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Comprehensive assessment of spatial quality in traditional village landscapes of the Yuanshui River Basin using semantic differential and Entropy Weight Methods

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The Yuanshui River Basin's traditional villages face significant threats of degradation and homogenization due to rural construction, suburban expansion, and agricultural modernization, endangering their cultural heritage, agrarian identity, and ecological diversity. This study proposes a robust framework for evaluating the spatial quality of traditional village landscapes, combining the Semantic Differential (SD) method with the Entropy Weight Method (EWM). Six core landscape components—traditional architecture, water bodies, roads, agricultural areas, vegetation, and environmental psychological landscapes—were analyzed. Subjective perceptions were captured through structured surveys and interviews, utilizing carefully designed semantic differential scales. Statistical analysis demonstrated high reliability (Cronbach's α = 0.747) and validity (KMO = 0.836; Bartlett's test of sphericity, $p < 0.001$). The entropy weights ranked the landscape components as follows: traditional architectural landscape (2.429), environmental psychological landscape (2.183), vegetation landscape (2.159), waterbody landscape (1.530), agricultural landscape (1.522), and road landscape (1.052). Regression analysis revealed a strong correlation between the SD and EWM methods (SD = –1.284 + 7.622EWM), and the average SD score (0.787) reflected favorable spatial quality in the basin's traditional villages. The results highlight tranquility, abundant vegetation, layered plant structures, and natural aesthetics as critical elements of spatial quality. These findings provide valuable insights for landscape conservation strategies and rural policy development.

KEYWORDS

spatial quality, traditional village landscapes, semantic differential, entropy weight, heritage preservation, landscape management

1 Introduction

Traditional villages serve as crucial reservoirs of cultural and architectural heritage, encapsulating the essence of historical epochs and embodying extensive intangible cultural assets (Chen et al., 2023; Liu et al., 2023; Zheng et al., 2021). Their preservation is often facilitated by geographical conditions, such as rugged topography and limited transportation infrastructure, which foster relatively isolated and self-sustaining environments. These factors have allowed numerous ancient villages to retain their original spatial and cultural configurations largely intact (Li et al., 2023; Zhou and Huang, 2023; Zhu et al., 2023). Such settlements are distinguished by unique locational attributes and a variety of landscape elements, including waterfront settings, agricultural fields, vernacular architecture, and forested surroundings, all of which collectively reinforce their strong regional identities (Cai et al., 2020; Liu et al., 2020). Social organization in these communities is traditionally centered on clan-based systems, fostering mutual support and cooperative development among kin groups. Architecturally, these villages predominantly showcase timber-framed, brick-and-timber, and rammed earth constructions, with typologies that include tile-roofed houses, wooden dwellings, and earth-built structures. They are also rich in historical artifacts, such as ancient bridges and historic pagodas, which contribute to their cultural depth. The lifestyles of residents remain intricately connected to traditional customs, as evidenced by the continuity of handicrafts, festivals, and agricultural practices, reflecting a deep-rooted adherence to cultural traditions (Wang et al., 2021; Zhuang et al., 2022).

The Semantic Differential (SD) method, pioneered by American psychologist Charles Egerton Osgood in 1957, has gained widespread application in the social sciences for capturing nuanced subjective experiences (Cho et al., 2019; Huang et al., 2012; Iwanami et al., 2011). This method quantifies individuals' attitudes, emotions, and evaluations toward specific subjects by employing bipolar adjective pairs, such as "good-bad" or "satisfied-dissatisfied" (Kurtaliqi et al., 2022). Participants rate entities along these opposing scales, and the resulting scores are analyzed to construct a comprehensive representation of subjective perceptions (Smirnova and Serkin, 2020). The SD method's adaptability has enabled its application across diverse landscape evaluations, including parks, university campuses, cultural districts, industrial zones, waterfronts, hospital exteriors, airport terminals, rural homestays, and green spaces (Cao and Huang, 2023; Ren, 2024; Zeng et al., 2024).

Comparative studies underscore the SD method's efficacy in landscape assessments, particularly in fostering culturally sensitive approaches (Kim and Kang, 2009). Integrating the SD method with complementary analytical frameworks has proven instrumental in capturing complex subjective evaluations in landscape studies (Li et al., 2024; Xu et al., 2024). In rural and urban contexts alike, the SD method has been extensively employed, notably in assessing traditional village landscapes within China's Jiangnan region (Zhao et al., 2022). For instance, research in Wuzhen Ancient Town engaged residents through questionnaires and interviews to assess how village landscapes influence emotional responses, cognitive evaluations, and attitudinal shifts, yielding insights into potential landscape enhancements. Despite its robust applicability, existing studies predominantly focus on individual case studies and lack regional breadth, with evaluation indicator weighting often based on subjective criteria. This limitation compromises the scientific rigor and objectivity of current evaluations, signaling a need for broader, regionally representative studies employing more rigorous methodological frameworks.

