ISSN: 1648-6897 / eISSN: 1822-4199

VILNIUS TECH
Vilnius Gediminas Technical University

JOURNAL of ENVIRONMENTAL ENGINEERING & LANDSCAPE MANAGEMENT

2025
Volume 33
Issue 1
Pages 85–96
https://doi.org/10.3846/jeelm.2025.22946

RECOGNITION AND OPTIMIZATION OF LANDSCAPE GENES IN TRADITIONAL SETTLEMENTS: A CASE OF MEISHAN AREA

Huasha XIA[1, 2]✉, Feihu CHEN[1]

[1]*School of Design, Hunan University, Changsha, China*
[2]*Hunan University Design and Research Institute Co., Ltd, Changsha, China*

Highlights:

- developed a landscape gene evaluation index system for Meishan's rural cultural landscape;
- topography and building decoration were identified as key elements for preservation in Meishan;
- building materials, traditional culture, and folk customs in Meishan require significant improvement;
- provided strategies to balance cultural preservation with modern development in Meishan's rural areas.

Article History:

- received 07 December 2023
- accepted 23 October 2024

Abstract. Traditional settlement landscapes provide vital ecosystem services and represent significant cultural heritage, making their preservation crucial for national cultural development and rural revitalization. This study focuses on Meicheng Town in the Meishan area, utilizing landscape gene theory to classify and identify cultural landscape features. By integrating the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE), the study develops a landscape gene sorting index system, systematically evaluating 16 sub-categories of landscape factors. The results highlight topography and building decoration as dominant features that should be prioritized for preservation. However, areas such as building materials, traditional culture, and folk customs require significant improvement. Additionally, the river and road landscapes present opportunities for enhancement to strengthen the town's cultural identity and aesthetic quality. The study provides practical recommendations for optimizing Meicheng Town's landscape, balancing the preservation of traditional elements with modern development needs. This approach addresses gaps in the literature on settlement landscape genes and offers strategies for sustainable rural cultural landscape development.

Keywords: rural culture landscape, traditional settlements, Meishan, analytic hierarchy process, fuzzy comprehensive evaluation.

✉Corresponding author. E-mail: ***xiahuasha@hndxsjyjyyxgs2.wecom.work***

1. Introduction

Central Plains culture and Jingchu culture are the two main streams of Chinese culture (Zhang & Chen, 2014). There is an important branch of Jingchu culture – Meishan culture, which has been neglected and unknown for a long time. In June 1981, the four provinces of Hunan, Hubei, Henan and Anhui jointly established the "Chu Culture Research Association" (Guo, 2022). Because of this historic opportunity, the culture of the ancient Meishan area gradually attracted the attention of the world.

The historical and cultural landscape of the Meishan area is the fruit of the wisdom of the Meishan people's survival and the living relics of the harmonious coexistence between man and nature (Luo & Chen, 2016; Zhong & Chen, 2015; Zou, 2008). It has extremely high research value, preservation value and exploration significance. However, in today's rapidly evolving social environment, the traditional buildings and landscape patterns in Meishan are struggling to meet modern living standards and environmental demands. This struggle stems from their inability to adapt to contemporary needs such as modern infrastructure requirements, energy efficiency standards, and updated residential comfort expectations (Miao et al., 2024a; Qiu & Chen, 2016; Zhao et al., 2023). As a result, the cultural landscape of Meishan is at risk of fading into obscurity. To prevent this, it is crucial to analyze and address these challenges from multiple perspectives, including landscape spatial pattern, architectural spatial pattern, and cultural heritage, to ensure that these cultural relics are not only preserved but also integrated into the ongoing development of the area.

In the broader context of rural revitalization and cultural landscape preservation, this study explores the traditional villages of Meishan, listed under the "List of Chinese Traditional Villages." The methodology includes field surveys, semi-structured interviews, and an innovative combination of Analytical Hierarchy Process (AHP) and

Fuzzy Comprehensive Evaluation (FCE). AHP is employed for its efficacy in multi-criteria decision-making, enabling a structured assessment of landscape elements by prioritizing various factors through expert judgment (Saaty, 1989). FCE complements this by offering a quantitative approach to interpret subjective evaluations (Feng & Xu, 1999), making it suitable for assessing the complex and multifaceted nature of cultural landscapes. This structured approach is further enriched by a questionnaire survey among Meishan's residents, aimed at understanding their perspectives and satisfaction levels with the cultural landscape. This element of the study is pivotal in identifying key areas for landscape revitalization and development, aligning the research with current trends in rural development and cultural preservation.

