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Original Research Article

VEGETATION STRUCTURAL CONFIGURATION AND CULTURAL ECOSYSTEM SERVICES IN LINPAN RURAL GREEN SPACES

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A b s t r a c t

Rural green spaces provide important cultural ecosystem services (CES). However, rapid urbanisation and rural transformation are altering vegetation structures and affecting inhabitants' everyday interactions with these spaces. The relationships between vegetation structural configuration (VSC), cultural ecosystem benefits, and actual spatial use remain insufficiently understood. Therefore, this study examines these relationships in two Linpan rural green spaces on the Chengdu Plain, China. An explanatory sequential mixed-methods approach was employed, combining questionnaire data from 190 respondents, Partial Least Squares Structural Equation Modelling (PLS-SEM), 570 behavioural observations, and spatial mapping. Exploratory factor analysis identified two VSC dimensions: Woody Structural Configuration (WSC) and Vegetation Layering and Naturalness (VLN), while cultural ecosystem benefits were represented by Experiences, Capabilities, and Identities. Both VSC dimensions were positively associated with all three benefit dimensions at both study sites, with WSC showing stronger associations, particularly with Capabilities. Behavioural and spatial analyses further revealed that recreation was the dominant form of CES use and that cultural practices were concentrated in vegetation settings associated with inhabitants' everyday activities. By integrating perceptual, behavioural, and spatial evidence, the findings support a conceptual synthesis linking VSC preferences, cultural ecosystem benefits, cultural practices, and actual spatial use. This study extends the application of the Ecosystem Services Cascade Model by providing a spatially explicit interpretation of ecosystem structure and highlights the importance of maintaining diverse, accessible, and functionally meaningful vegetation configurations in rural green space planning.

Keywords: vegetation structural configuration, cultural ecosystem services, Linpan, rural green space

1. INTRODUCTION

Global urbanisation and agricultural intensification have substantially transformed rural landscapes, contributing to the degradation of rural green spaces and the decline of their ecological and cultural

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functions (Mohamad, 2010; Sapawi et al., 2013; Mohamad & Said, 2014; Rahman et al., 2015; Jasmani et al., 2020; Wang et al., 2022; Zhang et al., 2025). Rural green spaces perform multiple ecological, social, recreational, and cultural functions by supporting biodiversity and ecological connectivity while providing settings for everyday activities, social interaction, recreation, and cultural connections with place (Mohamad, 2010; Wang et al., 2021; Wang et al., 2022). Experiences of these environments are also associated with perceived restoration and human well-being (Mohamad, 2000; Ojobo et al., 2015), while their cultural functions contribute to place character, cultural identity, landscape heritage, and traditional ecological knowledge (Mohamad et al., 2010; Danraka et al., 2026). These functions are interconnected through people's ongoing use and experience of green spaces (Mohamad et al., 2010; Keyvanfar et al., 2018). Therefore, understanding rural green spaces from a multifunctional perspective requires consideration of their ecological foundations, spatial characteristics, and interactions with inhabitants.

In this context, vegetation is a key ecological structure of rural green spaces, providing environmental settings that facilitate human–nature interactions (Fish et al., 2016; Kosanic & Petzold, 2020; Xie et al., 2023; He et al., 2025). The spatial characteristics of vegetation can shape how inhabitants perceive, experience, and use these spaces (Fish et al., 2016; Plieninger et al., 2013), with structural characteristics also associated with perceived restoration and well-being (Ojobo et al., 2015). Through their everyday engagement with vegetation and landscape settings, inhabitants derive cultural benefits that can be understood through the concept of Cultural Ecosystem Services (CES) (Millennium Ecosystem Assessment, 2005; de Groot et al., 2010). CES refer to the non-material benefits obtained from ecosystems, including recreation, aesthetic appreciation, social relations, educational value, sense of place, and spiritual experiences (Milcu et al., 2013). However, CES research has largely focused on people's perceptions and valuation, while the ecological structures underlying these benefits remain insufficiently understood (Milcu et al., 2013; Plieninger et al., 2013; Plieninger et al., 2015; Pan & Qu, 2024).

Furthermore, ecosystem services broadly refer to the benefits that people obtain from ecosystems and are commonly classified into provisioning, regulating, supporting, and cultural services (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). The Ecosystem Services Cascade Model further explains how these benefits arise by linking ecosystem structures and functions to ecosystem services, benefits, and ultimately human well-being (Haines-Young & Potschin, 2010; Potschin-Young et al., 2018). Within this framework, conventional indicators such as vegetation cover and canopy cover are useful for describing ecological conditions but provide limited insight into how vegetation is spatially organised and how different settings are perceived, experienced, and used by inhabitants (Dade et al., 2020). Vegetation Structural Configuration (VSC) addresses this limitation by providing a more spatially explicit representation of vegetation arrangement and structural characteristics. The arrangement of trees, bamboo groves, shrubs, ground-layer vegetation, and natural-like areas creates varying degrees of shade, enclosure, openness, accessibility, visual complexity, and naturalness, thereby influencing inhabitants' environmental preferences, cultural practices, and opportunities to obtain cultural ecosystem benefits (Daniel et al., 2012; Chan et al., 2012; Mao et al., 2023). Accordingly, VSC can be conceptualised as an ecological structure underlying the generation of CES within the Cascade Model. However, empirical evidence linking VSC to cultural ecosystem benefits and inhabitants' actual spatial use remains limited, particularly in rural green spaces (Fish et al., 2016; Plieninger et al., 2013).

Linpan rural green spaces on the Chengdu Plain, China, provide a suitable context for examining these relationships because of their distinctive vegetation structural configurations. Linpan integrates settlements, diverse vegetation, and surrounding farmland, forming distinctive vegetation-human

relationships that contribute to the ecological and cultural character of the Chengdu Plain (Zhang et al., 2025). Mature trees, bamboo groves, fruit trees, shrubs, and ground-layer vegetation form diverse settings characterised by varying levels of layering, openness, and spatial configuration, supporting inhabitants' everyday activities, human–nature interactions, and cultural experiences (Zhou et al., 2022; Zhang et al., 2025). However, rapid urbanisation, land-use change, and rural transformation have altered traditional Linpan vegetation structures, potentially affecting how inhabitants interact with and use these spaces (Li et al., 2019; Zhou et al., 2022). Therefore, this study explores the relationships between VSC, cultural ecosystem benefits, and inhabitants' actual spatial use in two representative Linpan rural green spaces. By integrating vegetation preferences, cultural ecosystem benefits, cultural practices, and actual spatial use, the study provides a more spatially explicit understanding of CES and the relationships among ecological structure, human experiences, and everyday cultural practices in rural green spaces.

