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Original Research Article

THE RELATIONSHIP BETWEEN LINPAN SETTLEMENTS AND PLANT DIVERSITY

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Abstract

Linpan settlements are characterized by rich biodiversity and play a critical role in the region's ecological and economic systems. They are significant carrier of agricultural civilization in the Chengdu Plain. However, rapid urbanization has resulted in the degradation of Linpan settlements, with the gradual reduction and even disappearance of natural landscape elements such as traditional agricultural land, woodlands, and water systems. Hence, this paper aims to explore the relationship between Linpan settlements and plant diversity to identify how plant diversity influences Linpan elements and supports biodiversity. This study investigates the distribution characteristics of Linpans in the Chengdu Plain by selecting 60 representative Linpans, categorized into four types: ecological, agricultural, agritourism, and functional industrial. Moreover, plant diversity and landscape unit characteristics were examined, and plant communities were analyzed using the Margalef richness index, Hurlbert diversity index, and Pielou evenness index. The findings indicate the agricultural Linpans exhibit significant advantages in species diversity, plant variety, and community structural integrity. Functional industrial and agritourism Linpans demonstrate lower vegetation coverage and simplified community structures, primarily due to anthropogenic disturbances. Additionally, the complexity of landscape unit structures positively influences the stability and diversity of plant communities. However, rational adjustments to land use patterns and an increased proportion of natural landscape elements are essential to improving landscape continuity and enhancing ecological functionality. Finally, the findings emphasize the number of landscape elements has a measurable impact on species diversity indices, relatively complex landscape structures promote the stable development of plant communities and Linpan settlements.

Keywords: Linpan, plant diversity, landscape units, landscape elements

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1. INTRODUCTION

As a unique carrier of China's agricultural civilization, Linpan settlements play a vital role in supporting the ecological and economic systems of the Chengdu Plain (Zheng et al., 2020). The spatial distribution of Linpan settlements is relatively decentralized, consisting of farmhouses surrounded by woodland, farmland, and water networks (Fig.1), creating a self-sustaining ecosystem (Chen et al., 2023). This dispersed settlement pattern has been essential to the agricultural stability and ecological resilience of the region for more than 2,000 years (Li et al., 2016). It as part of China's cultural landscape heritage, are now being integrated into modern urban planning strategies (Zhang et al., 2022). The Chinese government's policy of “bringing forests into cities and integrating cities into forests” has become a key strategy for improving urban sustainability and promoting regional economic development (Cai et al., 2024). In this context, Linpan settlements have evolved alongside urban-rural integration, becoming an integral part of the urban forest system in the Chengdu Plain (Lian et al., 2022). In addition to their agricultural and socio-economic roles, Linpan settlements, with their rich plant species, also contribute significantly to biodiversity conservation. Their diverse land-use patterns support species richness, similar to other globally recognized traditional agricultural landscapes, such as Satoyama in Japan and hedgerow systems in Europe (Jiang, 2019). By maintaining a balance between landscape heterogeneity and species diversity, Linpan settlements provide valuable insights into sustainable rural development, particularly in the context of global biodiversity loss and land-use change.