To address these challenges, the Entropy Weight Method (EWM) has emerged as a robust quantitative approach, complementing subjective assessment methods. Rooted in information entropy theory, EWM assigns objective weights to evaluation indicators by calculating the entropy values of each factor, thereby minimizing subjective bias (Liang et al., 2022). Both internationally and domestically, EWM has been successfully integrated with methods such as the Analytic Hierarchy Process (AHP) (Wang et al., 2020), Scenic Beauty Estimation (SBE) (Wang et al., 2024), the Pressure-State-Response (PSR) model, the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and the G1 method (Ding et al., 2024). Its applications span diverse domains, including risk management, resource allocation, decision-making, product quality assessment, rural revitalization, and natural landscape evaluation (Di et al., 2024; Xie et al., 2020; Yadollahi et al., 2012). Nevertheless, EWM's efficacy can be constrained by data quality sensitivity, and it may not fully capture interdependencies among indicators (Xu et al., 2023).

Given these considerations, this study presents an integrative framework that combines the SD method with EWM to evaluate the spatial quality of traditional villages in the Yuanshui River Basin, Hunan Province, China. This novel approach seeks to enhance the objectivity and comprehensiveness of landscape assessments by merging subjective perceptual analysis with quantitative weighting mechanisms. The outcomes of this research aim to establish a foundational model for sustainable development and strategic planning of traditional village landscapes, advancing both theoretical research and practical applications in rural heritage conservation and landscape design.

2 Materials and methods

2.1 Case study

The Yuanshui River Basin, located in Hunan Province, China, spans approximately 60,000 square kilometers and includes diverse regions such as Huaihua City, the Xiangxi Tujia and Miao Autonomous Prefecture, Changde City, Hanshou County, Taoyuan County, Yuanjiang City (Yiyang), and Suining and Chengbu Counties within Shaoyang (Figure 1). This expansive basin features a complex hydrological network composed of multiple tributaries, including the Wushui, Youshui, Chenshui, Qushui, and Xushui Rivers, as well as numerous smaller branches. The eastern and southern perimeters of the basin are bounded by the prominent Xuefeng Mountains, while the western boundary meets the Guizhou Plateau. The northern region is characterized by mid-sized mountains, low hills, and undulating terrain, culminating in a geomorphologically diverse landscape.

To ensure the robustness of the evaluation, the sample for this study was carefully selected to represent the diversity of traditional

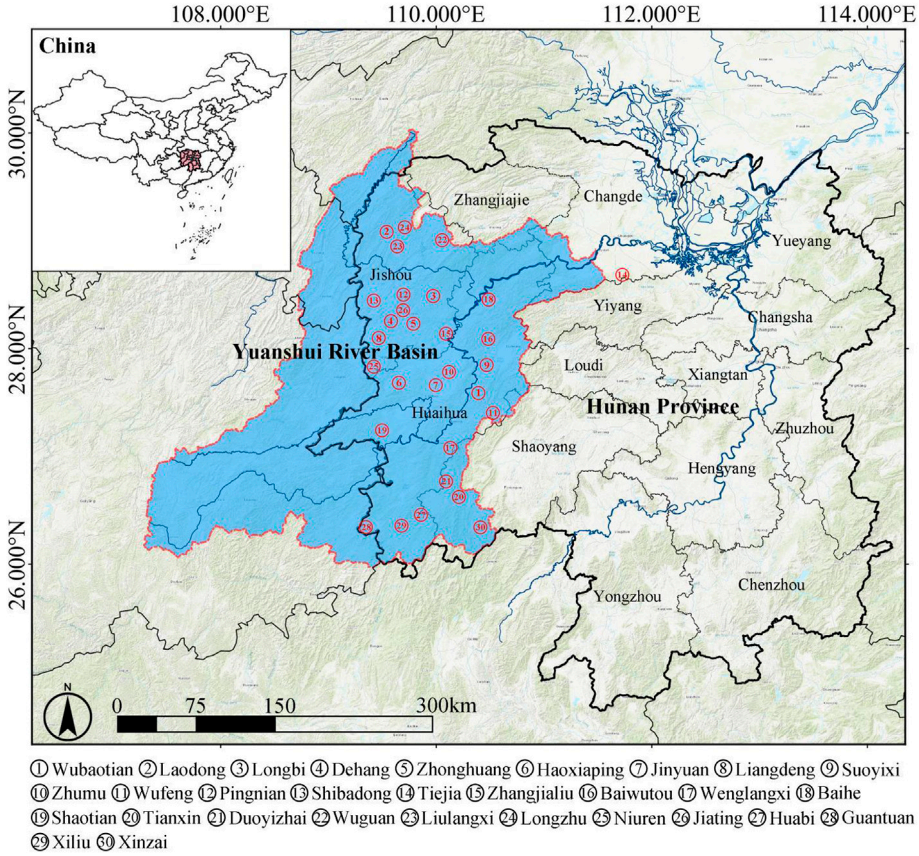

FIGURE 1
Study area.

village landscapes within the Yuanshui River Basin. A total of 30 villages were chosen based on their geographic distribution, cultural significance, and varying levels of preservation—Wubaotian, Laodong, Longbi, Dehang, Zhonghuang, Haoxiaping, Jinyuan, Liangdeng, Suoyixi, Zhumu, Wufeng, Pingnian, Shibadong, Tiejia, Zhangjialiu, Baiwutou, Wenglangxi, Baihe, Shaotian, Tianxin, Duoyizhai, Wuguan, Liulangxi, Longzhu, Niuren, Jiating, Huabi, Guantuan, Xiliu, and Xinzai—were meticulously surveyed. These villages were selected to provide a comprehensive understanding of the landscape quality across different regions and to capture a range of architectural, environmental, and cultural features. The selection process aimed to include villages that exhibited both well-preserved traditional landscapes and those that have undergone modernization, offering a balanced perspective on the impacts of urbanization and preservation efforts. This sampling approach ensured a diverse representation of traditional village landscapes, enabling the findings to be applicable across a broader context within the region. By capturing the unique environmental, historical, and cultural features of the villages, this investigation provides a comprehensive understanding of the basin's distinct characteristics. It also offers valuable insights into the socio-cultural fabric of the indigenous communities, shedding light on the enduring heritage of this ecologically and culturally significant region.