The study provides valuable insights into the current state of the rural cultural landscape in Meishan and suggests strategies for its optimization. By addressing gaps in existing academic literature on settlement landscape genes, particularly in rural Chinese contexts, this research contributes to a broader understanding of rural cultural landscapes. It emphasizes the importance of preserving local distinctiveness and cultural heritage while adapting to contemporary needs. This manuscript is structured to provide a comprehensive exploration of landscape gene recognition and optimization in the traditional settlements of the Meishan area. Section 2 presents a detailed literature review, highlighting current practices and methodologies in rural landscape evaluation and identifying research gaps relevant to the Meishan cultural landscape. Section 3 outlines the study's methodological framework, focusing on the selection of the study area and the application of the Analytic Hierarchy Process (AHP) combined with Fuzzy Comprehensive Evaluation (FCE) to systematically identify and classify landscape genes. Section 4 discusses the results of the landscape gene evaluation, utilizing a four-quadrant diagram model to analyze and prioritize areas of strength, maintenance, opportunity, and improvement within the cultural landscape of Meicheng Town. Section 5 provides a discussion on the implications of these findings, offering strategic recommendations for enhancing and preserving the architectural and cultural features of Meicheng Town. Finally, the conclusion summarizes the study's key contributions, emphasizing the innovative application of landscape gene theory and proposing directions for future research and practical applications in landscape architecture, urban planning, and cultural preservation, particularly in rural settings.

2. Literature review

2.1. The practice of rural landscape

There is an increasing interest today in landscape as a vital perspective in the context of promoting sustainable development (Yang & Lo, 2003). The practice of rural landscape is important in maintaining the ecological, social, and economic functions of rural areas (Gullino et al., 2018; Jongman, 2002; Vetter, 2013). In the late 1980s and early 1990s, scholars began to study landscape patterns by changing spatial scales and creating quantitative models (Krummel et al., 1987; O'Neill et al., 1988; Risser, 1990). With the development of remote sensing technology and geographic information system, scholars have used a series of landscape indices to quantitatively analyze landscape elements and spatial structures, established many different types of dynamic models, and the theoretical system has become increasingly mature (Liu et al., 2022; Wagner & Fortin, 2005; Wang & Fan, 2020). For example, Plexida et al. (2014) used various landscape indices, such as patch density and connectivity, to quantify the spatial structure of the landscape. Pinto-Correia and Kristensen (2013) proposed a conceptual model that contextualizes empirical research driven by practical problems. The model combines ecological and structural dimensions with socioeconomic and cultural ones, converging in the rural landscape at multiple scales. Parks et al. (2015) evaluated the ecological connectivity of landscapes under different urban gradients based on GIS technology, and drew a connection map that provided a spatial reference for planners and landscape designers.

Studying the evolution of high-frequency keywords helps to track research trends and identify potential research gaps (Miao et al., 2022). In this paper, the author conducted a bibliometric analysis of the research on rural landscapes in recent years. Using the Web of Science database and VOSviewer software, the author created a co-occurrence network of titles, keywords and abstracts based on the keywords "rural landscape" and "traditional settlement landscape". A total of 1397 articles published in the past ten years were identified (Figure 1). According to keyword analysis, 274 keywords appeared at least five times in 5453 keywords. As shown in Figure 1, the larger the font of keywords in the figure, the higher the frequency of occurrence. The diameter of each circle reflects the frequency of keywords, and the width of the link line represents the frequency of keywords used together. The color scheme shows the year of publication. Unlike Figure 1, Figure 2 shows the frequency of keyword usage. The keywords marked with bright yellow and large fonts are frequently used.

The above keyword co-occurrence network clearly demonstrates the main aspects involved in the traditional settlements landscape. Frequently occurring keywords in the relevant literature include "rural landscape", "biodiversity", "conservation", "politics" and "agriculture". The yellow circles in Figure 1 are keywords that appeared around 2019, which belong to relatively new or popular research fields. This shows that, for previous studies, scholars mainly focused on the relationship between rural landscape and ecosystem, land use, agriculture, conservation, and tourism.

