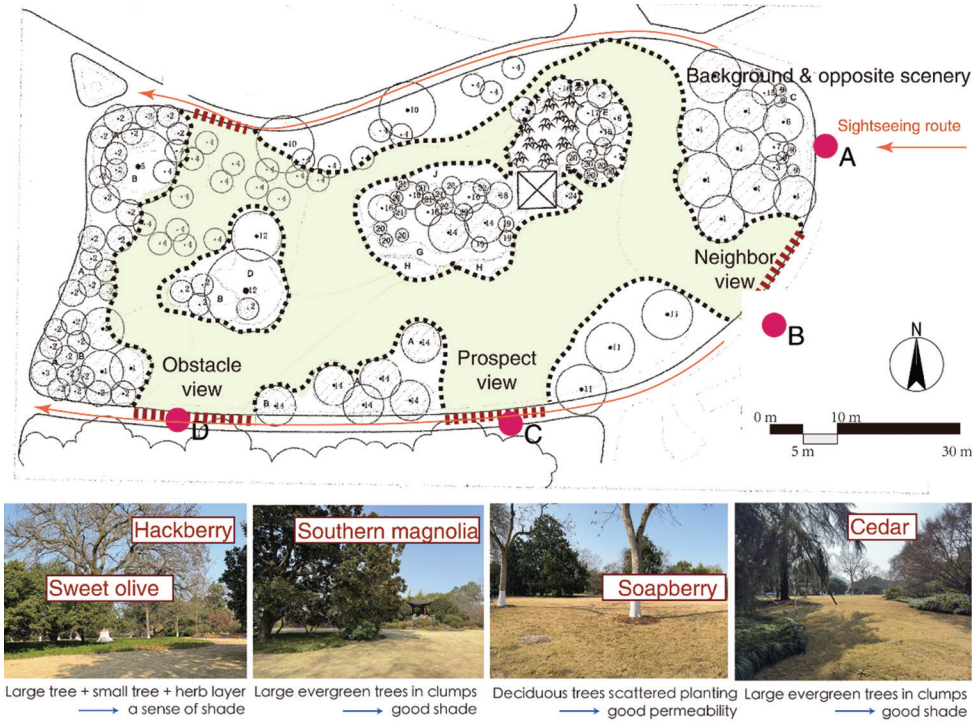

Figure 14. Cangshan Pavilion lawn
Source: Map by the authors; Photos by the authors (2024).

