

Article

Research on Historical Habitat Assessment Based on Ancient Tree Distribution: A Case Study of Chengdu, China

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Abstract

Chengdu, China, is endowed with abundant ancient and famous trees as well as historical habitats, which are crucial for sustaining urban biodiversity and cultural continuity. This study focuses on the historical habitats along the Second Ring Road and develops a comprehensive evaluation system across five dimensions: ancient and famous trees, species diversity, historical habitat quality, historical habitat health, and historical-cultural value. Twelve representative historical habitats were analyzed using fishnet analysis, image segmentation, and plant diversity surveys to characterize biodiversity patterns and develop strategies for optimizing urban biodiversity conservation and sustainable habitat management. Results indicate: (1) significant variation among historical habitat types, with Huanhuaxi Park achieving the highest overall quality; (2) except in park habitats, comprehensive quality shows no significant correlation with the density of ancient and famous trees, while habitat size exerts a strong influence; (3) the evaluation index system still requires refinement. This research provides practical guidance for the conservation of ancient trees and the sustainable management of historical habitats. At the theoretical level, it underscores the relevance of an “ecology–society–culture” framework, revealing how historical habitats simultaneously sustain ecological functions, support social practices, and embody cultural expression. Overall, the study offers a new perspective for integrating urban biodiversity conservation with cultural heritage protection.



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Keywords: heritage habitat; famous trees; biodiversity; urban planning; ecological–cultural framework; China

1. Introduction

Chengdu, a major city in southwest China, is characterized by its rich historical and cultural heritage as well as distinctive natural landscapes [1,2]. Ancient and famous trees, as representative natural heritage within urban ecosystems, constitute a vital component of historical habitats and play a crucial role in sustaining urban biodiversity and enhancing habitat quality [3,4]. Within these habitats, ancient trees often create unique microhabitats: their expansive canopies, complex trunk structures, and deep root systems provide shelter, breeding grounds, and foraging spaces for diverse organisms. The growth condition of these trees also serves as an important indicator of historical habitat quality, as their sensitivity to environmental changes reflects the overall health of the urban ecosystem. Moreover, the spatial distribution and ecological characteristics of ancient and famous trees have emerged as a key research focus [5]. Using these trees as an entry point to investigate

the relationship between historical habitats and biodiversity is therefore essential for maintaining urban biodiversity while preserving cultural continuity. To date, 9540 ancient and famous trees have been documented in Chengdu, with nanmu, cypress, and ginkgo as the dominant species [3]. However, rapid urban development and increasing environmental pressures have posed serious threats to both the trees and their associated habitat communities. While the definition of “ancient trees” varies across regions [3,6–9], this study, based on Chengdu’s urban construction and development context [10,11], designates trees over 60 years old as ancient.

The concept of historical habitat proposed in this study (Figure 1) refers to the dynamic evolutionary processes and outcomes that emerge across temporal and spatial dimensions through the interaction of organisms and their dependent environments, shaped by cultural and social factors during historical development. Essentially, a historical habitat is a complex ecosystem characterized by both temporal continuity and spatial heterogeneity. It not only reflects the evolutionary patterns of the natural environment but also embodies the historical stability and adaptability of ecosystems. In terms of composition, historical habitats typically integrate ancient and famous trees, historical buildings, surrounding vegetation communities, and human activities. Through long-term interaction and co-evolution, these elements form a distinctive ecological–social–cultural complex with significant ecological functions, cultural value, and spatial identity.

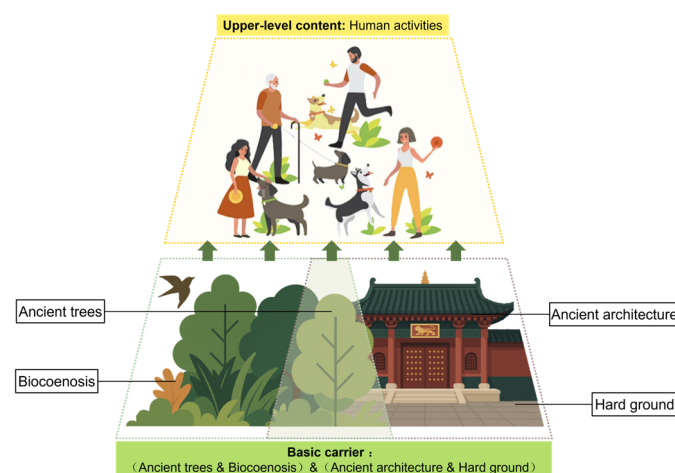


Figure 1. Conceptual map of historical habitats.

Urban habitat refers to the space in which organisms inhabit and reproduce within cities, and its quality directly influences the maintenance and enhancement of urban biodiversity. In China, scholars have acknowledged the positive and distinctive role of traditional culture in biodiversity conservation. However, existing research has primarily emphasized current status assessments and conservation strategies, including urban habitat quality evaluation [12], habitat creation [13], and habitat network optimization [14] while paying relatively little attention to urban habitat–ecosystem service relationships [15] and the planning of historical habitats. Consequently, progress in urban biodiversity conservation remains somewhat behind the international level [16]. Globally, it is widely recognized that historical land use patterns significantly shape urban biodiversity values [17]. Historical sites, as a special land use type, have been shown to provide important habitats for plant protection [18]. Comparative studies on plant communities from historical and contemporary perspectives further highlight the importance of historical factors in biodiversity conservation [19]. In addition, historical changes in urban forests have been employed to predict the impacts of urbanization on biodiversity [20]. Nevertheless, few studies have

systematically examined the long-term influence of historical habitats on urban biodiversity, leaving a critical gap in understanding their ecological, cultural, and planning significance.

By analyzing the spatial distribution of ancient and famous trees in conjunction with historical buildings, shifts in plant communities, and patterns of human activity, research can elucidate the evolutionary dynamics of urban historical habitats and provide a scientific basis for urban biodiversity conservation. Protecting and restoring ancient trees and their associated historical habitats not only enhances the city's ecological quality and cultural connotations but also contributes to creating a healthier, more attractive, and livable urban environment.

This study takes the spatial distribution and habitat assessment of ancient and famous trees within Chengdu's Second Ring Road as an entry point to examine the status of urban historical habitats, offering a new perspective and methodological approach for their quantitative analysis. From the standpoint of biodiversity conservation, proposing strategies to optimize historical habitat quality is crucial for safeguarding the authenticity of urban historical elements and preserving the distinctiveness of historical landscapes. The technical framework developed in this study also provides a transferable reference for historical habitat protection and management in other cities.

2. Materials and Methods

2.1. Study Sites

Chengdu [21], located in the western Sichuan Basin and on the eastern edge of the Qinghai–Tibet Plateau, lies between $102^{\circ}54'–104^{\circ}53'$ E and $30^{\circ}05'–31^{\circ}26'$ N, covering a total area of approximately 14,335 km² (Figure 2). The city has a subtropical monsoon climate, characterized by abundant heat, sufficient rainfall, distinct seasons, and the coincidence of rain and heat. The annual mean temperature ranges from 15.7 to 18.0 °C, with annual precipitation of 734.8–1142.3 mm. Horizontally, Chengdu belongs to the mid-subtropical humid zone of China [4]. However, due to significant altitudinal variation, vertical zonation is pronounced, resulting in a high diversity of biological resources [3]. Despite rapid urban expansion, Chengdu has retained a large number of ancient and famous trees as well as historical habitats.