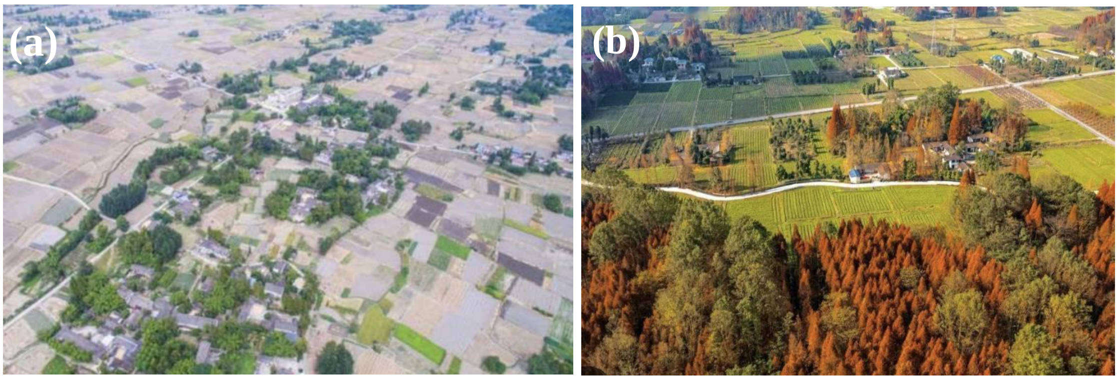

Fig. 1. Linpan settlements (a) Distribution and (b) Pattern

Source: Author

Since the 1990s, rapid urbanization and rising living standards have reshaped rural landscapes, leading to increasing public concern about the quality of the living environment (Turner, 2010; Taylor and Lennon, 2012; Jiao et al., 2012; Shu et al., 2013; Dearing et al., 2015; Jiang et al., 2015; Zong et al., 2020; Jiang et al., 2022).It has led to significant challenges for Linpan settlements, similar to those encountered by other rural settlements (Yang et al, 2010; Huang et al., 2012; Li et al., 2019). Urban expansion has gradually encroached upon natural environments, displacing traditional farming, and reducing biodiversity (Wang, 2009; Wu, 2010; Li et al., 2016). Moreover, large-scale farming practices have replaced more diverse and traditional agricultural methods, further exacerbating the loss of vegetation diversity and environmental stability. The migration of rural populations has also led to the phenomenon of hollow Linpans where vacant rural settlements obtain in reduced human intervention in the management of landscapes, leading to a decline in the area and scope of Linpan settlements (Cai, 2009; Yue et al., 2021; Zhang et al., 2022). Similar trends have been observed in other regions undergoing urbanization, where rural depopulation and agricultural intensification have led to ecosystem degradation (Li et al., 2019). The challenges faced by Linpans due to urbanization and modern agricultural practices have had significant impacts on plant communities. These include the replacement of diverse plant species with monoculture plantations, fragmentation of Linpan structures by hardscape installations and the gradual disappearance of dense bamboo groves (Qing et al.,2011; Zheng et al., 2020). Furthermore, the decline in rural population has significantly impacted vegetation production in Linpan settlements. As many rural residents migrate to urban areas, the labor force for vegetation management and cultivation has sharply diminished in these landscapes. This reduction in workforce has led to lower agricultural output and ineffective land management, further diminishing vegetation productivity. The abandonment of traditional farming methods and lack of human intervention in the vegetation growth process have exacerbated the decline in vegetation quality and yield in Linpan areas. This underscores the direct link between population decline and reduced vegetation production, beyond merely changes in landscape area. This phenomenon reveals the direct link between population decline and reduced vegetation production rather than focusing on the broader scope of landscape area (Cai, 2009; Yue et al., 2021; Zhang et al., 2022).

The survival challenges faced by Linpans have attracted substantial scholarly attention with much of the research focused on defining Linpans and examining their structural characteristics, functions, and landscape features (Cao et al., 2009; Wang, 2015; Chen et al., 2023; Zhong et al., 2020). To overcome these challenges, the Chinese government, particularly through regional initiatives has implemented strategies to mitigate the negative impacts of urbanization on Linpan settlements. By 2010, Chengdu had initiated a planning program that included 11 thematic rural-city demonstration routes, aligning with the city ambition to become a world modern garden city. This approach aimed to integrate urban development with environmental and cultural preservation, enhancing the sustainability of rural landscapes while promoting urban-rural integration. In addition, Chengdu updated its planning for Linpan settlements in the Chengdu Plain, focusing on sustainable development and the restoration of traditional agricultural practices (Zhou, 2017). These planning updates emphasize the importance of conserving Linpan settlements as unique cultural and ecological assets, ensuring their continued contribution to biodiversity and local livelihoods despite the pressures of urbanization. Similar efforts in other countries, such as the European Union’s rural development programs, showing the global trend of balancing urbanization with environmental conservation through strategic planning and sustainable land management. Thus, this study aims to integrate by analyzing the current developmental status of Linpans from a landscape science perspective.

This study reports the relationship between plant diversity and landscape unit composition across various types of Linpan settlements. Through a combination of field surveys and statistical analyses, the research aims to evaluate plant community composition, species diversity indices, and structural characteristics within four distinct Linpan types: agricultural, ecological, agritourism, and functional industrial. Furthermore, it examines the effect of different land use patterns (e.g., farmland-woodland integration and monoculture practices) on species richness, evenness, and distribution patterns. For instance, agricultural Linpans, the study assesses whether the composite model of farmland and woodland contributes to sustaining higher levels of species diversity. while functional industrial Linpans, the research examines the effect of large-scale economic crop cultivation on species homogenization and explore strategies for optimizing plantings to enhance community stability. Thus, these finding may provide suitable recommendations for optimizing land use and landscape element configuration to improve plant community stability, promote the sustainable development of Linpan ecosystems, and strengthen their ecological functions.

2. METHODLOGY

2.1. Study Site

The study area is situated within the Chengdu Plain (Fig.2), covering approximately 14,312 km² and focusing on regions with a high concentration of Linpans such as Wenjiang, Pidu, and Longquan Districts. The average elevation in the area is around 500 meters with minimal elevation variation of less than 20 meters. The region experiences a subtropical humid monsoon climate with an average annual temperature of approximately 18°C and annual precipitation exceeding 1,000 mm. The soil is primarily alluvial, made up of silt and clay from plateau rivers, contributing to its high fertility. This fertile soil supports extensive rice cultivation, and the area is renowned as the land of abundance. Vegetation in the region includes evergreen broad-leaved forests mixed evergreen and deciduous broad-leaved forests as well as bamboo groves.