2.2 Semantic differential method (SD method)

The SD method was applied in this study through a structured, three-step approach, detailed as follows.

2.2.1 Selection of adjective pairs

To systematically assess various landscape elements—including traditional architectural forms, water features, road networks, agricultural landscapes, vegetation cover, and environmental psychological attributes—a curated set of bipolar adjective pairs was employed. These adjectives were selected to comprehensively capture the perceptual characteristics and intrinsic qualities of the evaluated elements, resulting in a semantic differential factor matrix tailored to the study's objectives.

2.2.2 Sample selection and data collection

Data collection took place over 6 months, from April to October 2024, with photographic sampling as the primary method for capturing visual data. A standardized photographic protocol was followed, using a single camera to maintain consistent image quality and framing, and all images were taken under optimal weather conditions to ensure clarity and minimize visual disruptions. In total, 2,400 high-resolution photographs were captured across 30 representative villages, with each village contributing approximately 80 images. These photographs were carefully selected to represent a wide range of landscape elements, including architectural landscapes, water bodies, roads, agricultural areas, vegetation, and environmental psychological landscapes. The images were chosen to highlight the most significant and visually relevant features of each landscape category, with the distribution of images across categories varying depending on the specific characteristics of each village. This approach ensured a comprehensive and balanced representation of the diverse spatial features of the villages, providing a solid foundation for further analysis using the SD Method and Entropy Weight Method.

2.2.3 Evaluation and analysis

The selected bipolar adjective pairs were applied within a 7-point semantic differential scale, where each point corresponded to an evaluative state: "very poor," "poor," "somewhat poor," "neutral," "somewhat good," "good," and "very good," with assigned numerical values from −3 to 3, respectively. This instrument was administered to a target sample comprising local villagers and tourists, thereby incorporating a broad range of subjective perceptions regarding the visual and environmental qualities of the traditional villages. A total of 120 questionnaires were distributed, ensuring sufficient sample coverage to support robust statistical analysis. After rigorous screening and elimination of returned questionnaires, 100 valid questionnaires were retained for inclusion in the statistical analysis.

2.3 Entropy Weight Method (EWM)

The Entropy Weight Method (EWM) was used to assign objective weights to the landscape evaluation indicators, ensuring that each factor's contribution to the overall assessment was appropriately quantified. The process begins by normalizing the data to make all indicators comparable. Then, the entropy values for each indicator are calculated, which reflect the amount of information or variability contained in the data. Indicators with greater variability (more information) are assigned higher entropy values, while those with less variability are given lower values.

These entropy values are then normalized to determine the weight of each indicator, with higher-weighted indicators contributing more significantly to the final evaluation. For example, traditional architectural landscapes received the highest weight due to their crucial role in maintaining the cultural identity of the villages, while road landscapes, having less impact on spatial quality, were assigned a lower weight. This objective weighting process enhances the reliability of the evaluation by minimizing subjective bias and ensuring that the landscape components are assessed based on their true significance.

2.4 Data processing

In this study, expert opinions from disciplines such as landscape architecture, forestry, and environmental psychology were integrated with quantitative data analysis to strengthen the evaluation framework. These experts contributed to the selection and refinement of key landscape indicators, ensuring that subjective perceptions of spatial quality were effectively captured. To complement this, the Entropy Weight Method (EWM) was employed to assign objective weights to the indicators based on the collected quantitative data. This approach combined expert judgment with data-driven analysis, providing a balanced and comprehensive assessment of the spatial quality of traditional village landscapes.

The collected data were then analyzed using SPSS 22.0 software, applying procedures such as normality testing, variance analysis, and correlation analysis (Jawad Ul et al., 2023). The identified influencing factors for each landscape type were refined through both a review of the literature and expert consultations, establishing the primary landscape elements, as outlined in Table 1. Subsequently, mean values and entropy weights were computed to systematically evaluate the landscape components based on the response scales.

3 Results

3.1 Reliability and validity analysis

The reliability and validity of the questionnaire were rigorously evaluated using SPSS 22.0, with emphasis on the authenticity and structural coherence of the collected data (Lu et al., 2018; Zhan et al., 2024). The reliability analysis yielded a Cronbach's α coefficient of 0.747, exceeding the commonly accepted threshold of 0.7. This result indicates that the instrument demonstrates satisfactory reliability and a commendable degree of internal consistency. Additionally, the Kaiser-Meyer-Olkin (KMO) measure from the factor analysis was calculated at 0.836, confirming strong validity of the research data. All scoring items were consistent, affirming the questionnaire's efficacy in capturing valuable information for subsequent analyses. Bartlett's test of sphericity produced a significance level of $P = 0.000$, substantiating that the dataset comprising the 40 landscape evaluation items adheres to a normal distribution under optimal conditions, as shown in Table 2.