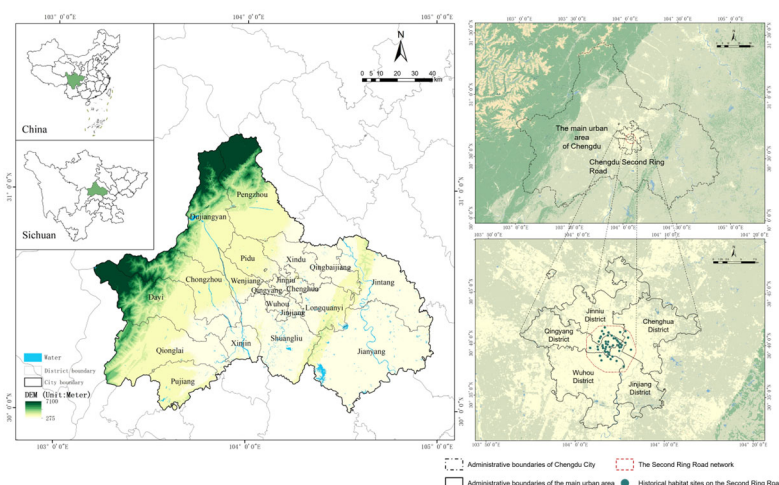


Figure 2. The geographical location of the historical habitat within the Second Ring Road of Chengdu City.

The spatial pattern of Chengdu has evolved progressively from enclosure to limited expansion, shaped by political, military, and geographical factors. During the Qin dynasty, the dual-city structure of Outer City and Inner City established a northeast–southwest axis consistent with the underlying geological structure of the plain. In the Tang dynasty,

the expansion of the Luocheng (Outer Enclosure Wall) formed a “two-river embracing” system, promoting commercial development in the eastern suburbs. The Ming dynasty reconstructed the city on the foundation of Tang–Song walls [22], and the Qing dynasty largely maintained this pattern until the demolition of the Manchu City in 1913, which altered the urban structure. In modern times, road construction initiated a locally driven planning model, combining passive demand with proactive development [23]. The first comprehensive plan in 1954 emphasized development around the old city, and the completion of the First Ring Road in 1962 reinforced this core. The 1982 plan introduced the “east industry–west residence” layout, followed by the completion of the Second Ring Road in 1993. In 1994, Chengdu shifted to a “central city & six development axes” model, and by 2011, a spatial structure of “old city within the Third Ring Road & new districts outside” had emerged, marking the city’s transformation into a modern metropolis (Figure 3).

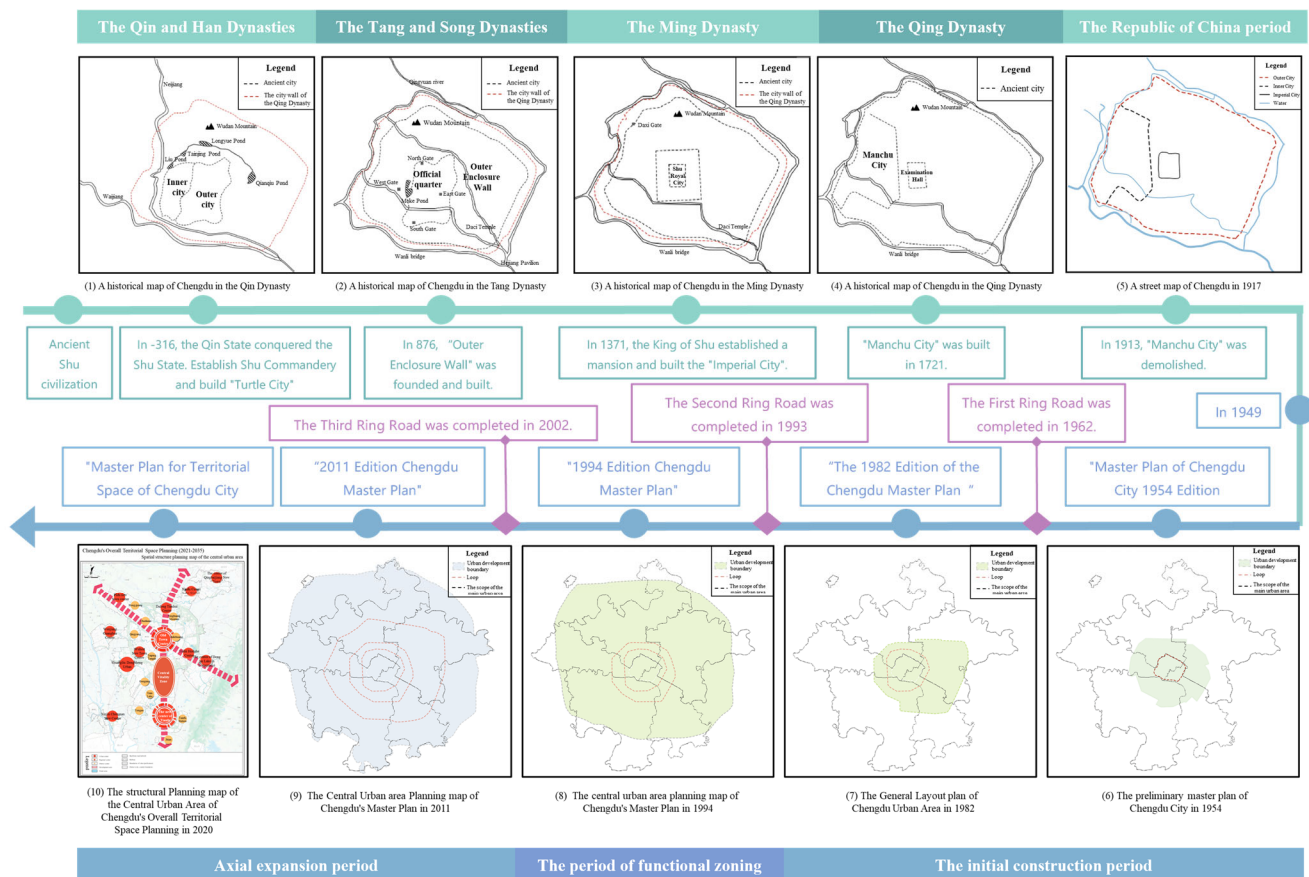


Figure 3. Map of Historical Changes in Chengdu.

Based on historical satellite imagery, the characteristics, scale, and extent of historical habitats were examined by comparing habitat changes across 51 sites (Figure 2). From this analysis, 12 representative historical habitats within the Second Ring Road were identified as core study areas. These include Huanhuaxi Park (Du Fu Thatched Cottage; hereafter “Huanhuaxi Park”), People’s Park, Wangjiang Tower Park, Wenshu Monastery (Wenshu-fang; hereafter “Wenshu Monastery”), Majia Garden Community, Chengdu Third People’s Hospital, Peace Bridge Catholic Church, Office Area No. 16 of Qingyang Commercial Street (hereafter “Commercial Street Office Area”), Xinhua Park, Jiagao Workshop 1913, Drum Tower Mosque, and Baima Temple District. Together, they encompass six types of historical habitats—parks, communities, religious sites, administrative spaces, medical facilities, and cultural areas (Table 1).

Table 1. Important Historical habitats.