2. METHODOLOGY

2.1. Study Site

This study was conducted in Song Linpan and Yang Linpan, two representative Linpan rural green spaces located in Tangchang, Pidu District, Chengdu, Sichuan Province, China (Fig.1). The two sites were selected because they exhibit contrasting vegetation structural configurations, providing suitable cases for examining the relationships between VSC and cultural ecosystem benefits.

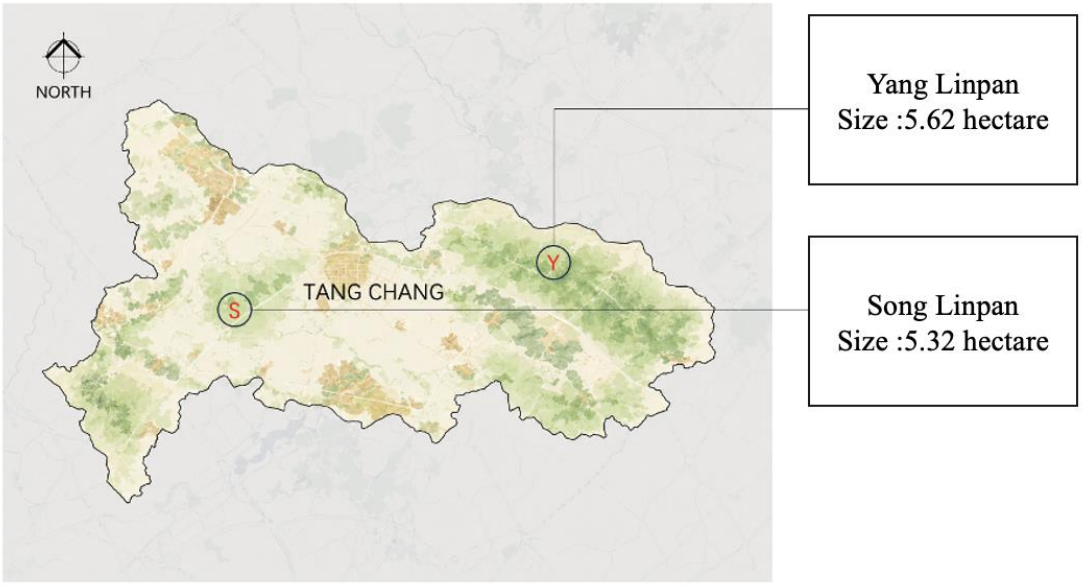


Fig. 1. Location of the study area and spatial characteristics of Song Linpan and Yang Linpan on the Chengdu Plain, China
Source: Authors' elaboration based on spatial data provided by the Pidu District Government, Chengdu, China, 2024

Song Linpan and Yang Linpan were selected because they represent contrasting vegetation structural configurations. Song Linpan (Fig.2) is characterised by a relatively open vegetation structure, with big solitary trees, fruit trees, bamboo groves, and tree clusters forming open and accessible spaces.

In contrast, Yang Linpan (Fig.2) exhibits denser and more vertically layered vegetation, where continuous tree canopies, bamboo groves, and natural-like areas create more enclosed, shaded, and naturalistic settings. These contrasting configurations provide suitable cases for examining the relationships between VSC, cultural ecosystem benefits, and actual spatial use.

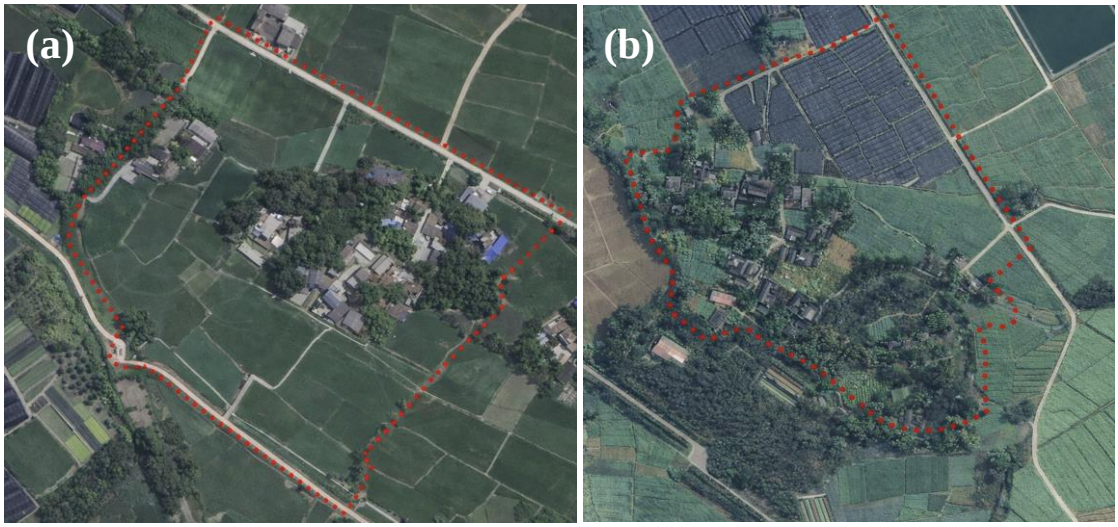


Fig. 2. Site characteristics and vegetation structural configuration of Song Linpan(a) and Yang Linpan(b)
Source: Author

The two study sites share similar climatic conditions, cultural backgrounds, and rural lifestyles but differ substantially in vegetation structural configuration. These contrasting characteristics provide an appropriate opportunity to investigate how different vegetation structural configurations influence cultural ecosystem benefits and their spatial use in Linpan rural green spaces.

