Morphological Characteristics, Plant Species Composition, and Distribution of Linpan Post-print

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Abstract

Forest disks are a widely distributed composite ecosystem in the Chengdu Plain, representing highly localized cultural and ecological resources, and serving as traditional rural settlement units that provide important ecosystem service values. Identifying the species composition and distribution characteristics of plants in forest disks is conducive to profoundly revealing the formation and change mechanisms of ecosystem services in forest disks, and providing scientific recommendations for their conservation and renovation. Using a method combining small unmanned aerial vehicle (UAV) aerial photography with field surveys, we analyzed the plant composition and distribution characteristics of forest disks in different regions and types. The results show that: (1) The morphology of forest disks is relatively regular, with a modest scale (average area of 6678.87 m^2), vegetation coverage of 43.5%-76.9%, and plants, houses, and other constituent elements are integrated with one another. (2) The forest disks contain a total of 310 species of vascular plants belonging to 106 families and 254 genera, including 236 native species (76.13% of the total), 35 domestic introduced species (11.29% of the total), and 39 introduced species from other parts of the world (12.58% of the total). (3) The floristic distribution of plant genera is dominated by North Temperate elements (22.31%) and Pantropical elements (16.12%), with the proportions of tropical-subtropical distribution and temperate distribution being relatively similar. (4) In terms of distribution characteristics, forest disks in the outer suburbs have the highest number of plant species ($P < 0.05$), followed by those in the inner suburbs, while those in the middle suburbs have relatively fewer species; species diversity shows a significant positive correlation ($P < 0.05$) with the scale of forest disks, but shows no significant relationship with vegetation coverage level; forest disks with a high proportion of timber-and-earth structures have more plant species, and the difference between medium-high proportions and low proportions is significant ($P < 0.05$).

Full Text

Preamble

Morphological Characteristics and Composition of Plant Species and Their Distribution Patterns in Linpan of the Chengdu Plain

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Abstract

Linpan is a complex ecosystem widely distributed across the Chengdu Plain. As a traditional rural settlement unit with distinctive local characteristics, it provides various important ecological service values. Identifying the composition and distribution characteristics of plant species in Linpan is essential for revealing the mechanisms underlying the formation and transformation of these ecosystem services, and can provide scientific guidance for Linpan conservation and restoration. This study analyzed plant species composition and distribution patterns across different regions and Linpan types using a combination of small unmanned aerial vehicle (UAV) aerial photography and field surveys. The results showed that: (1) Most Linpan units are small in scale (approximately 6678.87 m^2) with regular morphology and varying vegetation coverage (43.5%-76.9%), comprising integrated elements of plants, housing, and other landscape components. (2) A total of 310 vascular plant species belonging to 254 genera and 106 families were recorded, including 279 native species (76.13% of the total), 35 species introduced from other regions of China (11.29%), and 39 species introduced from foreign countries (12.58%). (3) The floristic elements of plant genera were dominated by north temperate components (22.31%) and pantropical components (16.12%), with tropical-subtropical and temperate distributions showing similar proportions. (4) In terms of distribution patterns, far-suburban Linpan exhibited the highest plant species diversity, followed by near-suburban areas, while mid-suburban areas had relatively fewer species. Species diversity showed a significant positive correlation with Linpan size ($p < 0.05$) but no clear relationship with vegetation coverage level. Linpan with a higher proportion of earth-wood structures contained more plant species, with significant differences observed among high, medium-high, and low proportion categories ($p < 0.05$).

Keywords: Linpan; plant species; distribution; Chengdu Plain

Introduction

Linpan is a composite ecosystem widely distributed throughout the Chengdu Plain, formed by rural homesteads surrounded by trees and forests. These traditional settlement units integrate living and production functions, typically featuring small scale, near-circular shape, regular morphology, and high vegetation coverage. Representing a unique cultural symbol and ecological resource of the Chengdu Plain [1–3], Linpan provides multiple ecosystem services including microclimate regulation, biodiversity conservation, and cultural preservation [4–5], while establishing a harmonious human-nature interaction [2,6].

Plants constitute the most important component of Linpan, with composition and structure showing distinct regional characteristics. While research on plant composition and distribution in urban green spaces [8–9] and rural-urban ecotone green areas [10] has become a focus, studies on rural settlement green spaces [11] have mostly relied on census or statistical data from "four-side forests" or rural courtyards [12–13], lacking specificity and accuracy. Linpan vegetation is characterized by diverse species [15], simple vertical structure, and rich vegetation types [14]. As Chengdu strives to build a world-class modern garden city, ecological civilization city, and beautiful countryside, the conservation and restoration of Linpan have become important priorities. However, the species composition and distribution characteristics of Linpan plants remain poorly understood. This study selected Linpan units from different regions and conducted detailed plant surveys and structural analyses to reveal relationships between plant diversity and Linpan type and structure, providing scientific references for vegetation conservation and plant configuration in new rural communities.