Number	Distribution Density of Ancient Trees	Name	Type	Region	Area(m ²)
1	high	Huanhuaxi Park(Du Fu Thatched Cottage)	Park	Qingyang District	458,653.34
2	high	People’s Park	Park	Qingyang District	139,512.53
3	high	Wangjiang Tower Park	Park	Wuhou District	152,055.00
4	medium	Wenshu Monastery (Wenshufang)	Religious	Qingyang District	81,728.62
5	medium	Majia Garden Community	Community	Jinniu District	49,013.7
6	medium	Chengdu Third People’s Hospital	Medical	Qingyang District	64,745.52
7	low	Peace Bridge Catholic Church	Religious	Qingyang District	15,819.09
8	low	Office Area No. 16 of Qingyang Commercial Street	Administrative	Qingyang District	40,560.46
9	low	Xinhua Park	Park	Chenghua District	95,312.36
10	no	Jiagao Workshop 1913	Cultural	Jinniu District	8808.49
11	no	Drum Tower Mosque	Religious	Qingyang District	1998.40
12	no	Baima Temple District	Cultural	Jinniu District	9077.81

2.2. Data Sources

Land use/land cover (LUCC) data since 1980 were obtained from the Resource and Environment Science and Data Center, Chinese Academy of Sciences (<https://www.resdc.cn/>). The dataset was derived primarily from Landsat TM/ETM imagery, supplemented by HJ-1 satellite data, and extracted using a human–computer interactive remote-sensing interpretation method. In addition, satellite imagery for the 1960s, 1970s, 1980s, 2014, and 2024 was acquired from the U.S. Geological Survey Earth Explorer platform (<https://earthexplorer.usgs.gov/>) to reflect Chengdu’s urban development across different periods and to support comparative analyses. Information on the distribution of ancient and famous trees, along with related attributes, was collected from the official Chengdu Ancient and Famous Trees public platform.

The study area was defined as the region within Chengdu’s Second Ring Road. Key urban development milestones were identified through a review of historical documents. All raw images were georeferenced to the GCS_WGS_1984 coordinate system to generate spatially referenced raster datasets. Green space information was then extracted to construct the LUCC dataset. Historical habitat dynamics were analyzed by comparing imagery across 92 sites, from which 51 sites meeting the definition and possessing research value were finally selected as core study objects (Figure 2).

2.3. Research Methodology

2.3.1. Plant Diversity Survey

To investigate plant diversity, a 200 × 200 m grid was generated within Chengdu’s Second Ring Road using the “Create Fishnet” tool in ArcGIS 10.5 (Figure 4). Based on the distribution density of ancient and famous trees, historical habitats that met the screening criteria were identified. After delineating the boundary and area of each habitat, sampling plots were established by combining grid sampling with typical sampling methods. Candidate sampling points were randomly generated in ArcGIS10.5, and those falling on buildings, roads, or water bodies were excluded and adjusted according to site conditions.

The number of plots allocated to each habitat was determined using the natural breaks method, according to habitat area: 1–2 plots for habitats ≤15 ha, 3–4 plots for 15–30 ha, and 5–8 plots for >30 ha. Within each sampling plot, the number of quadrats was further determined by plot size: two quadrats for $S \leq 200 \text{ m}^2$, three quadrats for 200–400 m², and four quadrats for $S > 400 \text{ m}^2$. Considering the large variation in habitat types and areas,

and the fact that most spontaneous species were herbaceous, a standardized quadrat size of 1×1 m was adopted following previous studies [2,24]. In total, 68 quadrats were surveyed in October–November 2024.

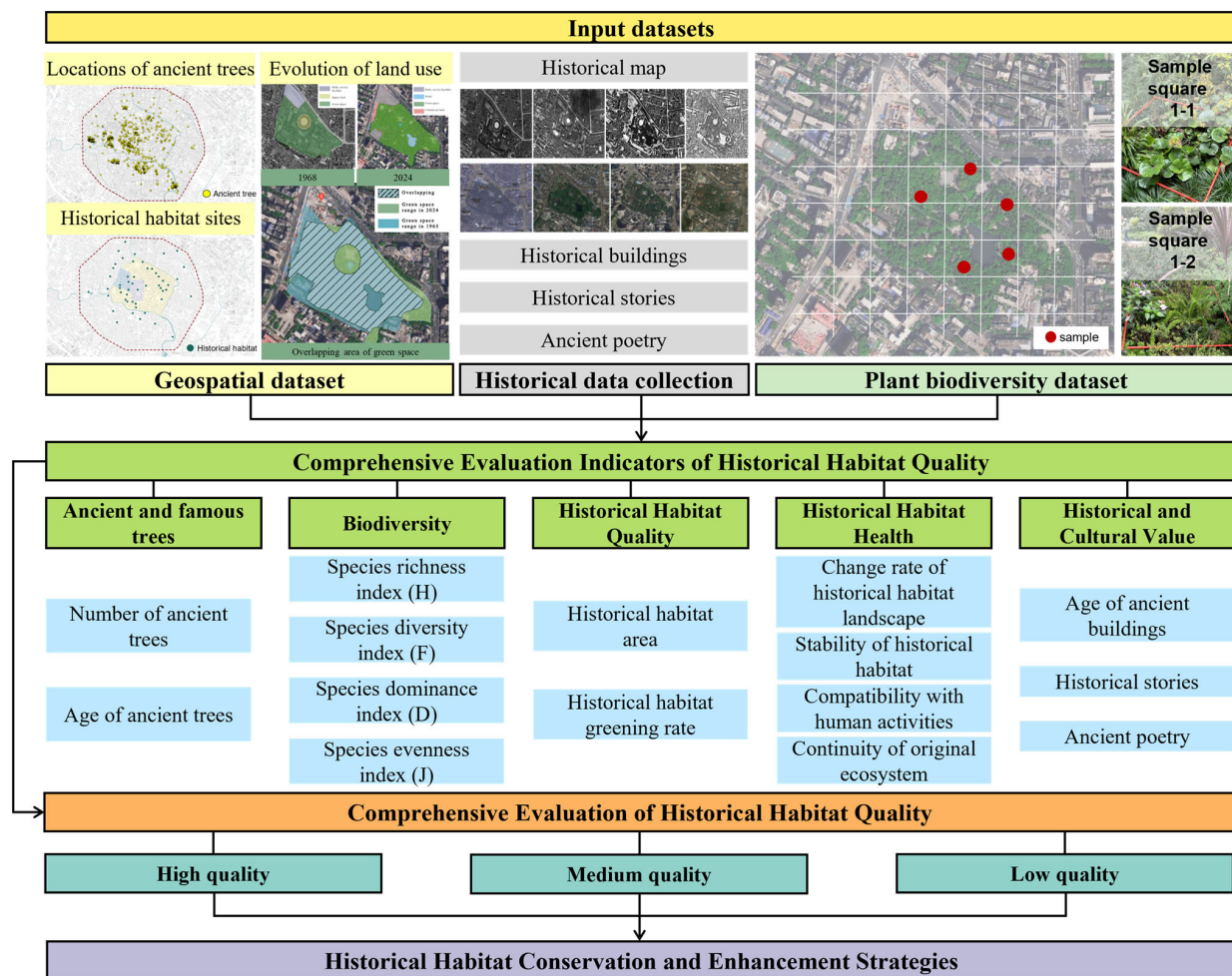


Figure 4. Research method design.

Survey indicators included:

- (1) Basic species information: species name, average height, coverage, and growth condition. Species identification followed Flora of China [25] and Flora of Sichuan [26].
- (2) Species composition: plants were classified as “cultivated” or “spontaneous.” Large woody species with evidence of artificial planting or pruning, and regularly distributed herbs were regarded as cultivated, whereas scattered, irregular herbs and occasional tree or shrub seedlings were classified as spontaneous [2].