3.2 SD index scores

Life Science Identifiers (LSIDs) for ZOOBANK registered names or nomenclatural acts should be listed in the manuscript before the keywords with the following format.

3.2.1 Overall evaluation of SD indices

The SD evaluation results are detailed in Table 2. The average SD score of 0.787 categorizes the overall landscape quality as "good." A total of 20 evaluation factors received high evaluation scores, specifically A1, A3, A4, A6, A7, B2, B3, B4, B5, C1, D8, E3, E4, E6, E8, F1, F2, F3, F4, and F5. These units exhibit vibrant architectural colors, a rich expression of regional culture, gracefully contoured waterfronts, thriving plant communities, and notable elevation changes. Together, these elements embody a robust regional cultural heritage and historical depth, further enhanced by their strong visual appeal, which enriches the cultural experience for visitors.

In contrast, units A5, A8, E1, E5, C2, D7, and B1 recorded lower evaluations. Common challenges identified include the quality of

TABLE 1 Evaluation elements for traditional village landscape spatial quality.

Classification (EWM values)	Serial number	Evaluation factor	Indicator interpretation	Relative adjective phrase	
				−3	3
Traditional Architectural Landscape A	A1	Texture of Traditional Architecture	The material's surface texture and its perception through visual and tactile interaction	simple	ample
	A2	Traditional Architectural Appearance	Encompasses visual impression, emotional resonance, and cultural perception of the building's aesthetic	confined	spacious
	A3	Traditional Architectural Color Features	The uniqueness and coherence of decorative colors used in traditional structures	tedious	vibrant
	A4	Regional Cultural Identity of Architecture	Reflects the building's cultural attributes as localized within a specific geographical context	featureless	distinctive
	A5	Traditional Building Quality	Assesses structural stability, material durability, and construction techniques	poor	desirable
	A6	Richness of Decorative Patterns	Diversity, complexity, and creativity in design, incorporating various motifs such as animal and plant forms, geometric shapes, and text symbols	tedious	ample
	A7	Architectural Harmonization	Design and construction alignment with surrounding environmental characteristics	disproportionate	coordinated
	A8	Restraint of External Factors	Degree to which visual or cultural value, historical ambiance, and overall harmony of the landscape are maintained against external impacts	none	extensive
Waterbody Landscape B	B1	Water Quality	The physical, chemical, and biological state of a water body, reflecting its cleanliness and ecological health	poor	desirable
	B2	Shoreline Morphology	The contours and form of waterbody edges, whether naturally curving or artificially straightened	stiff	elegant
	B3	Degree of Naturalness Surrounding Water	Extent of natural preservation, including vegetation, wildlife habitat, and areas free of human disturbance	tangible	natural
	B4	Plant Communities Surrounding Water	Presence and ecological impact of plant species along waterbody perimeters	sparse	lush
	B5	View Openness of Water Body	The openness of the water surface within the line of sight from specific observation points, affecting visual experience	confined	expansive
Road Landscape C	C1	Range of Roadside Visibility	Extent to which pedestrians can view surroundings along the road, including distant views	narrow	broad
	C2	Road Paving Texture	Type, texture, and pattern of road paving materials	uniform	varied
	C3	Harmonization of Roads	Degree of harmony between road design and adjacent environmental elements	disproportionate	coordinated
	C4	Road Cleanliness	Level of road cleanliness and maintenance	messy	neat
	C5	Aesthetic of Road Lines	Smoothness and aesthetic quality of road lines within spatial layout	stiff	elegant
	C6	Sense of Road Scale	Perception of the spatial scale of the roadway's width, length, and height, influencing user experience	cramped	expansive

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TABLE 1 (*Continued*) Evaluation elements for traditional village landscape spatial quality.

Classification (EWM values)	Serial number	Evaluation factor	Indicator interpretation	Relative adjective phrase	
				−3	3
Agricultural Landscape D	D1	Spatial Hierarchy of Agricultural Landscape	Layers and depth created by various landscape elements like crops, ridges, and trees	blurred	defined
	D2	Farmland View Extent	Visual coverage of farmland observed from a particular point	narrow	broad
	D3	Farmland Color Richness	Diversity of colors in agricultural fields, contributed by crops, soil, and vegetation	monotonous	vibrant
	D4	Farmland Cleanliness	Level of cleanliness in farmland, including absence of weeds and litter	unkempt	pristine
	D5	Crop Health	Indicators of crop vitality, density, and growth rate	wilting	flourishing
	D6	Agricultural Landscape Orderliness	Neatness and systematic arrangement of elements within agricultural fields	disorderly	organized
	D7	Crop Variety	Diversity of crop species present in farmland	sparse	diverse
	D8	Farmland Elevation	Degree of elevation variation and slope in farmland terrain	level	steep
Vegetation Landscape E	E1	Spatial Hierarchy of Plant Communities	Vertical distribution and layering of plant species within communities	blurred	structured
	E2	Plant Diversity	Variation in plant species based on morphological and ecological characteristics	simple	diverse
	E3	Spatial Enclosure by Vegetation	Sense of spatial enclosure or definition created by plant arrangement and growth	confined	open
	E4	Plant Community Morphology	Overall spatial morphology and arrangement patterns within plant communities	monotonous	dynamic
	E5	Plant Color Richness	Variety of colors presented by different plant species in a community	dull	vivid
	E6	Plant Health	Growth, vitality, and ecological function within the plant community	withered	thriving
	E7	Vegetation Coverage	Percentage of area covered by vegetation relative to the total landscape	sparse	dense
	E8	Degree of Natural Wildness	Level of originality and natural wildness in plant and animal habitats, as well as terrain features	artificial	ecological
Environmental Psychological Landscape F	F1	Novelty	Interest and curiosity evoked by new or unusual landscapes	mundane	unique
	F2	Sense of Wellbeing	Positive, pleasurable emotional response to landscape surroundings	discomfort	comfort
	F3	Light Sensitivity	Perception and response to light variations within the landscape	dim	bright
	F4	Seclusion	Degree of peace and tranquility within the landscape	noisy	tranquil
	F5	Sense of Attachment	Emotional connection and attachment experienced in relation to the landscape	low	high