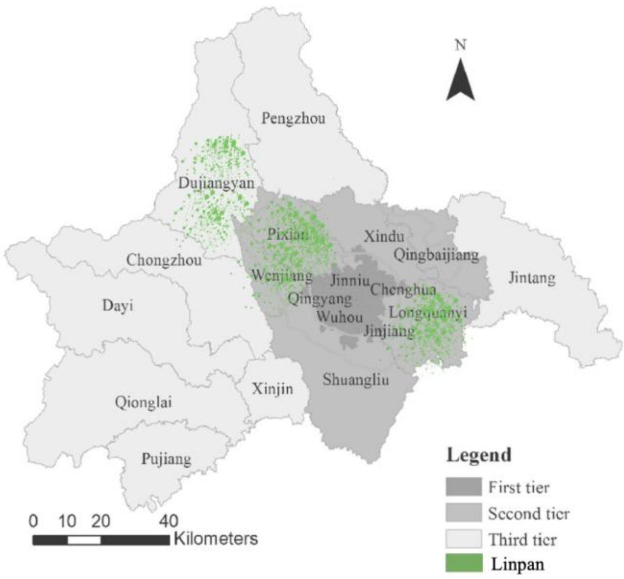

Fig. 2. Map of Chengdu Plain

2.2. Sampling Design

In 2024, a total of 160 representative Linpans were selected for investigation along the Dujiangyan irrigation system based on the Chengdu Linpan distribution map created by the Chengdu urban and rural construction committee in 2018 and the classification standards for Linpans in the Chengdu plain (Fig.3). These Linpans were categorized into four types based on the spatial distribution of residential settlements: ecological Linpans, agricultural Linpans, agritourism Linpans, and functional industrial Linpans. Each Linpan type included at least 40 Linpans for a comprehensive study. Ecological Linpans are aimed at maintaining a favorable ecological environment in the region while providing spaces for leisure and vacation activities, Agricultural Linpans primarily focus on agricultural production, Agritourism Linpans are based on agricultural production but leverage environmental and transportation advantages to develop rural inns, agritainment, and catering services, Functional industrial Linpans focus on non-tourism industries, such as off-season greenhouse vegetables, orchards, courtyard economies, and livestock or poultry farming. The selected Linpans were distributed across 60 rural settlements in Chengdu, ensuring a diverse representation of landscape types, industries, and vegetation characteristics.

2.3. Data Collection

A total of 160 Linpan settlements were initially selected based on historical records and the Chengdu Linpan distribution map. Among them, 60 settlements were chosen for in-depth field investigation due to accessibility constraints and data availability. The investigation focused on mapping the geographic distribution of Linpans, and assessing their primary industries, economic development, and landscape types. Vegetation characteristics within these Linpans were also examined. The survey also examined the vegetation characteristics within these Linpans. Vegetation data were collected for trees (species name, number of individuals, diameter at breast height (DBH), height, and canopy width), shrubs (species name, number of individuals, and height), and herbs (species name and coverage percentage). This comprehensive vegetation inventory aimed to capture the diversity and structure of plant communities within each Linpan. Three representative vegetation plots were randomly selected within each Linpan for detailed investigation. Each plot measured 20 m × 20 m, ensuring coverage of different landscape units such as farmland, woodland, waterways, and green spaces around residential areas, thereby achieving a balanced distribution of data. Tree layer survey was conducted using a standard plot sampling method, where all trees within each 20 m × 20 m plot were recorded, including species identification, individual counts, diameter at breast height (DBH), tree height, and crown spread. DBH was measured at 1.3m above ground level, tree height was determined using a clinometer, and crown spread was calculated as the average of the north-south and east-west crown diameters. The shrub layer, a 5 m × 5 m subplot was established within each tree plot, where shrub species, individual counts, and average height were recorded. The herbaceous layer was assessed using a 1 m × 1 m subplot within the tree plot, where species composition and percentage cover were documented.

2.4. Data Analyses

The Margalef richness index, Hurlbert diversity index, and Pielou evenness index were used to calculate species diversity, as suggested by researchers in previous studies (Grunewald et al., 2007; Rad et al., 2009; Lukács et al., 2013; Rocchini et al., 2016; Ren et al., 2018; Fayiah et al., 2019; Liu et al., 2021; Yang et al., 2022; Rahmanian et al., 2023). The specific formulas applied are as follows, e.g. (2.1;2.2;2.3) In these formulas, *S* represents the total number of species, *N* represents the total number of individuals, and *Ni* represents the number of individuals of the species, where *i* = 1, 2, ...

Margalef Richness Index： $H = \frac{(S-1)}{\mathrm{In}(N)}$ (2.1)

Hurlbert Diversity Index: $D = \frac{N\ (\frac{N}{S}-1)}{[\sum \mathrm{Ni}(\mathrm{Ni}-1)\,]}$ (2.2)

Pielou Evenness Index: $E = \frac{1-\sum \mathrm{Ni}\,(\mathrm{Ni}-1)}{[\mathrm{N}(\mathrm{N}-1)]}$ (2.3)

The experimental data were processed and analyzed using Excel 2017 and SPSS 18.0 software.