2.3.2. Image Segmentation Method

Image segmentation is a fundamental technique in computer vision, aiming to partition an image into semantically meaningful regions or objects, thereby enabling a deeper understanding of its content and structure. It underpins a wide range of visual tasks such as object detection, image editing, and autonomous driving. With the rapid advancement of deep learning, segmentation methods have evolved significantly, among which Transformer-based models have demonstrated remarkable performance [27].

In this study, a unified Transformer-based segmentation framework, OneFormer, was employed to conduct semantic segmentation on satellite images of Chengdu from 1968 and 2024. OneFormer integrates instance-aware feature extraction with multi-scale context mod-

eling, enabling efficient semantic parsing of complex imagery. However, the 1965 imagery consisted of single-channel grayscale data, lacking critical color information, which limited segmentation accuracy. To address this challenge, the preliminary segmentation results from OneFormer were manually refined using Adobe Photoshop. Manual corrections included edge refinement, region merging, and adjustment of ambiguous boundaries. These post-processing steps improved the accuracy of historical imagery segmentation and ensured comparability and reliability of temporal analyses across different time periods.

2.3.3. Indicator Construction Method

This study focused on the area within Chengdu's Second Ring Road. At the macro scale, the spatial density of registered ancient and famous trees was first analyzed. Based on their spatial clustering characteristics, 92 urban historical habitat units with significant ecological value were identified. By integrating multi-temporal satellite remote sensing images from 1968, 1978, 1982, 2014, and 2024 with Geographic Information System (GIS) techniques, the spatiotemporal evolution of these historical habitat units was quantitatively analyzed. On this basis, a set of criteria for determining historical habitats was established.

The criteria for historical habitats were defined as follows:

- (1) the presence of at least one registered ancient tree older than 100 years, or more than five trees older than 60 years;
- (2) a minimum green space area of 150 m² within the habitat boundary;
- (3) the presence of historical or old buildings older than 40 years.

All three conditions must be met simultaneously.

Based on these criteria, 51 historically continuous habitat units were further identified. According to the density of ancient trees, these units were classified into four levels: high, medium, low, and none. Using stratified sampling, the most representative three units from each density level were selected, yielding a total of 12 preliminary study sites.

Through field investigation, data collection, and spatial analysis, a comprehensive evaluation index system for historical habitats was constructed (Table 2). The system encompasses three dimensions: (i) ecological, including indicators such as ancient and famous trees and species diversity; (ii) eco-historical, including indicators of habitat quality and habitat health; and (iii) historical-cultural, including indicators of cultural value. This framework provides methodological support and practical guidance for subsequent research. To ensure the scientific validity and objectivity of indicator weights, the study applied a combination of the expert scoring method and the AHP–entropy weight approach [28,29] to calculate the comprehensive weights of influencing factors. The judgment matrix was established through pairwise comparisons, after which a consistency test was performed to assess the logical coherence of the comparisons. The average random consistency index was subsequently derived to confirm the overall consistency of the matrix.

Table 2. Indicators and Weights for Comprehensive Quality Assessment of Historical Habitats.

Evaluation Aspect	Impact Factor	Evaluation Significance	Weight
Ancient and famous trees	Number of ancient trees	A greater number of ancient and famous trees indicates better preservation of the original environment and higher stability of historical habitats.	0.4406
	Age of ancient trees	A higher average age of ancient trees reflects better maintenance of the native environment and improved conservation of historical habitats.	0.1784

Table 2. Cont.

Evaluation Aspect	Impact Factor	Evaluation Significance	Weight
Biodiversity	Species richness index (F)	A higher species diversity index (F value) suggests a greater number and variety of species within the ecological community, leading to a more complex ecosystem and better environmental suitability.	0.0535
	Species diversity index (H)	A higher species richness index (H value) indicates greater community diversity, which contributes to ecosystem stability and enhances its resilience to disturbances.	0.0984
	Species dominance index (D)	A larger dominance index (D value) implies a more uneven distribution of species abundance, where dominant species play a more prominent role. Such dominance may exert either positive or negative influences on the ecosystem.	0.0191
	Species evenness index (J)	A species evenness index (J value) closer to 1 suggests higher evenness among species, with more consistent ecological importance, thereby reflecting better environmental suitability.	0.0119
Historical Habitat Quality	Historical habitat area	Larger habitat area is usually associated with greater internal structural stability and higher overall habitat quality.	0.1123
	Historical habitat greening rate	A higher greening rate indicates better historical habitat quality.	0.0391
Historical Habitat Health	Change rate of historical habitat landscape	A higher ratio of historical habitat green space to the overall green space within the region implies healthier historical habitats.	0.0138
	Stability of historical habitat	A greater overlap between historical habitat green space and current habitat areas indicates a healthier historical habitat.	0.0146
	Compatibility with human activities	Higher compatibility of human activities within historical habitats reflects a healthier ecological condition.	0.0037
	Continuity of original ecosystem	Continuity of original ecological activities serves as an indicator of the health level of historical habitats.	0.0018
Historical and Cultural Value	Age of ancient buildings	The longer the preservation of historical buildings, the higher their historical and cultural value.	0.0077
	Historical stories	A greater number of historical stories enhances the historical and cultural value of the habitat.	0.0034
	Ancient poetry	A larger number of ancient poems associated with the site signifies higher historical and cultural value.	0.0017

2.3.4. Evaluation System and Indicator Calculation

(1) Species Diversity

Species diversity was quantified using four commonly applied ecological indices. Species richness (F) was measured by the Margalef index [30]; species diversity (H) was characterized by the Shannon index [31]; species dominance (D) was calculated using the Simpson index [32]; and species evenness (J) was evaluated using the Pielou index [33]. The equations are as follows:

$$F = (S - 1) / \ln N \quad (1)$$

$$H = - \sum_{i=1}^S P_i \ln P_i \quad (2)$$

$$D = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2 \quad (3)$$

$$J = H / \ln S \quad (4)$$

where S is the number of species recorded in the quadrat, n_i is the coverage of species i , P_i is the relative coverage of species i ($P_i = n_i/N$), and N is the total coverage of all species in the quadrat.

(2) Historical Habitat Health

The health of historical habitats was assessed from multiple dimensions. The rate of change in green coverage was calculated based on variations in greening rates between 1965 and 2024. Habitat stability was represented by the percentage of overlapping green areas during the same period. Compatibility with human activities was evaluated across five categories—sports and health, science popularization and education, daily life, recreation, and landscape—each weighted equally at 20%. The continuity of natural activities was derived from the dynamic degree of green land use and the comprehensive land use dynamic degree [34–36], calculated as follows:

$$G = \frac{U_{t1} - U_{t2}}{U_{t1}} \times \frac{1}{T} \times 100 \quad (5)$$

where U_{t1} and U_{t2} denote the green land area at the beginning and end of the study period, respectively; T is the length of the study period; G represents the dynamic degree of green land.

$$L = \frac{\sum_{i=1}^n |U_i - U_j|}{\sum_{i=1}^n U_i} \times \frac{1}{T} \times 100 \quad (6)$$

where L represents the comprehensive land use dynamic degree; U_i and U_j denote the green land areas at the beginning and end of each land use type; and n is the number of land use types.

$$O = \frac{1}{4 \times L + G \times 6} \quad (7)$$

where O indicates the continuity index of natural activities.