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TABLE 2 Analysis of evaluation factor scores for traditional village landscape spatial quality.

Classification (EWM values)	Evaluation factor	B	P	SD value	EWM value	Aggregate score	Ranking
	Constant	−15.429	0.000				
Traditional Architectural Landscape A (2.429)	A1 Texture and Material Perception of Traditional Architecture	1.631	0.000	2.301	0.532	2.973	2
	A2 Overall Aesthetic Perception of Traditional Architecture	−0.096	0.000	0.586	0.158	0.225	24
	A3 Color Characteristics of Traditional Architecture	1.139	0.002	2.159	0.439	2.302	5
	A4 Regional Cultural Features of Architecture	0.9	0.005	1.977	0.416	1.998	7
	A5 Architectural Quality	−2.422	0.000	−2.883	0.032	−0.218	37
	A6 Decorative Pattern Richness	1.588	0.000	2.288	0.528	0.934	13
	A7 Architectural Harmony with Surrounding Environment	0.36	0.000	1.068	0.273	0.708	18
	A8 Disturbance Factors	−1.814	0.001	−2.471	0.051	−0.306	40
Waterbody Landscape B (1.53)	B1 Water Quality	−0.716	0.000	−0.904	0.091	−0.126	35
	B2 Shoreline Morphology	0.97	0.000	2.091	0.433	1.385	10
	B3 Degree of Naturalness around Water Bodies	0.726	0.000	1.454	0.332	0.739	16
	B4 Plant Communities around Water Bodies	0.814	0.000	1.540	0.369	0.869	15
	B5 Water Body View Openness	0.414	0.000	1.250	0.305	0.583	19
Road Landscape C (1.052)	C1 Roadside Visual Field	0.354	0.000	1.023	0.251	0.270	22
	C2 Form of Road Paving	−0.925	0.010	−1.460	0.079	−0.121	34
	C3 Harmonization of Roads with Surroundings	−0.316	0.000	0.545	0.146	0.084	30
	C4 Road Cleanliness	0.163	0.000	0.795	0.216	0.181	28
	C5 Aesthetic Quality of Road Lines	0.214	0.000	0.863	0.228	0.207	26
	C6 Sense of road scale	−0.349	0.000	0.513	0.132	0.071	31
Agricultural Landscape D (1.522)	D1 Spatial Hierarchy of Agricultural Landscapes	−0.449	0.000	0.295	0.109	0.049	32
	D2 Farmland Field of View	−0.367	0.000	0.459	0.125	0.087	29
	D3 Farmland Color Richness	−0.546	0.000	0.284	0.099	0.043	33
	D4 Farmland Cleanliness	−0.013	0.000	0.716	0.193	0.210	25
	D5 Crop Health	0.261	0.000	0.909	0.239	0.331	21
	D6 Neatness of Agricultural Landscape	−0.041	0.000	0.682	0.188	0.195	27
	D7 Crop Variety	−0.891	0.000	−1.133	0.086	−0.148	36
	D8 Elevation	1.276	0.000	2.235	0.483	1.643	8
Vegetation Landscape E (2.159)	E1 Spatial Hierarchy of Plant Communities	−1.721	0.000	−1.891	0.062	−0.253	38
	E2 Plant Diversity	−0.043	0.000	0.611	0.171	0.226	23
	E3 Sense of Enclosed Space by Plants	0.398	0.000	1.159	0.287	0.718	17
	E4 Plant Community Morphology	1.276	0.000	2.203	0.461	2.193	6

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TABLE 2 (*Continued*) Analysis of evaluation factor scores for traditional village landscape spatial quality.

Classification (EWM values)	Evaluation factor	B	P	SD value	EWM value	Aggregate score	Ranking
	Constant	−15.429	0.000				
	E5 Plant Color Richness	−1.276	0.000	−1.704	0.072	−0.265	39
	E6 Plant Community Growth	2.071	0.000	2.346	0.551	2.791	3
	E7 Vegetation Cover	0.113	0.000	0.750	0.208	0.337	20
	E8 Natural Wildness	0.762	0.000	1.481	0.347	1.110	12
Environmental Psychological Landscape F (2.183)	F1 Novelty	0.589	0.000	1.341	0.319	0.933	14
	F2 Sense of Wellbeing	0.869	0.000	1.727	0.403	1.519	9
	F3 Light Sensitivity	0.854	0.000	1.613	0.385	1.356	11
	F4 Seclusion	3.313	0.000	2.402	0.568	2.978	1
	F5 Sense of attachment	1.572	0.000	2.266	0.502	2.483	4

traditional architecture, impacted by structural integrity, material longevity, and construction techniques. Additionally, aesthetic evaluations suffered due to limited diversity in plant coloration and restricted crop variety. Roadways in these villages frequently lack visual and functional appeal, attributed to the uniformity of paving materials, textures, and patterns. The rapid urbanization process has exacerbated these issues, introducing incongruent modern renovations that diminish the authentic character of traditional villages. Indicators of this trend include incongruous new buildings, unsuitable materials, compromised water quality, free-roaming livestock, and an abundance of utility poles and advertising banners. These factors collectively detract from the villages' aesthetic and visual coherence, diminishing their overall appeal (Xiao et al., 2020).