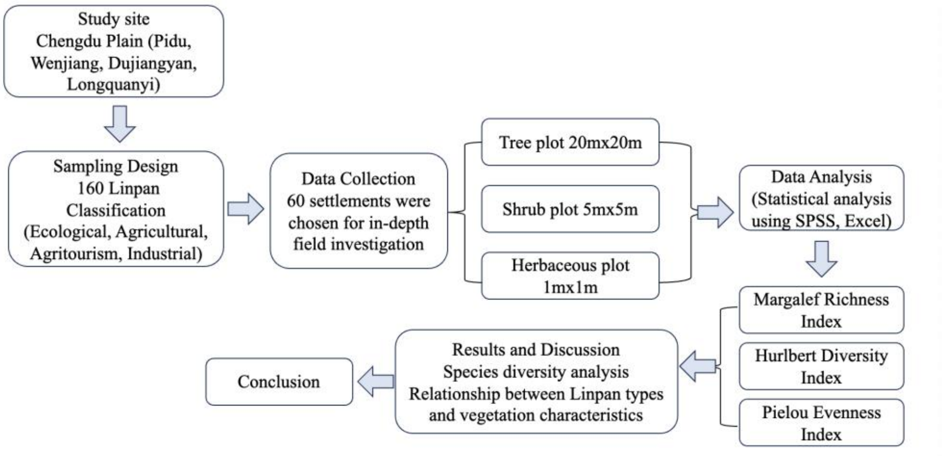

Fig. 3. Overview of method diagram

3. RESULTS

3.1. Plant Diversity of Linpan

Combing experimental research and computer simulations displayed the significant role of species diversity in assessing the richness of biological resources within a given region, directly influencing the overall quality of the living environment. A comprehensive study conducted across 160 Linpan settlements in the Chengdu Plain, a total of 226 plant species were documented, representing 110 genera and 60 families. The dominant families observed in these settlements include Rosaceae, Leguminosae, Gramineae, Moraceae, Compositae, Caprifoliaceae, and Araliaceae. These findings provid valuable insights into the biodiversity present in the area, which plays a crucial role in supporting ecological balance and contributing to environmental quality. The plant families identified are main components of the ecosystem, with each contributing to various ecological processes such as soil stabilization, nutrient cycling, and carbon sequestration. Each type of Linpan settlement on the Chengdu Plain features distinct dominant plant species (Table 1), tailored to its specific function. For instance, ecological Linpans are primarily composed of species like *Neosinocalamus affinis, Phyllostachys edulis, and Populus*, fostering a stable and ecologically beneficial vegetation structure. Agricultural Linpans include species such as *Ginkgo biloba, Neosinocalamus affinis, and Metasequoia glyptostroboides,* which balance ecological health with agricultural productivity. Agritourism Linpans blend ornamental and economic plants like *Bambusa multiplex, Osmanthus fragrans, and Gleditsia sinensis,* enhancing both aesthetic value and tourism potential. Meanwhile, Functional Industrial Linpans focus on economically valuable species such as *Pyrus, Prunus persica, and Eriobotrya japonica,* supporting industrial and commercial activities. These varying species compositions reflect the diverse ecological, economic, and aesthetic roles of each Linpan type. Table 1 illustrates the major species found in each Linpan along with their diversity status.

Table. 1. Dominant species in different Linpan types

Type of Linpan	Dominate Species
Ecological Linpans	*Neosinocalamus affinis*, *Phyllostachys edulis*, *Populus*, *Eucalyptus spp. Pinaceae*, *AlnuscremastogyneBurk Metasequoia glyptostroboides*
Agricultural Linpans	*Ginkgo biloba*, *Neosinocalamus affinis, Cunninghamia lanceolata*, *Metasequoia glyptostroboides, Platycladus orientalis*, *Pterocarya stenoptera, Camptotheca acuminata, Chimonanthus praecox, Magnolia denudate, Prunus cerasifera, Nerium oleander*
Agritourism Linpans	*Bambusa multiplex, Neosinocalamus affinis, Ginkgo biloba, Gleditsia sinensis, Metasequoia glyptostroboides, Osmanthus fragrans, Paulownia,Loropetalum chinense var.rubrum, Ophiopogon japonicus*
Functional Industrial Linpans	*Neosinocalamus affinis, Ginkgo biloba, Pyrus, Metasequoia glyptostroboides, Prunus persica, Prunus pseudocerasus Lindl, Eriobotrya japonica, Morella rubra*

As shown in Figure 4 for the same type of Linpan, the Margalef richness index and Hurlbert diversity index of trees were higher than those of shrubs, whereas the Pielou evenness index was higher for shrubs compared to trees. The diversity indices varied significantly among Linpan types. Overall, the Margalef richness index, Hurlbert diversity index, and Pielou evenness index for communities and tree layer were highest in agricultural Linpans. In contrast, the Margalef richness index for shrubs was highest in functional industrial Linpans. The lowest values of the Margalef richness index and Hurlbert diversity index for shrubs were observed in ecological Linpans, while the lowest values of the Hurlbert diversity index and Pielou evenness index for both communities and trees were found in functional industrial Linpans. Meanwhile, the Pielou evenness index for shrubs was lowest in agritourism Linpans.