The specific aim of this review is twofold. Firstly, it identifies significant challenges and opportunities in landscape heritage management, thereby establishing a robust foundation for addressing these issues within the Meishan context. Secondly, the analysis provides a scientific basis

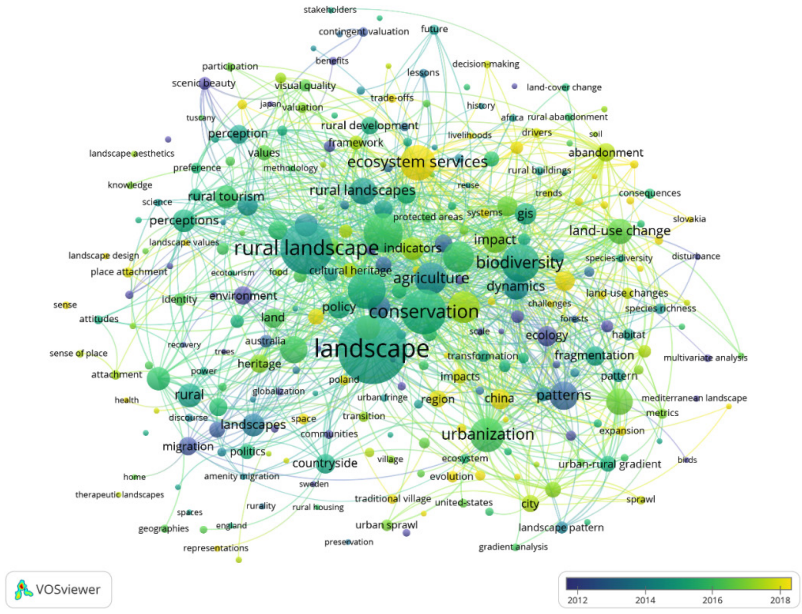

Figure 1. Co-occurrence of keywords produced by VOSviewer

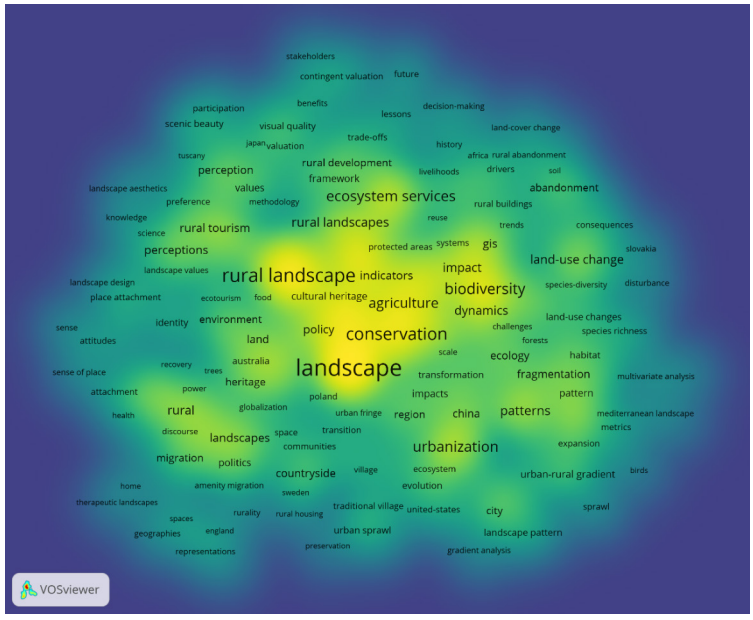

Figure 2. Visualization density of keywords produced by VOSviewer

for the selection of landscape cultural genes by revealing the interconnectedness and significance of various landscape elements. This approach ensures that the selection of cultural genes is grounded in well-established academic theories and empirical evidence, aligning with both the preservation of local distinctiveness and the adaptation to contemporary needs.

Building upon this foundation, the study aims to delve into the underexplored areas of rural landscapes, particularly focusing on the unique context of Meishan culture within traditional Chinese villages. While previous research has provided valuable insights into the general patterns and dynamics of rural landscapes, there remains a gap in the understanding of how these concepts specifically apply to the traditional settlements in the Meishan area. This study seeks to bridge this gap by exploring the intricate interplay between the physical landscape features and the rich cultural heritage of Meishan.

2.2. Landscape gene theory

The concept of "gene" in the biological sense stems from Gregor Johann Mendel's foundational work on inheritance in the 1860s, where he described "factors" that govern the inheritance of traits in organisms (Schwarzbach et al., 2014). These factors were later termed "genes" by Wilhelm Johannsen in 1909 (Churchill, 1974). Over time, the concept of genes has been metaphorically applied to cultural and spatial studies, representing the basic units that carry cultural and spatial traits across generations.