2.2. Data Collection

This study used an explanatory sequential mixed-methods design, integrating a structured questionnaire survey with unobtrusive behavioural observation (Creswell & Plano Clark, 2018). The first phase collected quantitative data on inhabitants' preferences for vegetation structural configuration (VSC), cultural activities, and perceived cultural ecosystem benefits. The second phase used unobtrusive behavioural observation and behaviour mapping to document inhabitants' actual activities and spatial use within the Linpan. Integrating the two phases enabled self-reported preferences and perceived benefits to be complemented by evidence of actual spatial behaviour.

2.2.1 Questionnaire Survey

The questionnaire was developed based on a literature review, preliminary interviews, and pilot site observations. It comprised three components: (1) socio-demographic characteristics and patterns of Linpan use; (2) preferences for vegetation structural configuration (VSC), including big and small solitary trees, tree groups and rows, bamboo clusters, fruit trees, tree-species diversity, shrubs, ground-layer vegetation, and natural-like areas; and (3) perceived cultural ecosystem benefits represented by Experiences, Capabilities, and Identities. Preferences for VSC and perceived cultural ecosystem benefits were assessed using a five-point Likert scale ranging from 1 (not important) to 5 (very important). The questionnaire was provided in both Chinese and English to ensure that respondents could clearly

understand the questions. The survey was conducted on-site in Song Linpan and Yang Linpan. Before completing the questionnaire, respondents were informed of the study's purpose, and their participation was voluntary. All returned questionnaires were reviewed, and those containing substantial missing data or invalid responses were excluded. A total of 190 valid questionnaires were retained for analysis, comprising 77 from Song Linpan and 113 from Yang Linpan.

2.2.2 Unobtrusive Behavioural Observation

The second phase of the study employed unobtrusive behavioural observation and behaviour mapping to document inhabitants' everyday cultural practices and actual spatial use of Linpan rural green spaces. A structured observation coding sheet was developed based on the questionnaire survey, preliminary interviews, and pilot observations. Drawing on the systematic observation principles of SOPARC (McKenzie et al., 2006), the observation indicators were adapted to the specific socio-ecological characteristics of Linpan rural green spaces. Systematic observation provides a means of documenting human activities together with the environmental contexts in which they occur (McKenzie et al., 2006). The coding sheet recorded observation time, activity location, vegetation structural configuration (VSC), activity type, inhabitant category, and the corresponding cultural ecosystem service (CES) category. Observations were conducted without direct interaction with inhabitants to minimise interference with their everyday activities. The locations of observed activities were simultaneously recorded on field maps. Three behavioural observations were associated with each questionnaire respondent, resulting in 570 observation records, comprising 231 in Song Linpan and 339 in Yang Linpan. Following the field survey, the behavioural and spatial data were digitised and integrated with VSC data in QGIS to visualise the spatial distribution and concentration of CES use and examine the spatial relationships between vegetation structural configuration, cultural practices, and actual spatial use. The integration of behavioural and spatial information is consistent with socio-cultural approaches that emphasise the spatial dimensions of ecosystem-service assessment (Scholte et al., 2015).

2.3. Data Analysis

Data analysis was carried out in three stages. Firstly, descriptive statistics were used to summarise respondents' socio-demographic characteristics, patterns of Linpan use, everyday activities, and preferences for different vegetation structural configurations. Secondly, Exploratory Factor Analysis (EFA) was performed to identify the underlying dimensions of VSC preferences and cultural ecosystem benefits. The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity were used to determine whether the data were suitable for factor analysis. The resulting constructs were then examined using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 3.0. The measurement model was evaluated based on indicator loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). The structural model was assessed using path coefficients (β), coefficients of determination (R^2), t-values, and significance levels (Hair et al., 2019). Separate models were developed for Song Linpan and Yang Linpan to examine the relationships between VSC and cultural ecosystem benefits under their respective vegetation settings. Thirdly, the behavioural observation data were organised according to activity type, associated VSC, and CES category. Six CES categories were considered: recreation, social relations, sense of place, educational value, aesthetic appreciation, and spiritual experiences. The locations of observed activities were subsequently mapped in QGIS to illustrate the spatial distribution and areas of concentrated CES use within the two Linpan sites. Finally, questionnaire, PLS-SEM, behavioural, and spatial findings were interpreted together to examine the relationships among VSC preferences, cultural ecosystem benefits, cultural practices, and actual spatial use.

3. RESULTS AND DISCUSSION

3.1 Vegetation Structural Configuration and Cultural Ecosystem Benefit Constructs

Exploratory factor analysis identified two distinct but complementary dimensions of inhabitants' preferences for vegetation structural configuration (VSC): Woody Structural Configuration (WSC) and Vegetation Layering and Naturalness (VLN). Cultural ecosystem benefits were represented by three dimensions: Experiences, Capabilities, and Identities. These constructs provide the basis for examining the relationships between VSC preferences and cultural ecosystem benefits in the subsequent PLS-SEM analysis.

3.1.1 Factor Structure of Vegetation Structural Configuration

Exploratory factor analysis of the ten vegetation preference indicators identified two latent constructs: Woody Structural Configuration (WSC) and Vegetation Layering and Naturalness (VLN). Together, these two constructs explained 63.943% of the total variance, with WSC accounting for 34.367% and VLN for 29.576%. WSC comprised seven indicators: bamboo clusters, big solitary trees, tree-species diversity, groups of trees, rows of trees, fruit trees, and small solitary trees. Bamboo clusters showed the highest factor loading (0.889), followed by big solitary trees (0.871). WSC exhibited satisfactory internal consistency (Cronbach's $\alpha = 0.897$) (Table 1). The grouping of these indicators within a single construct indicates that inhabitants tend to perceive woody vegetation as an interconnected structural component of Linpan rural green spaces rather than as a set of independent vegetation elements. VLN comprised three indicators: ground-layer vegetation, natural-like areas, and shrubs, with factor loadings of 0.788, 0.786, and 0.705, respectively. This construct also demonstrated satisfactory internal consistency (Cronbach's $\alpha = 0.789$). Collectively, these vegetation elements reflect the lower vegetation layers and naturalistic characteristics of Linpan rural green spaces.