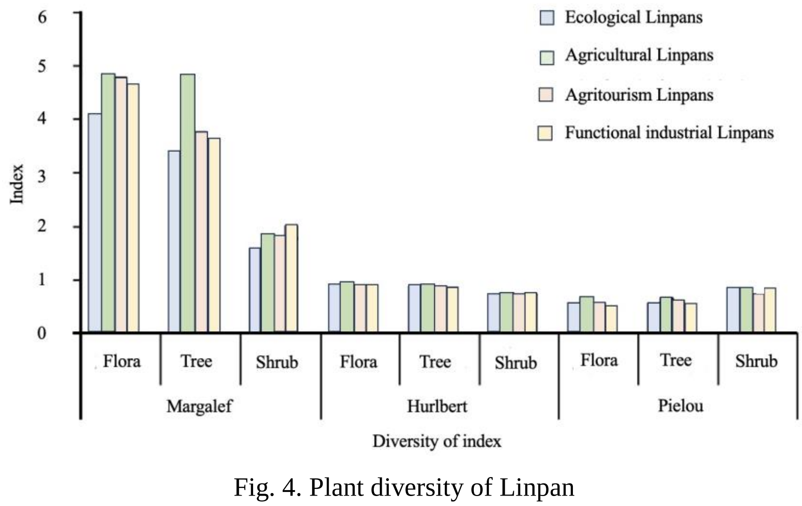

Fig. 4. Plant diversity of Linpan

3.2. Landscape Elements of Linpan

Landscape elements serve as the foundation of landscape units. In structurally intact Linpans, the primary landscape elements include courtyards, buildings, woodlands, roads, water systems, and farmland. As shown in Figure 5, the quantity and composition of these landscape structural elements have fluctuated over time in response to the production and living needs of Linpan residents, resulting in changes in the range and scale of some elements (Zhang et al., 2022). The woodland landscape element exhibits two notable characteristics, Bamboo and Woodland Composition. This element often includes a certain proportion of bamboo groves, forming a "bamboo + trees" vegetation community, which is one of the most distinctive features of traditional Linpans. This composition integrates aesthetic, economic, and functional roles, providing a material foundation and economic resource during the early formation of Linpans. However, with changes in agricultural production methods and economic restructuring, the bamboo grove area in some agritourism and functional industrial Linpans has been continuously reduced. In some cases, bamboo groves have been replaced by other economic forests, nurseries, ponds, or ecological land uses, as well as by non-ecological land uses such as courtyards, squares, and roads. The other characteristic is the origins and management of woodland, which is most woodland in Linpans originated as plantations, with management practices divided into near-natural management and intensive artificial management. Near-natural management woodland primarily consists of timber and ecological shelter woodland, while intensively managed woodland includes nurseries and orchards. The area of near-natural management woodland is proportionally higher than that of intensively managed woodland. However, in recent years, the expansion of intensively managed woodland has reduced the area and number of patches of near-natural management forests. In approximately 12% of Linpans, near-natural woodland has been replaced or entirely covered by intensively managed woodland. Additionally, the shift in traditional farming practices has led to changes in water systems and farmland landscapes. Due to changes in cultivation methods, people no longer rely on traditional water systems to meet daily production and living needs. The increasingly advanced pipeline technology has caused water systems to move underground, with their original locations being repurposed for other land uses. The survey revealed that water systems were present in only 26.0% of Linpans and are at risk of disappearing. Furthermore, the pursuit of diversified agricultural products and high economic returns has impacted farmland landscapes in some artificially managed Linpans. The study results indicate that farmland appears in just over half of the surveyed Linpans, highlighting the significant loss of farmland within these areas.

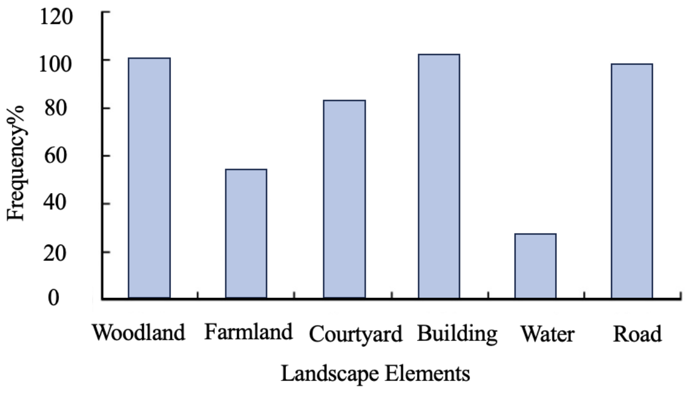

Fig. 5. General distribution of landscape elements for Linpan

3.3. Landscape Unit Classification and Frequency of Occurrence

Based on the spatial distribution of landscape elements, different Linpan settlements combine various elements to form distinct landscape units. We identified eight primary landscape unit types, classified according to the presence of woodland (W), farmland (F), courtyard (C), building (B), water system (WS), and road (R). To improve clarity, author use simplified abbreviations for classification:

- WF-CB-R: Woodland + Farmland + Courtyard + Building + Road
- WC-B-WS-R: Woodland + Courtyard + Building + Water System + Road
- WF-CB-WS-R: Woodland + Farmland + Courtyard + Building + Water System + Road
- WC-BR: Woodland + Courtyard + Building + Road
- WF-B-R: Woodland + Farmland + Building + Road
- WF-B: Woodland + Farmland + Building
- WC-B: Woodland + Courtyard + Building
- WB-R: Woodland + Building + Road
- WB: Woodland + Building

Among them, WF-CB-R (31%) and WF-CB-WS-R (25%) are the most common, while WB (3%) and WF-B (5%) are the least frequent (Fig.6). The results indicate that Linpan settlements exhibit diverse landscape unit structures, with farmland and courtyard elements being the most frequent. The high proportion of WF-CB-R and WF-CB-WS-R suggests that most Linpans retain a traditional mixed-use agricultural layout, combining farmland and woodland with residential spaces. In contrast, WB, WF-B and WC-B are significantly less common, indicating that pure woodland-building configurations are rare, likely due to the reduced agricultural function in modernized Linpans. Additionally, the exclusive presence of WF-B in ecological Linpans suggests that conservation-focused Linpans prioritize woodland and farmland elements while minimizing built infrastructure. The classification model also reflects the landscape complexity and integrity of different Linpan types. Units containing more elements (e.g., WF-CB-WS-R) exhibit higher complexity, whereas those with fewer elements (e.g., WB) demonstrate lower integrity due to reduced ecological connectivity. These findings highlight the relationship between land-use patterns and the sustainability of Linpan settlements.