In 1976, Richard Dawkins introduced the "meme" as a cultural parallel to biological genes, focusing on the transmission of cultural information (Dawkins, 2016). Building on this, scholars like Conzen and Susan Blackmore applied these ideas to landscape studies (Blackmore, 2000; Conzen, 2004). In 2003, Liu Peilin advanced this line of thought by introducing Landscape Gene Theory, defining landscape genes as core elements that distinguish one landscape from another (Liu et al., 2023; Peilin, 2015). This theory provides a scientific framework for analyzing and preserving the essential natural and cultural elements of landscapes.

To identify these genes, Peilin (2015) proposed four key principles: intrinsic uniqueness, extrinsic uniqueness, local uniqueness, and overall superiority. These principles ensure that landscape genes highlight distinctive and irreplaceable features in a settlement (Liu et al., 2023). Building on this, several methods have been developed for landscape gene extraction and classification. One of the most widely used is the feature deconstruction extraction method introduced by Zui et al. (2015). This method employs an object-oriented approach to categorize landscape genes into architectural, cultural, environmental, and layout features, which systematically identifies and classifies landscape elements. Other methods include the element extraction method, pattern analysis method, structure extraction method, and meaning analysis method (Yong & Xiang, 2024; Zui et al., 2015). Each of these approaches provides a distinct way to classify the various elements that shape and define landscapes.

At the application level, Landscape Gene Theory has been widely employed to address both cultural heritage protection and sustainable landscape planning, particularly in the conservation of traditional villages. Recent research has expanded the scope of landscape gene studies, focusing on key areas such as identifying and extracting landscape genes in traditional villages (Wang et al., 2023), analyzing landscape gene variations (Dang et al., 2020), studying the landscape gene information chain (Liu, 2014), and exploring strategies for the protection and inheritance of traditional village landscape genes (Wang et al., 2024; Xiang et al., 2020). For instance, Liu et al. (2024) applied Geographic Information System (GIS) to analyze the spatial distribution of cultural landscape genes in Linpu Village, China, offering valuable insights into heritage conservation in the region.

2.3. Rural landscape evaluation

In the past 20 years, many scholars have carried out research on landscape evaluation. One important aspect of rural landscape evaluation is the identification and evaluation of landscape features and attributes. Cadieux and Hurley (2011) summrised various perspectives on the trends of amenity migration and exurbia, thereby presenting a comprehensive overview of the current state of research in rural and cultural geography and political ecology. Lee et al. (2011) suggested a landscape resources evaluation strategy for rural waterfront villages along the river. Xiao et al. (2013) evaluated the main ecological effects of fine-scale rural landscape construction projects. This study intended to build a rural landscape evaluation model based on an integrated landscape assessment paradigm of rural regions using an additive integration index method and applied the model to the Seondong Region of Gochang-gun, Jeollabuk-do, Korea.

Another important aspect of rural landscape evaluation is the assessment of landscape quality and user satisfaction. Ren et al. (2018) analyzed the effects of soundscape on rural landscape evaluations, eight including landscape visual aesthetic quality (VAQ), landscape tranquility, and landscape nine preference, based on audiovisual information collected in typical rural villages using the methods 10 of an audiovisual experiment and eye-tracking test. Taking Yongfeng Village in Lanzhou as the research object, Yang et al. (2021) discussed the evaluation method of vernacular landscape attraction.

Overall, rural landscape evaluation is a complex and multifaceted topic that requires consideration of various factors such as landscape features, quality, cultural and social values, and ecological connectivity. Advances in technology and methodologies have provided new opportunities for quantitative evaluation of rural landscapes, while also highlighting the importance of qualitative and cultural perspectives in landscape evaluation.

Through literature research, the author found that the current research on regional landscape planning and evaluation mainly focuses on cities, river basins and other areas. However, there are few specialized studies on rural areas with an underdeveloped economy but important ecological functions, especially rural areas with regional cultural characteristics such as the Meishan area. In the face of the contradiction between economic development and resource protection, how to carry out rural revitalization and landscape planning better and more effectively is a new topic for rural landscape development.