Table. 1. Factor loadings of items measuring inhabitants' preferences for vegetation structural configuration
Source：Author

Construct	Indicator	Factor loading	Cronbach's Alpha
Woody Structural Configuration	Bamboo cluster	0.889	0.897 (N=190)
	Big solitary trees	0.871	
	Diversity of tree species	0.860	
	Group of trees	0.823	
	Fruit trees	0.795	
	Row of trees	0.810	
	Small solitary trees	0.741	
Vegetation Layering and Naturalness	Ground layer	0.788	0.789 (N=190)
	Shrub	0.786	
	Natural-like area	0.705	

3.1.2 Measurement Model Reliability and Validity

A second exploratory factor analysis identified the underlying dimensions of cultural ecosystem benefits experienced by Linpan inhabitants. The Kaiser–Meyer–Olkin (KMO) value was 0.912, and Bartlett's test of sphericity was statistically significant ($p < 0.001$), indicating that the data were suitable for factor analysis. The fourteen cultural benefit items were grouped into three latent constructs: Experiences,

Capabilities, and Identities (Table 2). These dimensions broadly correspond to the cultural ecosystem benefit framework proposed by Church et al. (2014) and subsequently applied in CES research (Fish et al., 2016; Bryce et al., 2016). Experiences represent sensory and affective benefits derived from interactions with Linpan environments, including natural scenery, tranquillity, vegetation, and environmental sounds. Capabilities reflect opportunities for recreation and everyday cultural practices, including the use of shaded spaces, harvesting, and bamboo-related activities. Identities represent longer-term relational and cultural benefits associated with place attachment, social connections, cultural identity, and traditional knowledge. The reliability and convergent validity of all five latent constructs were then assessed before estimating the structural relationships between VSC and cultural ecosystem benefits. Across both study sites, all constructs exhibited Cronbach's alpha and composite reliability (CR) values above the recommended threshold of 0.70, while all average variance extracted (AVE) values exceeded 0.50, indicating satisfactory internal consistency and convergent validity (Hair et al., 2019). For Yang Linpan, CR values ranged from 0.818 for Vegetation Layering and Naturalness (VLN) to 0.928 for Woody Structural Configuration (WSC), while AVE values ranged from 0.532 to 0.721. Experiences, Capabilities, and Identities also demonstrated satisfactory reliability and convergent validity, with CR values of 0.874, 0.886, and 0.852, respectively. Comparable results were obtained for Song Linpan (Table 2), supporting the adequacy of the measurement constructs for subsequent structural model assessment. Overall, the factor analysis and measurement model assessment identified two VSC constructs (WSC and VLN) and three cultural ecosystem benefit constructs (Experiences, Capabilities, and Identities), providing a basis for examining their structural relationships across the two Linpan sites.

Table. 2. Reliability and validity of constructs
Source：Author

Study Site	Construct	Cronbach's Alpha	Composite Reliability	Average Variance Extracted	Assessment
Yang Linpan	Experiences	0.831	0.874	0.635	Acceptable
	Capabilities	0.843	0.886	0.661	Acceptable
	Identities	0.806	0.852	0.591	Acceptable
	Vegetation Layering and Naturalness	0.757	0.818	0.532	Acceptable
	Woody Structural Configuration	0.906	0.928	0.721	Acceptable
Song Linpan	Experiences	0.811	0.856	0.598	Acceptable
	Capabilities	0.819	0.863	0.613	Acceptable
	Identities	0.816	0.859	0.605	Acceptable
	Vegetation Layering and Naturalness	0.888	0.867	0.620	Acceptable
	Woody Structural Configuration	0.821	0.914	0.681	Acceptable

3.2 Effects of Vegetation Structural Configuration on Cultural Ecosystem Benefits

The structural models were then assessed to examine the relationships between the two VSC dimensions (WSC and VLN) and the three cultural ecosystem benefit dimensions (Experiences, Capabilities, and Identities). Separate models were estimated for Yang Linpan and Song Linpan to compare these relationships across contrasting vegetation structural configurations.

3.2.1 Structural Relationships in Yang Linpan

The structural model for Yang Linpan showed that WSC and VLN jointly explained 31.1% of the variance in Capabilities ($R^2 = 0.311$), 26.3% in Experiences ($R^2 = 0.263$), and 21.9% in Identities ($R^2 = 0.219$). Therefore, the model showed the highest proportion of explained variance for Capabilities, followed by Experiences and Identities (Fig. 3).