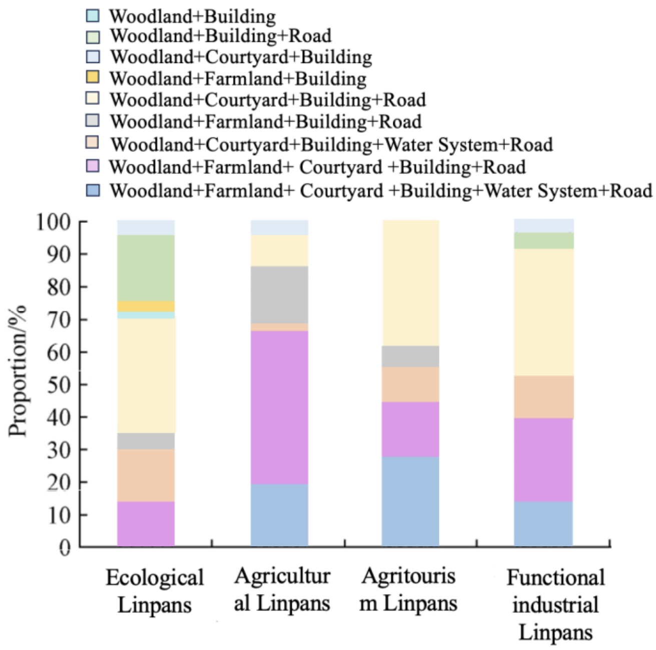

Fig. 6. Main landscape units and their distribution of Linpan

3.4. The Relationship Between Landscape Units and Plant Diversity

From Table 2, it can be observed that the landscape unit with the highest Margalef richness index is "Woodland + Building + Road + Farmland + Courtyard + Water System," with a value of 4.8438. The landscape unit with the highest Hurlbert diversity index and Pielou evenness index is "Woodland + Building + Road + Farmland + Water System," with values of 0.9211 and 0.8652, respectively. In contrast, the landscape unit with the lowest values for all diversity indices is "Woodland + Building + Road," with Margalef richness, Hurlbert diversity, and Pielou evenness indices of 4.5702, 0.8453, and 0.4962, respectively. Different landscape units exhibit varying levels of complexity and integrity, with distinct compositions of natural landscape elements, which in turn influence the composition and diversity of plant communities. To understand the impact of landscape units on plant communities, this study examines the relationship between landscape units and species diversity. The complexity of each landscape unit was scored based on the number of component elements and the frequency of natural landscape elements present, with scores ranging from 1 to 8, from lowest to highest complexity. Each Linpan was assigned a complexity score, which was then analyzed for its correlation with diversity indices.

Table. 2. Relationship between landscape units and species diversity

Landscape Unit	Margalef Index *H*	Hurlbert Index *D*	Pielou Index *E*
Woodland+Building+Road+Farmland+Courtyard	4.698 2	0.871 7	0.540 6
Woodland+Building+Road+Courtyard	4.651 3	0.881 9	0.583 3
Woodland+Building+Road+Farmland+Courtyard+Water system	4.843 8	0.899 6	0.529 6
Woodland+Building+Road+Courtyard+Water system	4.749 1	0.858 1	0.523 7
Woodland+Building+Road	4.570 2	0.845 3	0.496 2
Woodland+Building+Road+Farmland	4.791 5	0.898 6	0.571 2
Woodland+Building+Road+Farmland+Water system	4.614 8	0.921 1	0.865 2

From Table 3, it can be observed that the complexity of landscape units is significantly and positively correlated with the Margalef richness index, with a correlation coefficient R = 0.823 and P0.044 < 0.05, indicating a linear positive relationship. However, the complexity of landscape units shows no significant correlation with the Hurlbert diversity index or the Pielou evenness index, as indicated by P > 0.05. To further analyze the relationship between complexity and each species diversity index, partial correlation analysis was conducted.

Table. 3. Correlation between the complexity of landscape unit and species diversity

Item		Diversity Index			Complexity
		Margalef Index H	Hurlbert Index D	Pielou Index E	
H	Correlation Coefficient *R*	1.000	0.772	0.258	0.823*
	Significance Threshold *P*		0.071	0.621	0.043
	Sample Size *N*	160	160	160	160
D	Correlation Coefficient *R*	0.771	1.000	0.672	0.558
	Significance Threshold *P*	0.073		0.145	0.252
	Sample Size *N*	160	160	160	160
E	Correlation Coefficient *R*	0.258	0.672	1.000	0.118
	Significance Threshold *P*	0.621	0.145		0.821
	Sample Size *N*	160	160	160	160

Note: * means significant difference at 0.05 level (bilateral).

According to Table 4, the structural complexity of Linpan settlements shows no significant correlation with any of the three species diversity indices.

Table. 4. Partial correlation analysis of complexity of landscape unit and diversity index

Control variable	Item	Complexity	Diversity index Margalef Index H	Hurlbert Index D	Pielou Index E
NO	The level of complexity	1.000	0.823*	0.118	0.558
NO	H	0.823*	1.000	0.258	0.772
NO	E	0.118	0.258	1.000	0.672
E&D	The level of complexity	1.000	0.683		
H&D	The level of complexity	1.000		-0.008	
H&E	The level of complexity	1.000			-0.136

Note: * means significant difference at 0.05level.