[Figure 1: see original paper] The satellite image of Linpan and farmland landscape (Source: Google Earth)

1. Study Area Overview

The Chengdu Plain, also known as the Western Sichuan Plain, is located in the western part of the Sichuan Basin. The study area selected for this research covers Chengdu City, the main concentration area of Linpan distribution. The city contains approximately 121,100 Linpan units with a residential population of 3.6556 million, accounting for 72.40% of the rural population. The study area encompasses the main body of the Chengdu Plain.

[Figure 2: see original paper] Location of study area and survey area

2. Methods

2.1 Selection of Typical Linpan and Structural Characteristics Investigation

This study examined the area from central Chengdu to the northwestern mountain edge (straight-line distances of 17.40 km, 24.90 km, 32.40 km, and 52.06 km from the city center). Field reconnaissance and screening confirmed that the selected Linpan units were typical and representative. A small UAV (DJI Phantom 3 Professional) was used for vertical photography at 4000$\times$3000 resolution. The captured images were processed using Photoscan and ArcGIS software for image synthesis and analysis of area and structural characteristics of each component.

2.2 Linpan Plant Survey

To accurately identify plant composition and distribution characteristics, this study conducted comprehensive field surveys of all plants within each Linpan unit. Recorded indicators included tree species, shrubs, herbaceous plants, lianas, bamboo, coverage, and growth conditions.

2.3 Data Analysis and Processing

Plant names, life forms, and species origin information were recorded following conventional classification methods. Statistical analysis was performed using the least significant difference method and paired sample t-tests. Data were analyzed in combination with the location and structural characteristics of each Linpan unit.

[Figure 3: see original paper] Typical Linpan survey

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3. Results

3.1 Linpan Structural Characteristics

Analysis of aerial images and spatial data from typical Linpan units revealed that Chengdu Plain Linpan generally exhibits regular morphology with small scale. The minimum area was only 1630 m^2, while the maximum was 12,385 m^2, with an average area of 6678.87 m^2. Vegetation coverage ranged from 43.5% to 76.9%, primarily consisting of arbor forests, with some Linpan dominated by bamboo forests. The relationship between plants and farmhouses was generally enclosed or nested, with an average enclosure level of 75.62%. Other green space types accounted for relatively small proportions. The internal structure included earth-wood and brick-concrete houses, with differences in house quantity and structure due to varying construction ages and potential vegetation damage during construction.

3.2 Plant Species Composition

The survey recorded a total of 310 vascular plant species belonging to 254 genera and 106 families. In terms of family composition, Asteraceae (Compositae) had the highest number of species, accounting for 29.35% of the total. In genus composition, the most abundant genera were *Solanum*, *Cinnamomum*, and others, though most were monotypic genera. From a life form perspective, the Linpan contained arbor, shrub, herbaceous, liana, and bamboo species. Common arbor species included *Camptotheca acuminata*, *Celtis sinensis*, *Citrus maxima*, *Ginkgo biloba*, *Osmanthus fragrans*, *Metasequoia glyptostroboides*, and *Pterocarya stenoptera*. Common shrubs included *Gardenia jasminoides*, *Ligustrum lucidum*, *Rhapis excelsa*, *Chimonanthus praecox*, *Camellia japonica*, *Ligustrum sinense*, *Rhus chinensis*, and *Clerodendrum bungei*. Common herbaceous plants included *Sambucus chinensis*, *Alternanthera philoxeroides*, *Eleusine indica*, *Plantago asiatica*, *Solanum pseudocapsicum*, *Phytolacca americana*, *Lophatherum gracile*, and *Ampelopsis delavayana*. Common lianas included *Hedera sinensis* and *Humulus scandens*. Bamboo species were dominated by *Bambusa emeiensis* and *Indocalamus tessellatus*.

[Figure 4: see original paper] The species number of different-location Linpans

3.3 Species Origin

Analysis of species origin revealed that native Sichuan species accounted for 76.13% of the total, domestic introduced species for 11.29%, and foreign introduced species for 12.58%. This indicates that native species dominate the plant composition of Chengdu Linpan. While appropriate introduction and cultivation efforts could be strengthened, they must be adapted to local conditions to reduce the risk of alien species diffusion and invasion.