3.2.2 Individual evaluation discrepancies in SD indices

The evaluation revealed significant discrepancies in perceptions of water quality among assessors. Some respondents observed clean, clear water characterized by high transparency and minimal suspended particles or pollutants. Such conditions are essential for sustaining aquatic life and offer an inviting setting for recreational activities, which is particularly advantageous for eco-tourism and wellness initiatives, as it positively impacts visitor satisfaction. In planning village tourism projects, sites are traditionally selected for their natural assets, often including pristine lakes and rivers.

In contrast, other evaluators expressed concerns over degraded water quality, citing issues such as algal blooms and unpleasant odors. These negative perceptions may arise from the placement of tourism facilities near water bodies in an effort to enhance village attractions, as well as from untreated wastewater discharge from lodging and dining establishments into rivers. Such contamination introduces organic pollutants and leads to eutrophication, which undermines the ecological functions of these water bodies and poses potential health risks for nearby residents. These adverse evaluations highlight critical pollution issues that compromise both the environmental integrity and tourism appeal of traditional village settings.

3.3 EWM index weight calculation

The indicator weights within the landscape spatial quality evaluation framework for traditional villages in the Yuanshui River Basin, Hunan Province, were calculated using SPSS 22.0 software. The entropy weight values, presented in Table 2, are ranked as follows: Traditional Architectural Landscape (2.429) > Environmental Psychological Landscape (2.183) > Vegetation Landscape (2.159) > Waterbody Landscape (1.530) > Agricultural Landscape (1.522) > Road Landscape (1.052). This hierarchy underscores that the most critical considerations in assessing the spatial quality of traditional village landscapes are the traditional architectural features and the psychological experiences evoked within the village setting, particularly through the environmental psychological landscape (Zhao and Xiao, 2020).

For the Traditional Architectural Landscape evaluation, entropy weight values for sub-indicators are ranked as follows: Texture and Material Perception of Traditional Architecture (0.532) > Decorative Pattern Richness (0.528) > Color Characteristics of Traditional Architecture (0.439) > Regional Cultural Features of Architecture (0.416) > Architectural Harmony with Surrounding Environment (0.273) > Overall Aesthetic Perception of Traditional Architecture (0.158) > Disturbance Factors (0.051) > Architectural Quality (0.032). These findings underscore the importance of color characteristics, regional cultural attributes, and overall aesthetic perception in assessing traditional architecture. Structural integrity, decorative richness, and harmony with the surrounding environment also emerge as crucial factors warranting careful attention.

In the Waterbody Landscape evaluation, entropy weight values for sub-indicators are ranked as follows: Morphology of Waterfront Lines (0.433) > Plant Community Richness around Waterbodies (0.369) > Naturalness of Surrounding Environment (0.332) > Visual Openness of Waterbodies (0.305) > Water Quality (0.091). This data suggests that the morphological features of waterfronts, along with the diversity and richness of adjacent plant communities, are paramount in shaping initial impressions and eliciting emotional responses, thus carrying the highest weights within the evaluation framework.

TABLE 3 Correlation analysis between SD and EWM scores.

Correlation Analysis	SD	EWM
Pearson Correlation	1	0.889**
Significance (two-tailed)	-	0.000
N	40	40
Pearson Correlation	0.889**	1
Significance (two-tailed)	0.000	-
N	40	40

Note: Correlations were significant at the 0.01 level (two-tailed).

In the Road Landscape evaluation, entropy weight values are ranked as follows: Visual Range of Roadways (0.251) > Linearity and Shape of Road Patterns (0.228) > Cleanliness of Road Environment (0.216) > Harmony between Roads and Surroundings (0.146) > Perceived Scale of Roads (0.132) > Paving Material Forms (0.079). These rankings reveal that visual range is the most significant factor in road landscape evaluation, as it directly influences the pedestrian visual experience. The linearity of road patterns and cleanliness also emerge as essential considerations in assessing road aesthetics.

For the Agricultural Landscape assessment, entropy weight values are ranked as follows: Slope Gradient (0.483) > Crop Growth Conditions (0.239) > Cleanliness of Agricultural Landscape (0.193) > Overall Neatness of Farmlands (0.188) > Visual Range of Farmlands (0.125) > Spatial Stratification of Agricultural Landscape (0.109) > Color Diversity of Farmlands (0.099) > Crop Type Diversity (0.086). These results indicate that slope gradient is the most critical determinant, impacting key natural conditions such as irrigation, drainage, and soil erosion, which in turn influence crop growth and the visual aesthetics of farmlands. Crop growth conditions and landscape cleanliness are also significant, while crop type diversity is assigned the lowest weight (0.086), suggesting a comparatively minor influence within the overall evaluation framework.