4. DISCUSSION

4.1. Plant Diversity Characteristics and Conservation Strategies

Species diversity is a comprehensive reflection of the fundamental characteristics and ecological functions of plant communities. It is a critical indicator of the stability and sustainable development of these communities, representing the ecological adaptability of species to specific environmental conditions within their evolutionary spatial context (Jia et al., 2023). In addition to its fundamental ecological role, species diversity carries substantial landscape value and ecological significance (Fang, 2019). Particularly, woodland clusters show a high degree of species diversity with the plant community which has reached a stable developmental stage, demonstrating the ecosystem's sufficient capacity for self-maintenance and restoration. This stability reflects the harmonious coexistence and mutual benefit of the organisms within these habitats including bamboo forests, woodlands, and farmlands, ensuring the long-term sustainability of the forest cluster ecosystem (Cai, 2011; Han, 2007; Su et al., 2018). The findings reveal that the plant diversity within Linpan settlements exhibit the highest levels of species diversity, plant variety, and species evenness. These Linpans possess relatively well-preserved community structures and patterns, which indicates that the agricultural zones of the Chengdu Plain maintain a substantial quantity and diversity of plant life. The integrated model of woodland and farmland continues to offer a stable natural and developmental environment for Linpans, promoting ecological stability. In contrast, ecological Linpans, despite their abundant vegetation and wide distribution, are showing signs of partial abandonment. Insufficient management and maintenance have led to diminished species evenness and disordered community structures, indicating a need for more consistent ecological oversight. Agritourism Linpans, which mainly focus on the development of distinctive tertiary industries or those lacking significant industrial demand have showed a limited extent of farmland. These Linpans demonstrate moderate advantages in plant distribution evenness, community structure, and species richness. They host a variety of ornamental plants including colourful foliage and flowering species, creating pronounced seasonal effects that enhance the aesthetic and ecological value of these areas. Moreover, functional industrial Linpans prioritize the cultivation of valuable tree species, those are typically characterized by monocultures of easily managed and market-demanded ornamental plants. These large-scale nurseries encroach upon farmland, displacing traditional agricultural practices. Consequently, the plant communities in these Linpans are highly homogeneous with a limited number of species dominating the abundance and distribution. This species uniformity diminishes the overall biodiversity and ecological resilience of the system, revealing the need for a more diversified and sustainable approach to land use. Briefly, each type of Linpan settlement exhibits unique advantages and challenges regarding plant diversity. These findings emphasize the importance of managing and maintaining ecological balance through appropriate land use strategies. The observed patterns of species richness, evenness, and community structure indicate that targeted conservation strategies are necessary to sustain the ecological health of Linpan ecosystems and enhance their long-term stability.

The research findings on the landscape units of Linpans reveal distinct patterns across different settlement types. Ecological Linpans are predominantly characterized by the "woodland + courtyard + building + road" landscape unit with the "woodland + building + road" unit also being prevalent. These patterns are consistent with the current state of ecological Linpans, which are nearly devoid of farmland. In agritourism and functional industrial Linpans, the "woodland + courtyard + building + road" unit constitutes a significant portion of the landscape, further illustrating the absence of two critical natural landscape elements (farmland and water systems) (Zheng et al., 2020). This trend indicates that the natural environment in these Linpans has gradually been diminished under anthropogenic disturbance, resulting in more simplified and less diverse landscape structures. In contrast, agricultural Linpans exhibits relatively more complex and complete landscape structures. The most common landscape unit is "woodland + farmland + courtyard + building + road," followed by "woodland + farmland + courtyard + building + water system + road" and "woodland + farmland + building + road." These landscape configurations reflect the mutually reinforcing relationship between agricultural civilization and the continuous evolution of the landscape and ecological systems. The presence of farmland and its integration with other landscape elements emphasizes the critical role that agriculture plays in maintaining ecological stability and diversity within these settlements. Moreover, farmland and woodland are fundamental natural components of Linpan settlements, which play an important role in maintaining ecological integrity. The absence of these elements leads to a degradation of the overall landscape structure, reducing its ecological functionality. Thus, it is crucial to adjust land-use practices to increase the representation of natural elements such as farmland and water systems within the landscape units. These adjustments may not only enhance the diversity and rationality of the landscape but also contribute to the integration and long-term ecological sustainability of Linpan settlements.

Simultaneously, the utilization of natural resources must be carefully managed to avoid the formation of economic species plantations or the emergence of structurally disorganized and abandoned Linpans. When plant communities are merely composed of a quantitative accumulation of species without sufficient ecological structure, they fail to provide meaningful ecological benefits. Thus, it is crucial to implement rational land-use planning, particularly concerning the proportion of woodlands, to ensure the stability of plant communities. For instance, Agritourism Linpans characterized by a high proportion of non-natural landscape elements demonstrate low vegetation coverage and species diversity indices. To rectify this, adjustments in the composition and proportion of landscape elements are essential to restore a balanced ecological effect. Similarly, functional industrial Linpans with a significant land portion are dedicated to nurseries, optimizing the planting ratio of economic species which is vital to avoid inefficient and repetitive land-use practices. These adjustments could contribute to the long-term stability of plant communities and enhance the overall ecological functionality of the landscape.

The study shows that agricultural Linpans have the highest species diversity, plant variety, and species evenness with well-preserved structures and spatial patterns. These results align with previous research on traditional agricultural systems, which demonstrate that mixed land-use settlements such as those integrating farmland and woodland in enhancing biodiversity and ecological stability (Zhang et al., 2020; Li et al., 2018). Studies on traditional agricultural ecosystems in Hani Rice Terraces, China have identified similar patterns, demonstrating that traditional land-use practices can sustain high levels of species richness and functional diversity (Liu et al., 2014). However, the Hani terraces rely on large-scale water management systems, Linpan settlements are more decentralized and inherently adaptable to diverse topographic conditions, offering a flexible model that balances agricultural productivity with ecological integrity. Furthermore, comparisons with other traditional systems such as Japan's Satoyama rural landscapes reveal similar benefits of integrating cultivated land and grasslands for ecosystem resilience and biodiversity due to continuous human-nature interactions that shape and preserve their ecological integrity. (Takeuchi, 2010; Fukamachi et al., 2017). Moreover, European rural settlements allocated in France and the UK show that mosaic farming systems combining tree hedgerows and agricultural plots create diverse plant and animal species (Burel and Baudry, 1995). These comparisons indicate the ecological value of Linpan settlements in global biodiversity conservation and sustainable land management.