(3) Comprehensive Quality of Historical Habitats

The comprehensive quality of historical habitats was determined by integrating the above indicators through expert evaluation. Eight experts in urban–rural ecology scored the relative importance of each indicator pair. The weight vector was then calculated, followed by a consistency test to ensure reliability. The final weights were used to calculate the Historical Habitat Index (HHI), expressed as:

$$HHI = \sum_{i=1}^n W_i \times C_i \quad (8)$$

where W_i denotes the combined weight of indicator i and C_i represents the corresponding indicator value. Based on the HHI range, quality levels of historical habitats were classified into different grades.

3. Results

3.1. Characteristics of Ancient and Famous Trees Within Chengdu's Second Ring Road

According to the information provided by the Government affairs Disclosure of the People's Government of Sichuan Province, a total of 1485 ancient and famous trees were recorded within Chengdu's Second Ring Road, belonging to 23 families, 34 genera,

and 39 species (Figure 5). The most species-rich families were Fabaceae (6 species) and Lauraceae (4 species). In terms of abundance, the dominant families were Fabaceae (225 individuals), Lauraceae (186 individuals), and Ginkgoaceae (843 individuals), together accounting for 84.44% of all ancient and famous trees. Native species such as *Ginkgo biloba*, *Cinnamomum camphora*, *Phoebe zhennan*, *Gleditsia sinensis*, *Ficus virens*, and *Ormosia hosiei* were particularly well represented. Among them, *Ginkgo biloba* was overwhelmingly dominant, with 843 individuals (56.77%), followed by *C. camphora* (185, 12.46%), *P. zhennan* (35, 2.36%), *G. sinensis* (103, 6.90%), *F. virens* (56, 3.77%), and *O. hosiei* (97, 6.53%). In addition, rare and endangered species such as *Ginkgo biloba*, *C. camphora*, *P. zhennan*, *Cycas revoluta*, *Metasequoia glyptostroboides*, and *Camptotheca acuminata* were identified, totaling 1082 individuals (72.86%). These species not only provide essential ecological services such as soil conservation and air purification but also enrich the city's cultural heritage while offering valuable educational and research resources.

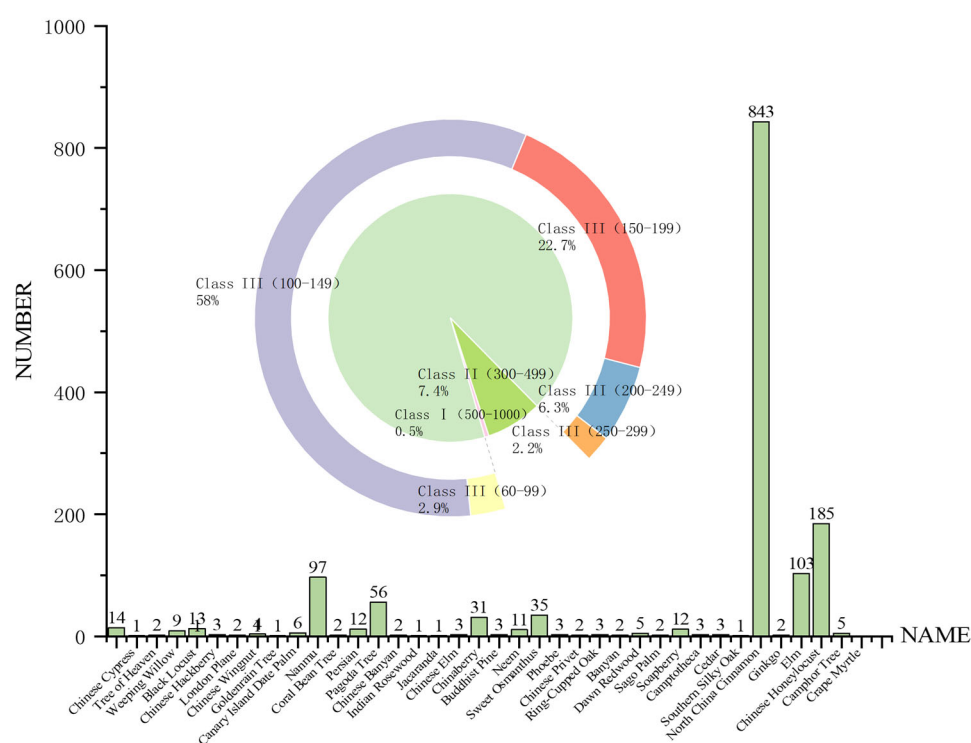


Figure 5. The types and grades of ancient and famous trees within the Second Ring Road of Chengdu.

The overall conservation status of ancient and famous trees within the study area is relatively sound. Trees under Class III protection constituted the majority (1324 individuals, 92.1%), while Class II and Class I accounted for 7.4% and 0.5%, respectively. By age, eight individuals exceeded 500 years, primarily *Ginkgo biloba*; 110 individuals ranged between 300–499 years, including *Ginkgo biloba*, *C. camphora*, *O. hosiei*, and *F. virens*; and 1324 individuals were between 100–299 years old, forming the largest cohort. Additionally, 43 trees were aged 60–99 years. Although not officially classified under Chengdu's protection system, they were also managed under Class III protection measures.

3.2. Spatial Distribution of Ancient and Famous Trees Within the Second Ring Road of Chengdu

Based on the latest survey data, combined with official statistics from the Chengdu Landscaping Engineering Team and field investigations, the spatial distribution of ancient and famous trees within Chengdu's Second Ring Road was mapped (Figure 6a), with detailed records of species, age, and geographic coordinates.

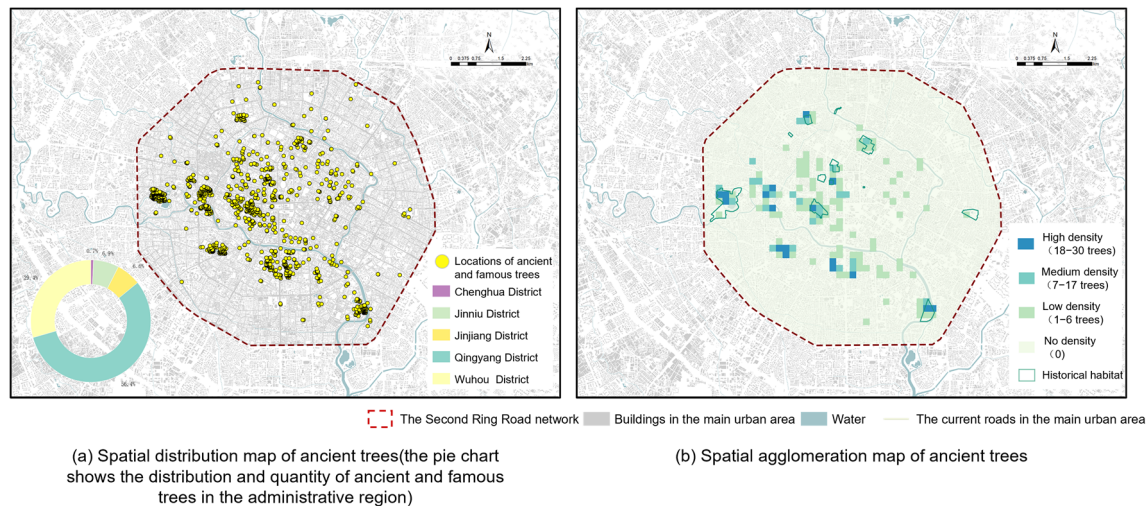


Figure 6. Spatial distribution and agglomeration map of ancient and famous trees.