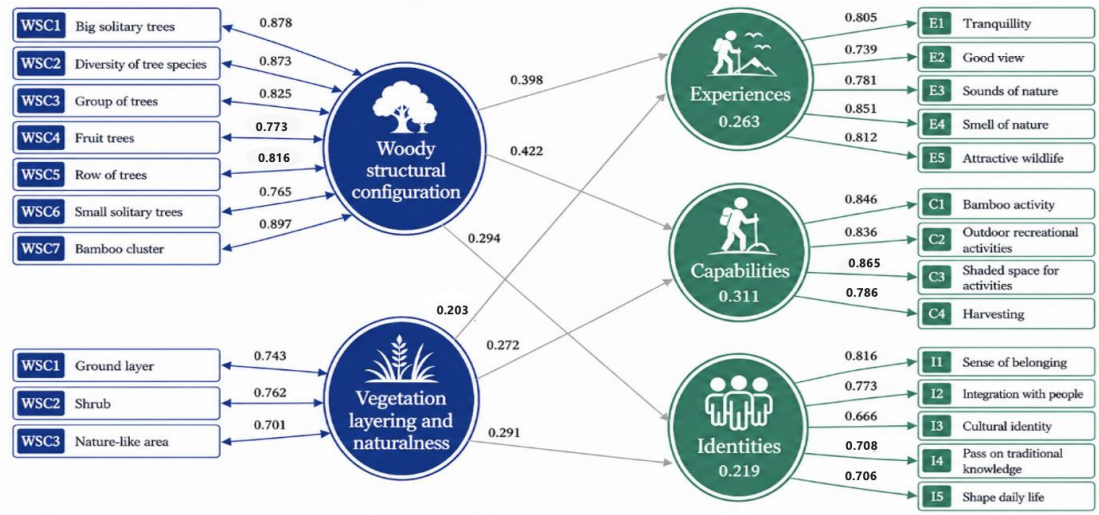


Fig. 3. PLS-SEM structural model for Yang Linpan.
Source: Author

All six structural relationships were positive and statistically significant. WSC showed the strongest relationship with Capabilities ($\beta = 0.422$, $t = 2.925$, $p = 0.003$), followed by Experiences ($\beta = 0.398$, $t = 2.922$, $p = 0.003$) and Identities ($\beta = 0.294$, $t = 3.283$, $p = 0.001$). VLN was also positively associated with all three benefit dimensions, although its relationships were comparatively weaker (Table 3). Overall, WSC showed stronger associations with cultural ecosystem benefits, particularly Capabilities. This finding is consistent with the spatial characteristics of vegetation in Yang Linpan. Continuous tree canopies, extensive bamboo clusters, and multilayered vegetation together create well-shaded and relatively enclosed spaces that provide suitable conditions for recreation, resting, harvesting, and other everyday activities. The relationship between WSC and Capabilities further indicates that the structural characteristics of woody vegetation are closely associated with opportunities for inhabitants to engage in cultural practices. In addition, the significant relationships of WSC with Experiences and Identities suggest that woody vegetation is associated not only with inhabitants' immediate perceptions and experiences of the environment, but also with longer-term place-based connections and cultural meanings. Although VLN showed comparatively weaker relationships, shrubs, ground layer, and natural like area complement these benefits by increasing vertical vegetation complexity, environmental diversity, and the perceived naturalness of the green space. This interpretation is consistent with relational approaches to CES, which emphasise that cultural benefits emerge through interactions

between environmental characteristics, human practices, and situated experiences (Fish et al., 2016; Raymond et al., 2018).

Table. 3. Results of structural path analysis for Yang Linpan
Source: Author

Yang Linpan				
Construct	β	t-value	p-value	Result
Woody Structural Configuration -Capabilities	0.422	2.925	0.003	Significant
Woody Structural Configuration -Experiences	0.398	2.922	0.003	Significant
Woody Structural Configuration -Identities	0.294	3.283	0.001	Significant
Vegetation Layering and Naturalness -Capabilities	0.272	2.524	0.012	Significant
Vegetation Layering and Naturalness -Experiences	0.203	2.021	0.043	Significant
Vegetation Layering and Naturalness -Identities	0.219	2.223	0.026	Significant

Note: A path is considered statistically significant when $t > 1.96$ and $p < 0.05$

3.2.2 Structural Relationships in Song Linpan

The structural model for Song Linpan revealed a broadly similar pattern to that of Yang Linpan. WSC and VLN jointly explained 32.0% of the variance in Capabilities ($R^2 = 0.320$), 26.0% in Identities ($R^2 = 0.260$), and 22.2% in Experiences ($R^2 = 0.222$). The model therefore showed the greatest explanatory power for Capabilities (Fig. 4).

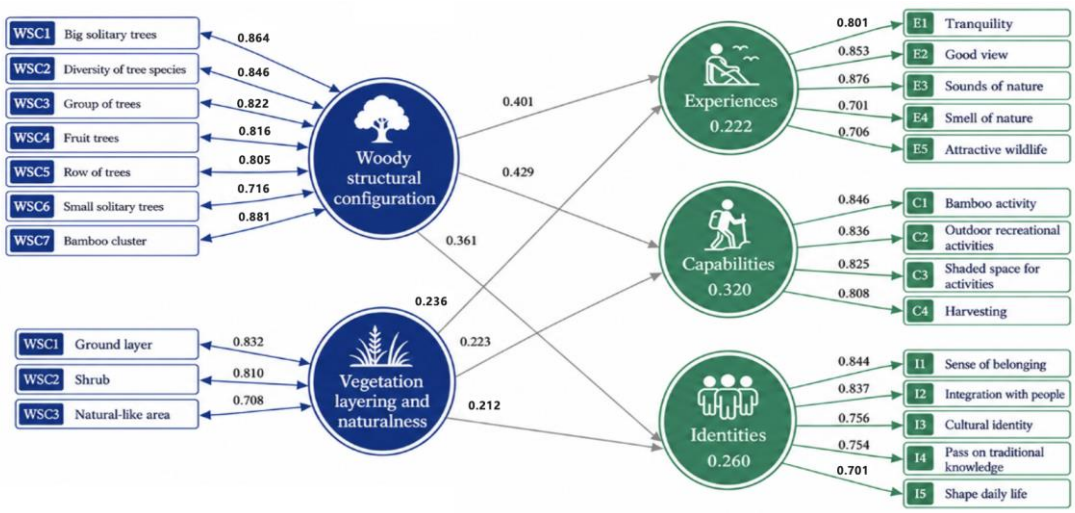


Fig. 4. PLS-SEM structural model for Song Linpan
Source: Author

All six structural relationships were positive and statistically significant. WSC showed the strongest relationship with Capabilities ($\beta = 0.429$, $t = 3.403$, $p = 0.001$), followed by Experiences ($\beta = 0.401$, $t = 2.985$, $p = 0.003$) and Identities ($\beta = 0.361$, $t = 2.225$, $p = 0.026$). VLN was also positively

associated with Experiences (β = 0.236, t = 2.221, p = 0.026), Capabilities (β = 0.223, t = 2.031, p = 0.042), and Identities (β = 0.212, t = 2.202, p = 0.028). Overall, WSC showed stronger relationships with all three cultural ecosystem benefit dimensions than VLN, particularly with Capabilities (Table 4).