Thus, to ensure the sustainable ecological functionality of Linpans, it is crucial to implement scientifically grounded conservation strategies. First, maintaining and optimizing the stability of Linpan ecosystems, particularly for ecological and agricultural types is crucial. While ecological Linpans demonstrate robust vegetation growth, certain areas suffer from reduced species evenness and disordered community structures due to inadequate management practices. Restoration efforts should be focused on controlling invasive species and weeds, while reintroducing native species like *Phyllostachys pubescens*, *Metasequoia glyptostroboides*, and *Ginkgo biloba* to enhance natural regeneration capacity of these ecosystems. Agricultural Linpans are vital carriers of the Chengdu Plain’s farming culture, maintain a structurally complete landscape of "woodland + farmland + courtyard + buildings + roads," which offers substantial ecological value. To maintain this advantage, intercropping and crop rotation practices should be encouraged to preserve soil fertility and promote the sustainability of farmland ecosystems. Secondly, it is essential to adjust the planting structure within functional industrial Linpans and optimize the proportion of economic crops. These Linpans focus on large-scale nursery cultivation (often rely on monoculture plantations), leading to simplified plant communities and reduced ecological stability. To overcome this issue, a mixed-species afforestation model should be introduced to enhance plant diversity. In addition, ecological buffer zones between nursery plots should be established to prevent soil erosion and water loss. The adoption of eco-friendly agricultural practices such as organic farming and biological pest control is crucial to minimize chemical inputs and reduce pollution in soil and water resources. These measures can offer a balance between economic development and ecological conservation.

Furthermore, landscape optimization in agritourism Linpans is a promising way to increase the proportion of natural landscape elements and enhance ecological value. These Linpans often have limited farmland, leading to reduce ecological integrity. Farmland and water systems could be integrated to improve landscape diversity. In addition, aesthetic vegetation such as colourful foliage and ornamental flowering plants could be strategically placed to enhance seasonal visual appeal. This approach ensures that Linpans not only serve ecological functions but also provides an aesthetically pleasing recreational environment. Moreover, establishing ecological corridors and landscape buffer zones around Linpans can facilitate wildlife connectivity and migration, further supporting biodiversity conservation. Briefly, the conservation of plant diversity in Linpans should involve ecological restoration, industrial restructuring, and landscape optimization. By implementing sound land-use strategies, enhancing ecosystem stability, and promoting biodiversity, Linpans can achieve long-term sustainability in ecological, economic, and cultural dimensions.

4.2. Limitations

This study has made valuable explorations in the analysis of Linpan settlements with certain limitations remain unexplored. First, the research focuses on Linpans within a specific region, making it challenging to directly generalize the conclusions to other areas with different geographical environments and socio-economic conditions. Second, this research is mainly based on landscape structure analysis with relatively limited consideration of ecological processes such as nutrient cycling, soil health, and species interactions. Future research should explore the dynamic changes in the ecological functions of Linpan ecosystems. Furthermore, the long-term and complex impacts of human activities such as urbanization and policy-driven land use changes on Linpans require ongoing monitoring to fully assess their effects on the ecosystem.

4.3. Strengths

The strengths of this report focus on its systematic approach, which classifies Linpan settlements and clearly illustrates the ecological characteristics and biodiversity potential of different Linpan types. By comparing Linpan settlements with other traditional agricultural landscapes worldwide, the study broadens its relevance and theoretical significance, illustrating that Linpans are not only integral to China’s agricultural ecosystems but also provide valuable insights for global sustainable land management. Furthermore, it shows that Linpan settlements contribute to biodiversity conservation by maintaining species diversity, plant variety, and evenness. This aligns with findings from other traditional agricultural systems such as Japan’s Satoyama and European hedgerow systems, which demonstrate that mixed land-use patterns enhance ecological resilience. In the face of global challenges like biodiversity loss and land degradation, the Linpan model offers valuable strategies for balancing agricultural productivity with ecosystem sustainability.

4.4. Future Direction

The findings of this study have significant implications for future land use planning and ecological conservation. Policymakers and urban planners can utilize these results to develop strategies that prioritize the protection and restoration of Linpan’s natural landscape elements. This is particularly crucial in ecologically fragile regions, where integrating traditional agriculture with ecological conservation can help maintain biodiversity and support rural economic development. Future research should focus on the dynamic interactions between Linpan settlement structure and ecological functions, incorporating remote sensing technology and long-term ecological monitoring to track changes in Linpan settlements. Additionally, the role of community participation in Linpan conservation should be explored, examining ways to balance development and ecological protection. Lastly, given the profound impact of climate change on ecosystems, future studies should further investigate its potential effects on Linpan settlements and develop adaptive strategies to ensure their long-term ecological stability.

5. CONCLUSION

The plant diversity of Linpan settlements serves as a crucial indicator for assessing their ecological stability and sustainable development. Different types of Linpan vary significantly in species richness, community structure, and evenness. However, the reduction of certain natural landscape elements has affected the integrity of landscape units. Farmland, woodland, and water systems are key natural elements emblematic of the traditional agricultural culture of Linpans. Due to anthropogenic disturbances, these elements have diminished or even disappeared in some landscape units. The simplification of landscape unit structures reflects the decline of traditional agricultural practices in some Linpans. These traditional practices have been replaced by new modes of production and living. As a result, intact landscape units are rare and primarily concentrated in agricultural Linpans. Preserving traditional land use patterns can increase the complexity of landscape structures, which not only helps build more stable and high-quality living environments but also plays a significant role in the inheritance and protection of agricultural culture. While most species diversity indices show no significant correlation with the complexity of landscape structures, species richness indices demonstrate a positive correlation with structural complexity. This suggests that the abundance of landscape elements can influence species diversity indices to some extent. Relatively complex landscape units contribute to the stable development of plant communities and the sustainable evolution of Linpans.

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