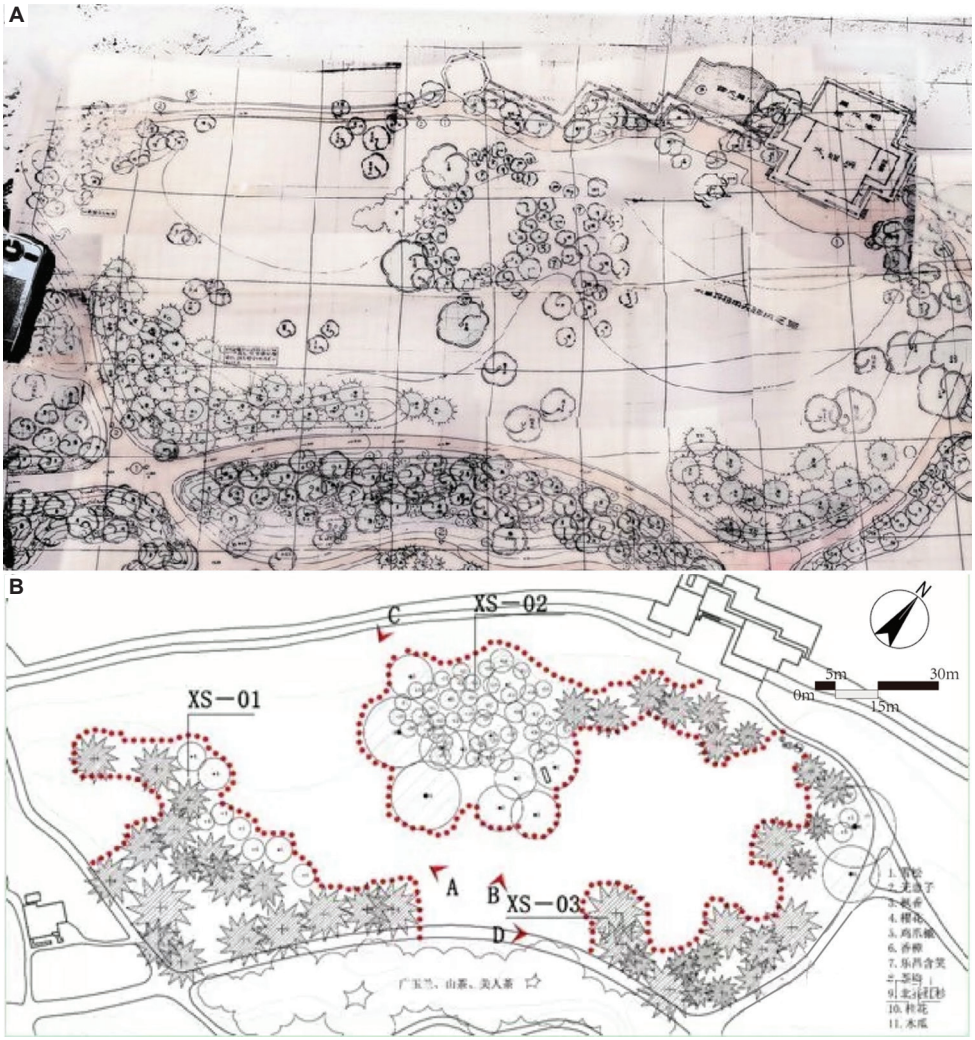

Figure 15. Planning and measured drawings of the snow cedar lawn. (A) Planning diagram. (B) Site measurement drawing.
Source: Maps by Li Weiqiang (heibao-gongshe; https://mp.weixin.qq.com/s/4eHN_1MLfIiBNPZ5pwINDQ).

(ii) Integrate multifunctionality and cross-scale planting: island-based spaces are particularly well-suited for layering different scales and uses. By adjusting cluster size and density, designers can avoid excessive fragmentation or overcrowding. When differences in elevation and boundary conditions are used skillfully, each cluster can establish horizontal and vertical relationships that allow visitors to explore the flexible "island–lawn" structure from multiple routes.

(iii) Treat the entire site as a cohesive system: island-based spaces and their associated thematic concepts must work in concert to form a modern park landscape that integrates cultural depth with functional flexibility.

3.4. Synthesis of the three topological spatial types

The spatial design of open-forest lawns fundamentally consists of a topological relational network formed by plant entities and the lawn substrate. Through case studies, it can be observed that the three spatial types – node-based, pathway-driven, and island-based – achieve synergy between overall themes and spatial functionality by adjusting degrees of enclosure, connectivity, and dispersal. Node-based spaces establish cultural focal points through ring-shaped enclosed interfaces but require diverse planting configurations to avoid monotony. Pathway-driven spaces use linear connectivity and gradual infiltration to construct narrative sequences while needing to balance structured linear guidance with the organic fluidity of free exploration. Island-type spaces employ dispersed clusters to foster multiple usage modes, but must guard against fragmentation and insufficient dwell time.

These spatial morphologies can be flexibly combined within open-forest lawns to form a multi-layered, adaptive,

and interactive system. Overall, a "theme-first" design strategy effectively coordinates the level of enclosure, circulation routes, and plant arrangements, thereby avoiding conflicts between functionality and esthetics and providing a systematic approach to planting design.

4. Diverse spatial forms

To facilitate in-depth exploration, the preceding discussion categorized open-forest lawn spatial forms into three types. Essentially, they hinge upon the dynamic transformations and layered combinations of topological relationships. While node-, pathway-, and island-type classifications offer a conceptual framework for research, in real landscapes, multiple topological structures typically coexist within extensive transitional zones (Figure 15). In exemplary planting design, topological nesting and deformation often dissolve typological boundaries, producing integrated and diverse outcomes.

This dynamism is notably evident in the historical evolution of the snow cedar lawn (H1) at Huagang Guangyu Park. The composite spatial form originally designed by Sun Xiaoxiang (1921 – 2018) essentially embedded a node-based topological core within an island-type space. A central *Osmanthus* grove formed a closed space akin to a "singularity" in topological terms, exerting gravitational pull within the open lawn. By applying the "solid conceals void" technique, the inversion of the plant interface and lawn substrate endowed the site with the multi-interpretive character typical of Chinese gardens (Sun & Hu, 1959). Regrettably, due to subsequent management changes – including lawn restrictions and natural plant growth – the once-accessible void was reduced to a mere visual symbol. This shift exposed a topological conflict between artificial interventions and natural succession: when the dynamic equilibrium is disrupted, spatial richness diminishes.