In the Vegetation Landscape evaluation, entropy weight values are ranked as follows: Growth Condition of Plant Communities (0.551) > Overall Plant Morphology (0.461) > Naturalness and Wildness of Vegetation (0.347) > Spatial Enclosure by Vegetation (0.287) > Vegetation Coverage (0.208) > Plant Types (0.171) > Color Diversity of Vegetation (0.072) > Spatial Stratification of Plant Communities (0.062). These results underscore that growth conditions, health, and ecological functionality of diverse plant communities are paramount in evaluating vegetation landscapes. Additionally, the spatial distribution and structural arrangement of these communities considerably affect the visual impact. Naturalness and wildness play a critical role in enhancing landscape aesthetics, while plant color diversity and spatial stratification have relatively lower importance within the evaluation framework.

For the Environmental Psychological Landscape assessment, entropy weight values are ranked as follows: Sense of Tranquility (0.568) > Sense of Attachment (0.502) > Sense of Pleasure (0.403) > Sense of Light (0.385) > Sense of Novelty (0.319). This ranking indicates that tranquility and attachment are the most influential indicators, emphasizing that the degree of quietude and the emotional resonance fostered by the environment are essential for enhancing psychological comfort, satisfaction, and overall landscape appeal for both visitors and residents.

3.4 Comprehensive evaluation of SD and EWM methods

3.4.1 Correlation analysis

A linear analysis conducted with SPSS 22.0 yielded the following relationship model: SD = −1.284 + 7.622 EWM. This model demonstrates a significant positive correlation between EWM and SD scores, indicating that for each unit increase in the EWM score, the SD score is expected to rise by an average of 7.622 units. The sizable coefficient underscores the substantial influence of EWM scores in shaping subjective SD assessments.

The model's robustness is confirmed by an R^2 value of 0.790, surpassing the 0.6 threshold, which signifies a strong fit, accounting for 79% of the variability in SD scores and reflecting commendable predictive accuracy. Additionally, the Durbin-Watson statistic (DW = 1.982), approximating 2, suggests an absence of significant first-order autocorrelation within the regression residuals, an ideal condition that enhances model accuracy and validity. Moreover, as shown in Table 3, the significance level (P = 0.000) is below 0.05, further substantiating the statistically significant impact of EWM on SD (Zhao and Xiao, 2020).

3.4.2 Threshold analysis

Based on the secondary indicator scores derived from the SD method and integrated with weights obtained from the EWM method, a comprehensive set of 40 secondary indicator scores was developed. These scores cover diverse landscape dimensions, including traditional architectural landscapes, waterbody landscapes, road landscapes, agricultural landscapes, vegetation landscapes, and environmental psychological landscapes. These scores were subsequently aggregated to compute the corresponding values for the primary indicators, facilitating the overall score (S) for the quality of landscape construction in traditional villages within the Yuanshui River Basin, which was calculated using Equation 1:

$$S = W_j \sum W_j \times F_i \tag{1}$$

where W represents the weight values of each indicator level, i denotes the secondary indicators, j corresponds to the primary indicators, and F signifies the scores derived from the SD method.

(1) Top Three Indicators

As illustrated in result, the comprehensive score for Sense of Tranquility is 2.978, ranking highest among evaluative factors. This finding underscores the pivotal role of tranquility in the environmental psychological landscape, significantly enhancing the overall spatial quality of traditional village settings. The prominence of tranquility may be attributed to rural depopulation trends, where substantial outmigration for urban employment has left a population primarily consisting of children and the elderly, amplifying the quietude of these communities. The second-highest score, 2.973, is attributed to Texture and Material Perception of Traditional Architecture. The surface textures and material properties of traditional buildings exert a considerable influence on the overall landscape perception. Additionally, EWM weight calculations reveal that Growth Condition of Plant Communities ranks third among evaluative factors, with an EWM score of 0.551, following Texture of Traditional Architecture (0.532) and Decorative Pattern Richness (0.528). This ranking highlights the critical role of plant community growth conditions in assessing the spatial quality of traditional village landscapes, as it reflects the ecological health and sustainability of the landscape—essential for maintaining high quality and ecological integrity in village environments.

(2) Bottom Three Indicators

Figure 1 indicates that Disturbance Factors score −0.306, positioning them at the bottom of the ranking. The presence of these disturbance factors substantially undermines both the visual appeal and cultural value of the landscape. Plant Color Diversity scores −0.265, placing it second from the bottom, reflecting a lack of color diversity and richness within the plant community. Finally, Spatial Stratification of Plant Communities scores −0.253, ranking third from the bottom, indicating that the spatial arrangement of plant communities requires considerable improvement to elevate the overall landscape quality.

4 Discussion

4.1 Architectural and psychological landscape quality

While the overall landscape quality in the Yuanshui River Basin's traditional villages is generally assessed as "good," significant differences exist between individual villages, reflecting their unique histories, cultures, and spatial characteristics. For instance, some villages, such as Dehang and Wufeng, showcase particularly well-preserved traditional architectural landscapes with rich decorative patterns and vibrant regional cultural features. These villages have maintained their architectural integrity through effective preservation efforts, resulting in high scores for architectural aesthetics and harmony with the surrounding environment. In contrast, villages like Shibadong and Liulangxi have experienced more severe damage to their architectural landscapes, with modern renovations and urbanization causing a loss of traditional architectural elements and a decline in visual coherence. This is reflected in their lower evaluation scores for traditional architecture, where factors such as material durability and architectural harmony with the environment received less favorable assessments. Additionally, the environmental psychological landscapes vary widely among villages. Villages such as Zhonghuang and Haoxiaping scored highly in terms of tranquility and attachment, with abundant green spaces and limited external disturbances, fostering a deep sense of wellbeing among residents and visitors.