Table. 4. Results of structural path analysis for Song Linpan
Source: Author

Song Linpan				
Construct	β	t-value	p-value	Result
Woody Structural Configuration -Capabilities	0.429	3.403	0.001	Significant
Woody Structural Configuration -Experiences	0.401	2.985	0.003	Significant
Woody Structural Configuration -Identities	0.361	2.225	0.026	Significant
Vegetation Layering and Naturalness -Capabilities	0.223	2.031	0.042	Significant
Vegetation Layering and Naturalness -Experiences	0.236	2.221	0.026	Significant
Vegetation Layering and Naturalness -Identities	0.212	2.202	0.028	Significant

Note: A path is considered statistically significant when $t > 1.96$ and $p < 0.05$

The WSC–Capabilities relationship indicates that woody vegetation structures are strongly associated with opportunities for inhabitants to engage in everyday cultural practices, including outdoor recreation, the use of shaded spaces, harvesting, and bamboo-related activities. However, the vegetation setting in Song Linpan differs from that in Yang Linpan. Song Linpan is characterised by a comparatively open vegetation structure, where big solitary trees, tree groups, bamboo clusters, and fruit trees form accessible vegetation nodes within everyday activity spaces. This suggests that cultural benefits do not necessarily depend on dense or continuous vegetation cover; accessible and spatially distributed woody vegetation can also provide suitable settings for everyday cultural practices. The significant relationships between WSC and both Experiences and Identities indicate that woody vegetation structure is associated not only with inhabitants' perceptions and experiences of the surrounding environment but also with longer-term place-related cultural benefits. Although VLN exhibited comparatively weaker associations, its significant relationships with all three benefit dimensions suggest that vegetation layering and naturalness contribute to the cultural ecosystem benefits experienced by inhabitants (Daniel et al., 2012; Fish et al., 2016; Raymond et al., 2018; Mao et al., 2023).

3.2.3 Cross-site Comparison of Vegetation structural configuration and Benefit Relationships

A comparison of the structural models for Yang Linpan and Song Linpan revealed a similar overall pattern despite clear differences in their vegetation structural configurations. The models explained the largest proportion of variance in Capabilities at both sites, with R^2 values of 0.311 for Yang Linpan and 0.320 for Song Linpan. Similarly, the WSC–Capabilities relationship exhibited the largest path coefficient in both models, with values of 0.422 and 0.429, respectively. This common pattern indicates that woody vegetation structure is closely associated with environmental conditions and opportunities that enable inhabitants to engage in everyday cultural practices. Despite these similarities, some

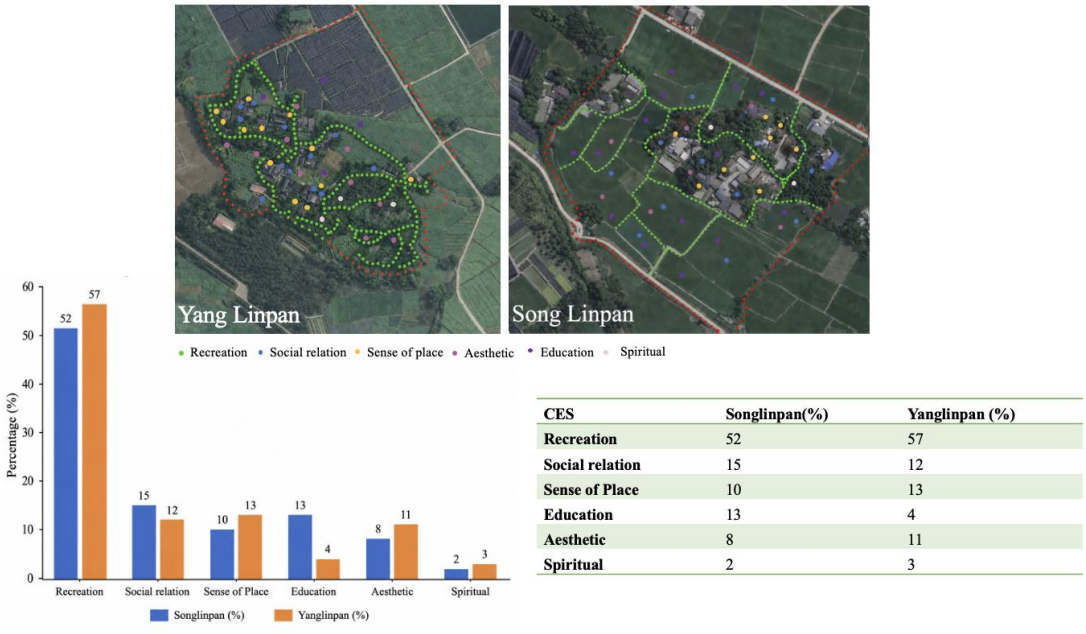
differences were evident between the two sites. In Yang Linpan, the model explained a greater proportion of variance in Experiences than in Identities ($R^2 = 0.263$ vs. 0.219), whereas the opposite pattern was observed in Song Linpan ($R^2 = 0.222$ vs. 0.260). These differences related to the distinct vegetation settings of the two sites. The denser and more continuous vegetation structure of Yang Linpan is more closely associated with direct sensory and environmental experiences. In contrast, the more open and accessible vegetation configuration of Song Linpan provides greater opportunities for frequent everyday activities and sustained interactions with place, which, in turn, are associated with place-related benefits. Such context-dependent relationships are consistent with the relational perspective of CES, which emphasises interactions among people, environmental settings, and cultural practices (Fish et al., 2016; Raymond et al., 2017). Based on the results from both sites, WSC exhibited stronger associations with Experiences, Capabilities, and Identities than VLN. Notably, this common pattern remained evident despite the contrasting vegetation structures of the two sites: Yang Linpan is characterised by denser, more continuous, and multilayered vegetation, whereas Song Linpan exhibits a more open and accessible spatial configuration. These findings suggest that cultural ecosystem benefits are associated not only with vegetation quantity or canopy cover but also with how vegetation is spatially configured and encountered through everyday activities (Plieninger et al., 2013; Fish et al., 2016; Raymond et al., 2018). Furthermore, these findings support the conceptualisation of VSC as a spatially explicit representation of ecosystem structure through which cultural ecosystem benefits emerge from interactions between ecological settings and human practices (Haines-Young & Potschin, 2010). The consistently larger WSC–Capabilities path coefficients observed in both models suggest that opportunities for cultural practices represent an important link between vegetation structure and cultural ecosystem benefits. However, as mediation was not statistically tested, this relationship should be interpreted conceptually rather than as an established mediating pathway.