The lesson of topology is that layering spatial forms is fundamentally the reweaving of a relational network. The centripetal tendency of node-type spaces, the connectivity of pathway-driven spaces, and the discreteness of island-type spaces are not mutually exclusive. Instead, they can be effectively merged through techniques, such as shifting real–virtual boundaries along the woodland fringes or using topological "view corridors" to permeate visual fields. For instance, at a larger scale, a node-based space may serve as a climactic stage in a pathway sequence, while island-type clusters can soften the rigidity of linear spaces. Such integration should not be confined to mechanically combining physical elements; rather, it should establish topological homologies by leveraging the spatial attributes of plant communities (e.g., canopy branch angles, shrub density gradations). This approach enables visitors to intuitively perceive shifts in spatial types as they move through the site.

Contemporary landscape architects must place greater emphasis on the elastic adaptability of topological structures. As plants grow, spatial forms keep evolving, reflecting topological relationships that adjust over time. Drooping deodar cedar branches, for instance, alter perceived boundaries, while expanding oriental cherry groves reshape sightline networks (Heibao-Gongshe, 2015). The designer's task is not to resist this dynamism but to guide it toward a desired trajectory through an initial framework. Inspired by the principle of "becoming even before completion" found in traditional Chinese gardens, the appeal of planting spaces lies in their ongoing interplay between stability and change. Designers should transcend a static mindset of classification, instead building flexible systems along the "enclosure–permeation–dispersal" topological continuum. In so doing, spatial forms become vehicles for conveying thematic intentions, ultimately achieving a topological congruence of function, esthetics, and ecology. This provides a theoretical foundation for further inquiries into the emergence of composite spatial forms.

5. Conclusion

Across an analysis of case studies from urban parks in Hangzhou and Shanghai, China, this research develops a design framework for open-forest lawns based on topological principles, underscoring that the essence of open-forest-lawn design lies in balancing and coupling spatial relationships. By classifying and interpreting three topological forms – node-based, pathway-driven, and island-based – and examining how these types often create more complex spatial sequences through "hybridization" or "transitions" in overall planning, this study transcends the previously simplistic correlation between function and form. It further demonstrates the profound influence of spatial structure on thematic expression, planting configurations, and user experience. Aligning "thematic intention–spatial typology–planting schemes" not only enables flexible combinations in modern urban parks to meet diverse user needs but also reinforces the esthetic, functional, and regional significance of open-forest lawns.

Nevertheless, three limitations remain. First, there is insufficient dynamic tracking of plant growth and the ensuing spatial evolution. Second, adaptation across multiple climatic zones has been only superficially explored. These constraints reflect a broader shortcoming in current planting-design studies, which often emphasize static spatial structures over temporal processes. Open-forest lawns should not be regarded as static landscape

specimens, but rather as integral components of ever-evolving urban ecosystems, constantly adapting to plant succession and shifting usage requirements. Within this spatiotemporal interplay, the "relational" mindset advocated by topology can assume a more pivotal role, enabling designers to flexibly organize space along the "enclosure–permeation–dispersal" continuum in response to the growing demands of ecological civilization for both resilience and cultural expression.

Thus, the insights topology offers to landscape design are not confined to static spatial forms; more fundamentally, they address how we might cultivate a forward-looking spatial intelligence within the context of ecological civilization.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: Chenqin Du, Qingqing Yu
Investigation: Chenqin Du, Qingqing Yu, Shiyuan Lou
Methodology: Chenqin Du, Qingqing Yu
Visualization: Chenqin Du, Shiyuan Lou
Writing – original draft: Chenqin Du
Writing – review & editing: Chenqin Du, Qingqing Yu

Ethics approval and consent to participate

Not applicable.

Consent for publication

Informed consent was obtained from all individuals featured in the study (including expert interviewees) for the publication of field photographs and interpretations.

Availability of data

Primary and secondary sources and data supporting the findings of this study were all publicly available at the time of submission. The datasets generated and analyzed during the current study, including field notes, drawings, and interview records, are available from the corresponding author upon reasonable request.

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