According to the Chengdu Ancient and Famous Trees platform, a total of 1496 registered trees are distributed within the area, showing marked spatial heterogeneity. Qingyang District contains the largest share with 831 trees (56.43%), mainly concentrated in Huanhuaxi Park, Baihuatan Park, Cultural Park, and People's Park. Wuhou District ranks second with 456 trees (30.48%), distributed around Wuhou Shrine Museum and Wangjiang Tower Park. Jinniu, Jinjiang, and Chonghua Districts host 103 (6.89%), 95 (6.35%), and 11 trees (0.74%), respectively. In Jinniu, trees are mainly found in residential courtyards such as Majia Garden Community, while in Jinjiang they are clustered around the Sichuan Academy of Forestry and Tazishan Park. Chonghua has the fewest trees, concentrated in the Zoo and Zhaojue Temple.

Kernel density analysis (Figure 6b) shows that high-density areas are concentrated in the western part of Qingyang District, followed by Wuhou and Jinniu, whereas Chonghua and Jinjiang present relatively sparse distributions.

The distribution pattern of ancient and famous trees within Chengdu's Second Ring Road is closely related to historical context, green space layout, and land use characteristics. Qingyang and Wuhou, as cultural heritage-rich districts, exhibit significantly higher densities, while Jinniu and Jinjiang reflect the ecological value of residential and public spaces. Overall, these results highlight the ecological and cultural significance of ancient trees as vital components of Chengdu's urban landscape.

3.3. Screening of Key Historical Habitat Units

Based on the types, locations, number of ancient trees, historical-cultural attributes, and greening coverage, twelve representative historical habitats were selected from 51 identified units, distributed across high-, medium-, low-, and non-density zones.

In the high-density category, three of Chengdu's most renowned historical gardens—Huanhuaxi Park, People's Park, and Wangjiang Tower Park—were selected as research sites. Huanhuaxi Park, located in Qingyang District and adjacent to the Du Fu Thatched Cottage to the north, is the only five-star urban park in Chengdu [37]. As Du Fu once resided in Huanhuaxi Temple and constructed his thatched cottage nearby [38], the two sites are analyzed jointly in this study. The park's planning began in 1985, and by 2005, poetic cultural elements were integrated into its design, creating a unique style that harmonizes natural and urban landscapes as well as classical gardens and modern architecture. The park's ancient and famous trees are dominated by ginkgo, nanmu, camphor, and coral bean. People's Park, established in 1911 and originally named Shaocheng Park, was the

first park in Chengdu's history and remains the largest open historical urban park in the city center [39], bearing witness to more than a century of transformations in public space. Wangjiang Tower Park was constructed to commemorate the Tang dynasty poetess Xue Tao and her affinity for bamboo [40]. Today, it is the largest bamboo-themed park in China, hosting the greatest diversity of bamboo species. Its earliest surviving historic structure is Wangjiang Tower, formerly known as Xue Tao Well [41].

The medium-density category includes Wenshu Monastery, Majia Garden Community, and Chengdu Third People's Hospital. Wenshu Monastery is one of the four major historical and cultural districts in Chengdu. Centered around the millennium-old monastery [1], the district has restored traditional western Sichuan dwellings and revived the historical neighborhood pattern of "nine streets and ten temples." Majia Garden Community derives its name from the villa of a Sichuan warlord built during the Anti-Japanese War period and was incorporated into the urban area in 1952. Chengdu Third People's Hospital originated as Chengdu Public Hospital, established in 1941, and has undergone several expansions and renamings.

The low-density category includes Peace Bridge Catholic Church, Commercial Street Office Area, and Xinhua Park. Peace Bridge Catholic Church was established in 1896 and originally comprised a cathedral and bishop's residence. The Commercial Street Office Area lacks formal historical records or local chronicles, but based on its establishment, it is presumed to have been built around 1952. Xinhua Park, formerly an industrial site, has since been transformed into a public comprehensive park characterized by modern landscape design.

The no-density category includes Jiagao Workshop 1913, Drum Tower Mosque, and Baima Temple District. Jiagao Workshop 1913 was founded as Sichuan's first vocational school following the Xinhai Revolution and has been redeveloped into a cultural and creative industrial park. Drum Tower Mosque, established in 1375, is one of the oldest mosques in Sichuan. Baima Temple District, believed to have been modeled after the Baima Temple in Luoyang [42], now retains only the temple name. During the 1920s, it gained scholarly importance with the excavation of bronze artifacts and the emergence of the "Bashu Culture" concept but gradually declined with urban development.

3.4. Evaluation of Historical Habitats

3.4.1. Quality Evaluation of Ancient and Famous Trees

As shown in Figure 7a, Huanhuaxi Park and Wangjiang Tower Park, as core green spaces in Chengdu, exhibit relatively well-established protection systems for ancient and famous trees, with their habitat integrity effectively maintained. Among them, Wangjiang Tower Park is particularly notable for its stock of ancient trees, ranking first among all study areas, with an average tree age of approximately 110 years. People's Park is categorized as a medium-quality area, with the number of ancient and famous trees second only to Huanhuaxi Park and Wangjiang Tower Park, and an even higher average tree age of around 150 years. The remaining nine historical habitats are classified as low-quality areas.

From the perspective of habitat types, parks represent the primary spaces for the conservation of ancient and famous trees, though significant variations exist in preservation status. For instance, Xinhua Park contains only five ancient trees, yet their average age reaches 262 years. Cultural historical habitats (such as Jiagao Workshop 1913 and Baima Temple District), although limited in quantity, are characterized by high-aged dominant species such as ginkgo. Historical map analysis further reveals that these habitats demonstrate relatively strong ecological continuity. By contrast, religious historical habitats are generally categorized as low-quality areas: the average tree age in Wenshu Monastery and Peace Bridge Catholic Church is about 140 years, whereas in Drum Tower Mosque it is only

78 years, reflecting notable differences in the degree of attention paid to tree conservation across religious sites.

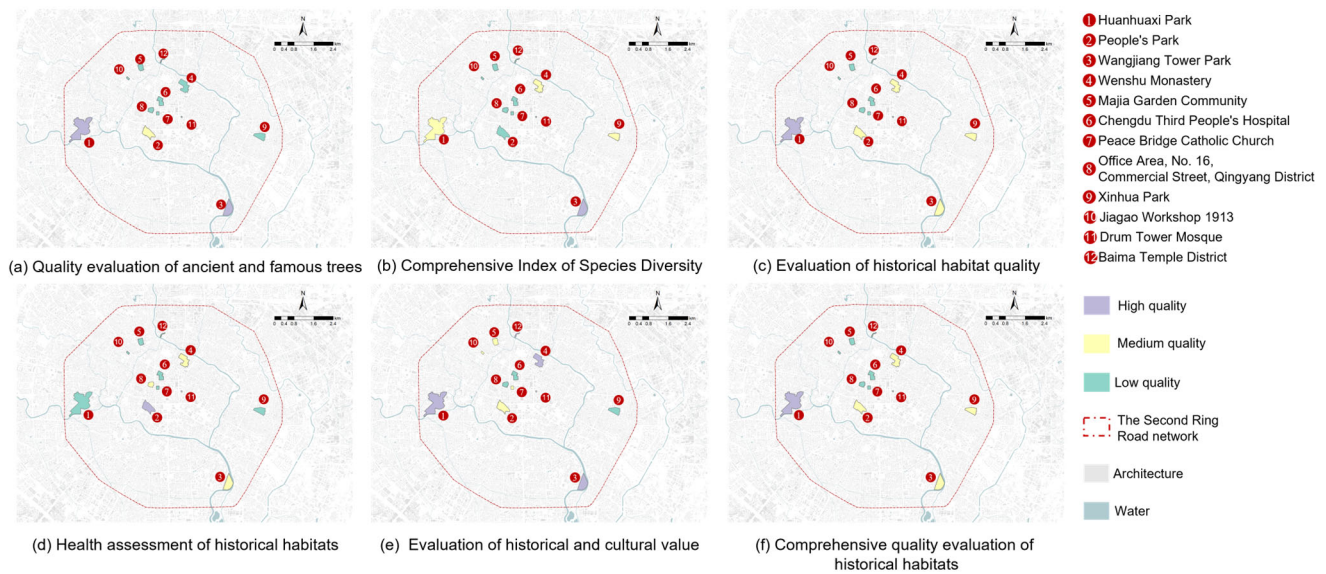


Figure 7. Distribution map of historical habitat evaluation.