4.2 Variability among villages and Implications for conservation

The study highlights significant variability in landscape quality across different villages, reflecting the diverse nature of traditional village landscapes. While some villages have successfully preserved their landscapes, others have been adversely affected by modernization and homogenization. This variability underscores the need for site-specific conservation strategies that address the unique challenges of each village. These findings are consistent with those of Xu et al. (2023) and underscore the importance of regional efforts to protect traditional landscapes from the pressures of urbanization. Recognizing and understanding these differences is essential for developing tailored strategies that preserve each village's cultural and architectural identity, while mitigating the homogenizing effects of urban development. By addressing these challenges, we can ensure the long-term sustainability of traditional village landscapes and protect their cultural heritage. Future research should investigate how these landscapes evolve over time, fostering dynamic approaches to their conservation and management.

4.3 Limitations

Several limitations of this study should be acknowledged: (1) Sample Size Constraints: Due to limitations in time and resources, this research was restricted to a select number of traditional villages within the Yuanshui River Basin, resulting in a relatively small sample size. This limitation may affect the generalizability of the findings. Future studies should consider expanding the sample scope to enhance the representativeness and reliability of the results. (2) Comprehensiveness of Data Collection: While the data collection process was designed to capture a broad range of dimensions and perspectives, potential omissions or biases may still be present. Notably, villagers' perceptions are significantly influenced by subjective factors, which may impact data accuracy. Future research should seek to refine data collection methodologies to improve the comprehensiveness and reliability of information gathered. (3) Dynamic Nature of the Evaluation Framework: Traditional village landscapes are dynamic and continuously evolving, shaped by a variety of external and internal factors (Liu et al., 2022). Although the evaluation framework developed in this study offers a degree of flexibility and adaptability, it requires ongoing adjustments and optimization to respond to changing conditions. Regular monitoring and assessment are essential for identifying and addressing potential issues, thus ensuring the sustained aesthetic and ecological integrity of village landscapes and supporting the sustainable development of traditional villages.

5 Conclusion

This study employs a hybrid approach, integrating SD and EWM, to conduct a comprehensive assessment of the spatial quality of traditional village landscapes within the Yuanshui River Basin. The findings reveal that key landscape components—including traditional architectural landscapes, waterbody landscapes, road landscapes, agricultural landscapes, vegetation landscapes, and environmental psychological landscapes—significantly impact the subjective experiences of residents and visitors.

1. The evaluation framework synthesizes expert insights across six distinct dimensions. The entropy weights assigned to each dimension, ranked in descending order, are: Traditional Architectural Landscape (2.429) > Environmental

Psychological Landscape (2.183) > Vegetation Landscape (2.159) > Waterbody Landscape (1.530) > Agricultural Landscape (1.522) > Road Landscape (1.052). This hierarchy highlights the significance of traditional architecture and environmental psychological landscapes in the village setting, underscoring the role of traditional architecture in preserving historical narratives and reflecting regional identity.

2. The model's robustness is further validated through goodness-of-fit assessments from regression analysis, supported by the Durbin-Watson statistic and correlation analysis between SD and EWM scores (Yuan et al., 2022). The resulting equation, SD = −1.284 + 7.622 EWM, demonstrates congruence between the two evaluative approaches, addressing the limitations of a single-method evaluation. By combining expert opinions with quantitative data analysis, this approach enhances objectivity and generalizability, effectively incorporating participants' subjective experiences with a scientifically grounded weighting mechanism, leading to comprehensive and reliable outcomes.
3. The spatial quality of traditional village landscapes in the Yuanshui River Basin is classified as "good," with key features including tranquility, healthy vegetation, robust plant community structures, and a natural charm that enhances ecological integrity. The distinctive textures and materials of traditional architecture reflect unique regional cultural heritage and embody a legacy of craftsmanship (Liu and Shang, 2019). Collectively, these elements create a unique landscape and a rich cultural tapestry for traditional villages in the basin.

However, notable challenges remain, including visual disturbances, limited color diversity in vegetation, low spatial stratification within plant communities, deterioration of traditional buildings, and significant water pollution. Addressing these challenges requires multi-faceted interventions: reducing visual distractions from power lines and advertisements through legislative protections; enhancing biodiversity with a more diverse vegetation palette and ecological restoration initiatives (Gessesse et al., 2016; Zhong et al., 2019); renovating traditional structures, fostering community involvement in preservation efforts, and thoughtfully incorporating modern design elements; remediating water pollution to restore natural purification capacities in aquatic ecosystems and expanding environmental education (Yang et al., 2022); and developing strategic protective planning and management frameworks to encourage multi-stakeholder participation in sustainable village development.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

LW: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Resources, Software, Validation, Writing – original draft. JZ: Investigation, Software, Visualization, Writing – original draft. MW: Conceptualization, Project administration, Resources, Supervision, Writing – review and editing. RA: Formal Analysis, Investigation, Methodology, Supervision, Validation, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2025.1552489/full#supplementary-material

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