Analysis of the source of plant species

3.4 Floristic Elements

The study area' s plants encompassed all 15 areal-types of Chinese seed plant genera. North temperate elements and pantropical plants were the main types, accounting for 22.31% and 16.12% of species respectively, followed by cosmopolitan and East Asian distributions at 9.09% and 8.68% respectively. The ratio of tropical to temperate species was approximately 1:1. Chinese endemic genera accounted for 2.89%. The floristic distribution types were diverse, with rich tropical-subtropical and temperate components, reflecting the transitional characteristics of the regional flora that align with Chengdu' s climate conditions.

The analysis of the areal-types of seed plants of Linpan

3.5 Spatial Distribution Patterns

Different Locations: Based on straight-line distance from central Chengdu, Linpan units were classified as near-suburban, mid-suburban, and far-suburban.

Far-suburban Linpan showed the highest plant species diversity ($p < 0.05$), followed by near-suburban areas, while mid-suburban areas had relatively fewer species. The average number of species per Linpan unit followed the same pattern.

Different Scales: Classified by area into large ($ 9000m{2}), medium(5000–9000m{2}), andsmall(5000m^{2}$) categories, both total species count and average species number per Linpan showed large-scale units as most abundant, followed by medium-scale, with small-scale units significantly reduced. This indicates a significant positive correlation between Linpan scale and plant species diversity ($p < 0.05$).

[Figure 5: see original paper] The species number of different-scale Linpans

Different Coverage Levels: Classified by vegetation coverage into high ($ 70 $50%) categories, no clear patterns were observed in total species count or average species number per Linpan. This suggests that plant species composition has little relationship with coverage level.

[Figure 6: see original paper] The species number of different-coverage Linpans

Different House Structures: Based on the proportion of earth-wood structures, Linpan units were divided into high proportion ($ 70 $50%) categories. Both total species count and average species number increased with higher proportions of earth-wood structures, with significant differences between high and low proportion categories ($p < 0.05$).

[Figure 7: see original paper] The species number of different-housing structure Linpans

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4. Conclusion and Discussion

Through investigation and analysis, this study identified that Chengdu Plain Linpan exhibits regular morphology with generally small scale, averaging 6678.87 m^2 in area and 43.5%–76.9% vegetation coverage. Plants and farmhouses show an enclosed or nested relationship with moderate housing density. A total of 310 vascular plant species were recorded, dominated by native species (76.13%), with domestic introduced species (11.29%) and foreign introduced species (12.58%). The floristic elements show clear transitional characteristics, with north temperate (22.31%) and pantropical (16.12%) components dominating, and tropical-subtropical and temperate distributions showing similar proportions.

In terms of distribution patterns, far-suburban Linpan had the most plant species, followed by near-suburban and mid-suburban areas. Species diversity showed a significant positive correlation with Linpan scale ($p < 0.05$) but no clear relationship with vegetation coverage level. Linpan with higher proportions of earth-wood structures contained more plant species, with significant differences among proportion categories ($p < 0.05$).

Compared with mountainous areas of Chengdu, Linpan plant diversity is significantly lower but higher than other plain regions [20]. As a special landscape type and cultural symbol, Linpan provides important ecosystem services [4] such as fuelwood provision, animal habitat, carbon sequestration, and climate regulation. Unlike typical rural courtyards with high species similarity [21–22], Linpan features peripheral protective forest belts and combines artificial management with natural growth attributes. Although species richness is not exceptionally high, the structure is more complex and plays vital ecological functions [23–24].

The absolute dominance of native species (76.13%) indicates that Chengdu Linpan maintains strong regional characteristics. While appropriate introduction of some exotic species could enhance diversity, ecosystem risks from excessive alien species must be avoided [25]. With rapid urbanization, traditional timber forests have decreased while ornamental cultivated species have increased. Invasion phenomena remain uncommon, with only a few invasive plants such as *Anredera cordifolia* and *Alternanthera philoxeroides* identified.

The floristic distribution aligns with Sichuan' s geographic position at the intersection of tropical and temperate flora [18,28], showing obvious transitional features. From a spatial perspective, most studies show species richness increasing with distance from urban centers [10,12], which partially matches our findings. However, near-suburban areas, despite having more ornamental plants, may have lower habitat stability [31]. The positive correlation between Linpan scale and species richness mirrors patterns observed in home gardens [32], as landscape patterns including patch area, shape, and connectivity influence species diversity [33–34].

House structure and proportion reflect the degree of Linpan modification, with large-scale construction potentially destroying vegetation integrity and reducing species richness. This study provides fundamental identification of Linpan morphological structure and plant composition. Despite limitations in sample size and selection randomness, the overall trends are reliable. Future efforts should strengthen Linpan plant conservation and management, focusing on enhancing ecosystem stability and function. We recommend increasing utilization of native tree species while appropriately introducing cultivated plants, while avoiding landscape homogenization and excessive alien species to ensure biodiversity conservation.

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Note: Figure translations are in progress. See original paper for figures.