3.3 The Spatial Actual Using of Cultural Ecosystem Services

Behavioural observations and spatial mapping were further used to examine how the relationships identified through PLS-SEM were reflected in inhabitants' cultural practices and actual spatial use of Linpan rural green spaces. A total of 570 behavioural observations were recorded in the two study sites, comprising 231 observations in Song Linpan and 339 in Yang Linpan. Observed activities were classified into six CES categories: recreation, social relations, sense of place, educational value, aesthetic appreciation, and spiritual experiences.

3.3.1 Spatial Patterns of Cultural Ecosystem Service Use

Recreation represented the dominant form of CES use in both Linpan sites (Fig. 5), accounting for 52% of observations in Song Linpan and 57% in Yang Linpan. In Song Linpan, recreation was followed by social relations (15%), educational value (13%), sense of place (10%), aesthetic appreciation (8%), and spiritual experiences (2%). In Yang Linpan, sense of place (13%) and social relations (12%) constituted the next largest categories, followed by aesthetic appreciation (11%), educational value (4%), and spiritual experiences (3%).



CES	Songlinpan(%)	Yanglinpan (%)
Recreation	52	57
Social relation	15	12
Sense of Place	10	13
Education	13	4
Aesthetic	8	11
Spiritual	2	3

Fig. 5. Composite maps and percentage distribution of cultural ecosystem service in Song and Yang Linpan
Source: Author

The predominance of recreation across both sites indicates that Linpan rural green spaces function primarily as settings for everyday activities rather than solely as landscapes for passive appreciation. Walking, resting, informal outdoor activities, and other forms of daily recreation were embedded in spaces routinely used by inhabitants. This pattern is consistent with the PLS-SEM results, in which Capabilities exhibited the highest proportion of explained variance in both Yang Linpan and Song Linpan. Together, these findings suggest that an important cultural contribution of vegetation structural configuration lies in the opportunities it provides for inhabitants to engage in everyday activities. Nevertheless, differences between the two sites indicate that contrasting vegetation structural configurations are associated with different combinations of CES. Song Linpan exhibited relatively higher proportions of social relations and educational value, whereas Yang Linpan exhibited higher proportions of recreation, aesthetic appreciation, sense of place, and spiritual experiences. These differences suggest that CES use is shaped not only by the presence of vegetation but also by the spatial and structural characteristics of the settings in which everyday activities occur (Church et al., 2014; Plieninger et al., 2013; Fish et al., 2016; Dade et al., 2020; Zuo & Zhou, 2023).

3.3.2 Vegetation Structural Configuration and Spatial Patterns of CES Use

Spatial mapping revealed that CES use was unevenly distributed across the two Linpan sites, with activities concentrated in specific vegetation settings. In Song Linpan (Fig. 6), four main areas of concentrated activity (A–D) were identified. These hotspots were associated with relatively open and accessible vegetation settings, where big solitary trees, tree groups, and bamboo clusters provided localised shade within a spatially permeable landscape. Recreational and social activities were frequently observed in these accessible settings, suggesting that open woody vegetation configurations can support everyday cultural practices by providing shade, accessibility, and spatial connectivity. These patterns are consistent with the view that accessibility and opportunities for repeated interaction play

important roles in translating environmental settings into cultural ecosystem benefits (Church et al., 2014; Raymond et al., 2018; Valánszki et al., 2022; Crouzat et al., 2022).

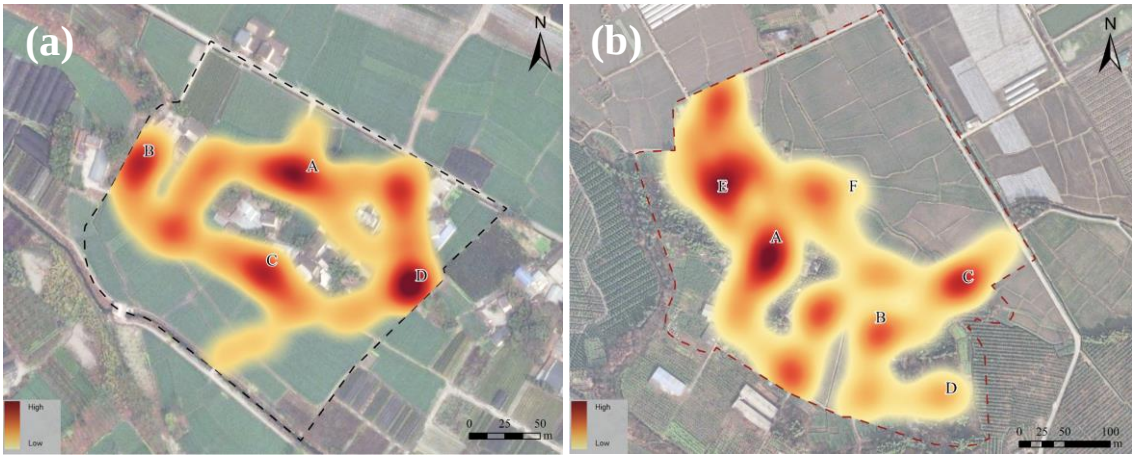


Fig. 6. Hotpots maps of Song Linpan CES (a) and Yang Linpan (b)
Source: Author

In Yang Linpan (Fig. 6), six activity hotspots (A–F) were identified within a comparatively denser and more multilayered vegetation structure. Activities were concentrated around settings characterised by continuous tree canopies, bamboo clusters, tree groups, and relatively enclosed vegetation spaces. These settings provided shaded and visually complex environments associated with recreation and other cultural practices. The spatial concentration of activities further indicates that even within a relatively densely vegetated landscape, actual CES use occurs primarily in specific vegetation settings that are accessible and usable rather than being evenly distributed throughout the site (Daniel et al., 2012; Fish et al., 2016; Mao et al., 2023).