3.4.2. Evaluation of Species Diversity

As shown in Figure 7b, species diversity across the study areas exhibits pronounced spatial heterogeneity. Wangjiang Tower Park demonstrates the highest overall species diversity, while Huanhuaxi Park, Wenshu Monastery, and Xinhua Park fall within the medium range. The remaining eight historical habitats are characterized by relatively low levels of species diversity.

More specifically, species diversity varies considerably among parks. Wangjiang Tower Park records the highest values for both the species diversity index and dominance index but the lowest species richness index, suggesting that although the number of community types is limited, the ecosystem exhibits strong disturbance resistance. The uneven species distribution highlights the dominance of bamboo and ginkgo. In contrast, Huanhuaxi Park—combined with Du Fu Thatched Cottage for analysis—benefits from a complementary species pool, enhancing overall species diversity. It shows the highest species richness and dominance indices, indicating not only greater numbers but also a wider range of species, reflecting good environmental adaptability. People's Park, however, ranks lower in overall species diversity, likely due to frequent replacement of seasonal ornamental plants under greening policies and commercial operations. This practice undermines community stability and contributes to habitat fragmentation. Its tree layer is dominated by resilient privet and camphor, while the shrub layer contains scattered plantings of azaleas. The prevalence of artificially introduced species results in an inflated species diversity index, which obscures the true diversity of natural communities.

Cultural historical habitats, by contrast, consistently exhibit low diversity indices. Jiagao Workshop 1913, in particular, records the lowest diversity and evenness indices, underscoring the poor conservation of species diversity. Repeated reconstruction and long-term human disturbance have degraded the original vegetation systems, leading to severe habitat fragmentation and a further decline in diversity. In other historical habitats, such as the Commercial Street Office Area, the highest species evenness index coincides with a relatively high dominance index. This pattern may reflect limited total species numbers, where artificial management creates a “pseudo-evenness” in individual distribution, while ginkgo remains the overwhelmingly dominant species among ancient trees.

3.4.3. Quality Assessment of Historical Habitats

As shown in Figure 7c, Huanhuaxi Park demonstrates the highest historical habitat quality, followed by Wangjiang Tower Park, People's Park, Xinhua Park, and Wenshu Monastery, all of which are classified as medium quality. The remaining seven historical habitats fall into the low-quality category.

The results reveal a clear relationship between habitat area and quality level. Huanhuaxi Park, the largest historical habitat, exhibits greater internal ecosystem stability compared with the smallest, Drum Tower Mosque. Larger habitats are more capable of sustaining ecological processes and mitigating edge effects. Among the study sites, Drum Tower Mosque records the lowest greening rate due to its extensive hard paving, whereas Wangjiang Tower Park maintains the highest level of green coverage.

From the perspective of spatial density, the high-density areas—represented by Wangjiang Tower Park, People's Park, and Huanhuaxi Park—generally maintain higher greening rates, while the no-density areas are consistently characterized by lower greening levels. This pattern may be attributed to the functional advantages of parks: as designated green spaces, they are more likely to allocate land for planting and preserving vegetation, thus maintaining higher coverage. In contrast, no-density areas, such as community or religious facilities, are constrained by limited space, resulting in more fragmented greening layouts.

Furthermore, medium-quality habitats are more frequently found in high- and medium-density areas, indicating a positive correlation between the density of ancient and famous trees and greening rates. This finding underscores the crucial role of ancient tree resources in enhancing the overall quality of historical habitats.

3.4.4. Health Assessment of Historical Habitats

As shown in Figure 7d, People's Park and Drum Tower Mosque exhibit the highest levels of historical habitat health. Three sites—Commercial Street Office Area, Wenshu Monastery, and Wangjiang Tower Park—fall into the moderately healthy category, while the remaining seven sites are classified as relatively unhealthy.

Between 1965 and 2024, People's Park demonstrated the strongest continuity of original ecological activities, while Drum Tower Mosque showed the highest degree of overlap between historical green space and current habitat, resulting in greater habitat stability. Both sites successfully integrated diverse human activities, including fitness, science education, leisure, daily life, and landscape appreciation, indicating effective protection and continuation of their ecological and social functions, with vegetation cover maintaining a dynamic equilibrium.

In contrast, Chengdu Third People's Hospital, Jiagao Workshop 1913, and Wenshu Monastery all experienced negative rates of green cover change, reflecting a decline in green space and revealing that their habitats were not adequately protected during construction, with even original ecosystems being disrupted. Huanhuaxi Park recorded the highest rate of green cover change, suggesting the greatest degree of habitat alteration, consistent with its complex historical transformations. Xinhua Park, rebuilt from an industrial site into a public park under policy directives, exhibited the lowest stability and continuity of original ecological activities.

3.4.5. Evaluation of Historical and Cultural Value

As shown in Figure 7e, Huanhuaxi Park, Wangjiang Tower Park, Wenshu Monastery, Baima Temple District, and Drum Tower Mosque demonstrate high historical and cultural value due to their profound heritage and well-preserved cultural continuity. At Wangjiang Tower Park, most of the historic buildings date back to the Ming and Qing

dynasties, providing significant historical and artistic value [40]. Within Huanhuaxi Park, the Du Fu Thatched Cottage, designated as a national key cultural relic protection unit [43], retains architectural features characteristic of Ming and Qing dynasty restorations [44], representing important value for architectural history. The Baima Temple District contains some of the earliest historic structures in the study area, while Wenshu Monastery and Drum Tower Mosque embody rich cultural connotations through historical narratives and literary inscriptions. Collectively, these high-value historical habitats are characterized by heritage designation status, associations with significant historical events, and preservation of traditional spatial patterns.

By contrast, sites such as Majia Garden Community and People's Park are categorized as having moderate cultural value, given their relatively recent historical origins or weaker cultural memory. Meanwhile, the Commercial Street Office Area and other similar sites are assessed as having low value due to the absence of distinct historical or cultural attributes.

3.5. Comprehensive Quality Evaluation of Historical Habitats

Based on the multidimensional comprehensive evaluation system, the historical habitats within the study area exhibit a clear gradient in quality (Figures 7f and 8). Huanhuaxi Park stands out as the sole high-quality habitat, with a high number of ancient and famous trees of considerable age, including those listed under level-three or higher protection. Its vegetation exhibits a vertically stratified structure with well-developed tree, shrub, and herb layers, while green space has increased significantly over the past 60 years, and human disturbance remains minimal.