Comparison of the two sites revealed contrasting spatial patterns of CES use. Song Linpan was characterised by relatively open and accessible woody vegetation nodes, whereas Yang Linpan provided more continuous, shaded, and multilayered vegetation settings. Despite these differences, both sites showed clear concentrations of activities around particular woody vegetation structures. This spatial pattern corresponds with the PLS-SEM results, in which WSC showed its strongest relationship with Capabilities at both sites, suggesting that woody vegetation is particularly relevant when its structural configuration provides opportunities for inhabitants' everyday cultural practices. In sum, the findings indicate that no single vegetation configuration supports all forms of CES equally. Rather, different structural configurations provide different environmental conditions and opportunities for cultural practices. The cultural value of Linpan rural green spaces therefore appears to depend on maintaining diverse, accessible, and usable vegetation structural configurations, rather than increasing vegetation density alone. This supports a spatially explicit interpretation of CES in which vegetation structure becomes culturally relevant through its relationship with inhabitants' everyday practices and actual spatial use (Plieninger et al., 2013; Fish et al., 2016; Gugulica & Burghardt, 2023).

3.3.3 Linking Perceived Benefits with Actual Spatial Use

The questionnaire and behavioural findings collectively indicate complementary relationships among vegetation structural configuration (VSC), inhabitants' preferences, cultural ecosystem benefits, cultural practices, and actual spatial use. PLS-SEM showed that preferences for both Woody Structural

Configuration (WSC) and Vegetation Layering and Naturalness (VLN) were positively associated with Experiences, Capabilities, and Identities, with WSC exhibiting the strongest association with Capabilities. Behavioural observations provided further insights into how these relationships were reflected in inhabitants' everyday practices and spatial use. Activities such as walking, resting, social interaction, and nature observation were concentrated in specific vegetation settings. Although vegetation configurations differed between Song Linpan and Yang Linpan, both sites exhibited spatial associations between cultural practices, CES use, and vegetation settings encountered in everyday life.These findings support the following conceptual synthesis: VSC Preferences → Cultural Ecosystem Benefits → Cultural Practices → Actual Spatial Use of CES

This conceptual synthesis extends the interpretation of the Ecosystem Services Cascade Model by integrating preferences for vegetation structural configuration, cultural ecosystem benefits, everyday practices, and spatial use (Haines-Young & Potschin, 2010; Church et al., 2014; Fish et al., 2016; Potschin-Young et al., 2018; Raymond et al., 2018). PLS-SEM directly tested the relationships between VSC preference constructs and cultural ecosystem benefit constructs, while behavioural observations and spatial mapping provided complementary evidence of cultural practices and actual spatial use. The proposed sequence should therefore be interpreted as an integrated conceptual framework supported by perceptual, behavioural, and spatial evidence, rather than as a statistically validated causal or mediating pathway.

3.4 Limitations

This study has several limitations. First, it focused on two Linpan rural green spaces on the Chengdu Plain, and the applicability of the findings to other rural contexts requires further investigation. Second, the questionnaire survey and behavioural observations were conducted within a specific period and therefore did not fully capture seasonal variations in vegetation conditions and inhabitants' spatial use. In addition, although PLS-SEM identified significant relationships between VSC preferences and cultural ecosystem benefits, the subsequent links to cultural practices and actual spatial use were interpreted using complementary behavioural and spatial evidence rather than being tested as a complete causal pathway. Therefore, the proposed pathway should be regarded as a conceptual synthesis rather than a statistically validated causal relationship.

3.5 Strengths

A key strength of this study lies in the integration of perceptual, behavioural, and spatial evidence to examine the relationships between vegetation structural configuration and cultural ecosystem services. By combining inhabitants' VSC preferences and perceived cultural ecosystem benefits with PLS-SEM, behavioural observations, and spatial mapping, the study extends beyond perception-based assessment to consider cultural practices and their actual spatial use. In addition, the comparison of two Linpan sites with contrasting vegetation structures provides insights into how different vegetation configurations are associated with CES. In sum, this integrated approach connects inhabitants' perceptions with observed behaviour and spatial use, providing a more comprehensive understanding of how vegetation structural configuration relates to cultural ecosystem benefits in rural green spaces.

3.6 Future Direction

Future research could extend this framework to a broader range of rural green spaces with different ecological, cultural, and socio-spatial characteristics to further assess the applicability of the findings. Seasonal and longitudinal studies could also examine how vegetation structure, inhabitants' activities,

and cultural ecosystem benefits change over time. Building on these findings, future studies could use larger samples and integrated structural models to further investigate the relationships among VSC preferences, cultural ecosystem benefits, cultural practices, and actual spatial use. Combining longitudinal behavioural observations with participatory mapping and qualitative interviews could provide a deeper understanding of the connections between inhabitants' perceptions, everyday practices, and spatial use, while informing rural vegetation planning that considers both ecological quality and inhabitants' cultural needs.

4. CONCLUSION

This study explored the relationships among vegetation structural configuration (VSC), cultural ecosystem benefits, and inhabitants' actual spatial use in Linpan rural green spaces. The findings showed that both Woody Structural Configuration (WSC) and Vegetation Layering and Naturalness (VLN) were positively associated with Experiences, Capabilities, and Identities, with WSC showing consistently stronger associations, particularly with Capabilities. Behavioural observations and spatial mapping further revealed that recreation was the dominant form of CES use at both sites and that cultural practices were concentrated in specific vegetation settings characterised by shade, accessibility, and usability. Despite differences in vegetation structure between the two Linpan sites, the findings indicate that cultural ecosystem benefits are associated not only with vegetation quantity but also with its spatial configuration and relationship with inhabitants' preference and everyday activities.

By integrating perceptual, behavioural, and spatial evidence, this study conceptualises VSC as a spatially explicit ecological structure within the Ecosystem Services Cascade Model and proposes a conceptual linkage among VSC preferences, cultural ecosystem benefits, cultural practices, and actual spatial use. This extends CES research beyond perception and valuation towards a more integrated understanding of inhabitants' everyday practices and spatial use. The findings also suggest that rural green space planning should consider not only vegetation cover or density but also structural diversity, accessibility, shading, and their relationships with everyday activities. Future research could extend this approach to a broader range of rural green spaces and incorporate seasonal and longitudinal observations to further examine the relationships among VSC, cultural ecosystem benefits, cultural practices, and actual spatial use.

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