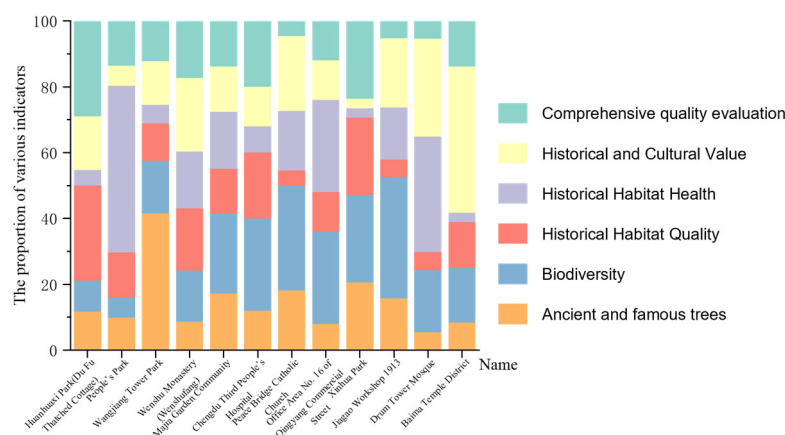


Figure 8. Historical habitat evaluation map.

Medium-quality habitats have an average tree age of 165.5 years and display variations in vegetation management. Park-type habitats primarily feature ornamental shrub pruning with relatively low proportions of multilayered vegetation, whereas religious habitats such as Wenshu Monastery face more ecological limitations due to high building density and extensive hardscape coverage.

Low-quality habitats have an average tree age of 114 years and commonly suffer from inadequate management practices. In community-type habitats, green space is largely guided by property management rather than ecological considerations; in religious habitats, traditional pruning practices may reduce ecological functionality; and in cultural habitats, repeated modifications coupled with limited ecological maintenance have disrupted ecological continuity.

4. Discussion

4.1. Research Findings

The study's findings can be summarized in three main aspects:

Variation in ancient and famous tree resources across historical habitat types: Significant differences exist in the number, protection level, and management systems of ancient and famous trees among different types of historical habitats. Natural green spaces represented by parks exhibit higher resource density and stronger ecological continuity, whereas cultural, religious, and community-type historical habitats generally experience spatial compression and individual isolation. Park-type historical habitats consistently outperform other types in species richness, diversity, and evenness indices, highlighting the influence of historical land use and spatial organization on ecosystem structure. In highly urbanized historical habitats, such as Wenshufang, species homogenization and ecological function degradation are evident. Habitat area also plays a substantial role in evaluating habitat quality; for instance, the area of Huanhuaxi Park is nearly 52 times that of Jiagao Workshop, suggesting that, according to island biogeography theory, the relationship between historical habitat area and quality may not be strictly linear and warrants further investigation.

Correlation between habitat quality and habitat type: Park-type historical habitats generally fall into medium-to-high quality categories, whereas most cultural, religious, and community habitats are of low quality, with the exception of Wenshu Monastery among religious habitats. Therefore, in assessing historical habitats, it is necessary not only to consider the relative weighting of ancient and famous tree and species diversity indicators but also to critically evaluate the rigor of defining habitat density solely based on tree distribution. Additionally, the ecological–social–cultural impacts—both positive and negative—emanating from protected historical areas must be considered.

The ecological carrying capacity of historical habitats is largely constrained by their spatial scale, proportion of green space, and internal structural diversity. Huanhuaxi Park, with its large-scale, continuous green areas and complex landscape structure, exhibits significantly higher habitat integrity than other historical sites. Wangjiang Tower Park, owing to its Tang-era Xue Tao Well cultural heritage and the Ming–Qing bamboo groves and historic building clusters, demonstrates a unique eco-cultural composite value. Consequently, habitats with high historical and cultural value often combine traditional spatial patterns, continuity of cultural narratives, and ecological representation, reflecting a dual historical depth encompassing both ecological and cultural dimensions.

Based on remote sensing and literature data from 1965 to 2024, an apparent opposite trend was observed between the health status of historical habitats and the intensity of urban development and human activities, whereas a positive trend existed with landscape management and the maintenance of historic buildings. Regions exhibiting higher health levels typically possess a well-defined historical function, long-term ecological continuity, and strong spatial autonomy. People's Park, as a representative traditional garden, has largely preserved the continuity of its original ecological activity spaces, sustaining and promoting the local "teahouse culture." Similarly, the Drum Tower Mosque exhibited a green area change rate of 0, with the highest overlap of green space and compatibility with human activities, indicating that land use patterns have remained largely unchanged, the green infrastructure has been effectively maintained, and the cultural resilience of religious historical habitats has been upheld.

Moreover, the less healthy historical habitats are often subject to land use changes, severe compression of ecological space, and spatial alterations driven by urban development and tourism. For instance, Baima Temple District was transformed from a religious site into a commercial cultural area without protection or restoration of the original temple;

Chengdu Third People's Hospital was converted from residential land to public service use, resulting in a substantial reduction in green space; although Wenshu Monastery preserved its original street and alley structure, excessive commercialization and the expansion of hardscape surfaces have severely compromised its species diversity.

4.2. Research Limitations

There are several limitations in the historical habitat quality evaluation framework used in this study. First, calculations of the number and average age of ancient and notable trees may contain biases, as a systematic registration and monitoring mechanism is currently lacking. Second, some areas with high species diversity may include introduced ornamental plants rather than naturally occurring native communities, potentially skewing ecological assessments. In future research, the intrinsic characteristics of the plants should also be incorporated, including whether they are native species, the phytosanitary condition of their habitats, growth rates, mortality patterns, and other relevant environmental variables. Third, the study period relies heavily on interpretation and reconstruction of historical imagery, lacking continuous observational data; the earliest available satellite imagery dates to 1964, limiting analysis of longer-term dynamic changes. Additionally, the current assessment of historical habitat health does not fully account for the intensity of ongoing human activities. Historical cultural value evaluation primarily depends on literature and interviews, lacking systematic quantitative models and cross-comparison data. Future research should further distinguish the ecological weights of native versus non-native species and incorporate additional indicators such as aquatic habitats [45], heritage protection levels of historical buildings, and animal diversity [46] to enhance the evaluation framework. This study primarily focuses on meso- and micro-scale habitats, with insufficient consideration of macro-scale historical habitat corridors and matrix ecosystem services. Moreover, given the substantial variation in habitat area, the current framework requires refinement to comprehensively reflect historical habitat characteristics across different spatial scales.

5. Conclusions

This study, from an urban biodiversity perspective, highlights significant differences among historical habitat types in terms of ecological function capacity and the continuity of historical expression, emphasizing that “ecological–social–cultural synergy” is a key characteristic of high-quality historical habitats. These findings have important implications for promoting the integrated conservation of historical habitats and cultural heritage within urban ecosystems. Starting from the spatial distribution of ancient and notable trees within Chengdu's Second Ring, potential historical habitat areas were identified, and 12 representative historical habitats were selected for detailed field investigation. Subsequently, a comprehensive historical habitat quality evaluation framework was established. The assessment revealed that, while park-type historical habitats exhibited a clear relationship between ancient tree density and overall quality, other types showed no such relationship; instead, habitat area largely determined quality, influencing the overall evaluation. Additionally, historical habitat quality was negatively associated with urban construction intensity and human activity, but positively correlated with vegetation and building management practices.

In summary, protection strategies should be differentiated according to historical habitat type and quality. At the macro scale, an optimized spatial framework of “ancient trees–historical habitats–habitat networks” should be established; at the meso scale, high-quality habitats should be strictly conserved, while medium- and low-quality habitats should be restored and enhanced through vegetation supplementation and the creation

of ecological buffers; at the micro scale, integrated designs combining historical landscape elements and ecological features should be implemented, complemented by digital technologies to visualize habitat evolution and establish dynamic monitoring systems for ancient trees.

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