Based on the above problems, this paper takes the Meishan area as the research scope. On the basis of existing relevant research, using field surveys, questionnaire surveys, expert interviews, combined with an analytic hierarchy process and fuzzy comprehensive evaluation methods, the rural cultural landscape resources in the Meishan area are sorted out, and its landscape genes and identification features are analyzed. Then, the author evaluates the rural landscape satisfaction in Meicheng Town, discusses the landscape development strategies and models, and puts forward feasible improvement strategies. The methodological implications of this research approach have significant implications for landscape planning in similar areas.

3. Methodology

3.1. Study area

The study area is in Meishan, the central region of Hunan Province in southwest China (Figure 3).

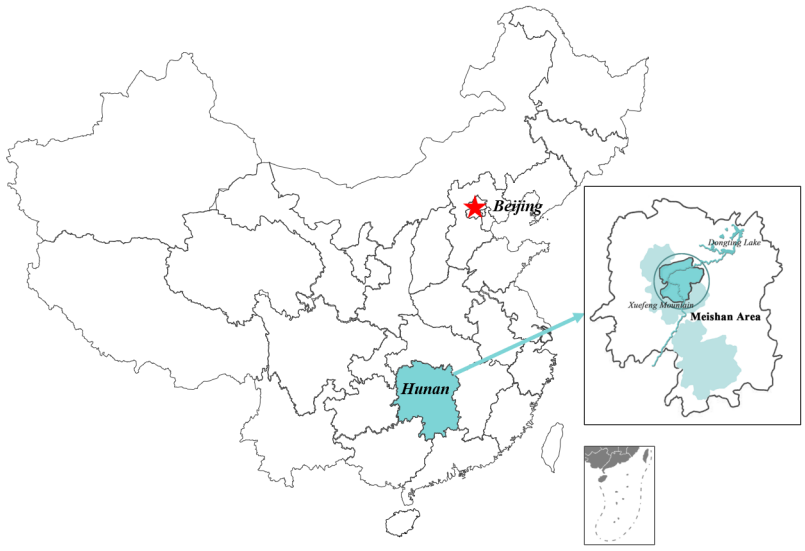

Figure 3. Location of Meishan area in China

The Meishan area mainly covers the central part of Hunan. The southwest is mainly mountainous, and external transportation is inconvenient. Hence economic development lags (Jing & Hua, n.d.). The terrain in the east is relatively flat and primarily hilly plains. It is close to the provincial capital Changsha and has many external contacts. Due to the particular natural and geographical environment, Meishan has abundant natural and cultural landscape resources on nearly 50,000 square kilometers of land, providing favorable basic conditions for ecotourism development. Notably, many traditional villages are scattered throughout the mountains and forests, and simple folk customs are preserved in the fields. These precious materials and intangible heritages have evolved and developed within the natural geographical environment, accumulating and precipitating over an extensive period of time through the region's rich history and culture.

The development of the local area is subject to the influence of the historical political structure and geographical environment (Semple, 1911). After the Northern Song Dynasty, communication with the outside world gradually strengthened. Meishan culture, Central Plains culture and Jingchu culture are the three ancestor cultures. In the long process of historical development, Meishan culture has retained its mysterious and original characteristics, presenting a multi-cultural symbiosis appearance.

3.2. Selection of landscape genes

The gene refers to the basic unit of organism inheritance, and its concept comes from biology. Inspired by the gene theory in biology, Liu Peilin proposed the concept of cultural genes in traditional settlement landscapes (Peilin, 2015). A cultural landscape gene is a cultural factor inherited from generation to generation and recognized from other cultural landscapes. It plays a decisive role in the formation of a certain cultural landscape, and vice versa. It is also a determinant for identifying this cultural landscape (Hu et al., 2021). In essence, the cultural elements of traditional settlement landscapes are landscape genes. Its practical significance lies in combining various cultural characteristics and elements that constitute traditional settlements, and then exploring and analyzing ancient villages from a microscopic perspective to obtain the corresponding "genetic information". Therefore, the study of landscape genes plays an important role in identifying the cultural landscape of traditional settlements.

There are several methods for the classification of landscape genes, among which the feature deconstruction extraction method is more commonly used. This approach involves using object-oriented techniques to classify the landscape features of traditional settlements by establishing detailed identification index elements. The process merges the identification results according to the principle of "merging if the categories are similar" (Zui et al., 2015). The Object-Oriented Classification Pattern for Landscape's Genes (OOCPLG) classification model complements this method by treating traditional settlements as objects, analyzing their attributes to establish classification standards based on differences among these attributes, and refining them into a specific indicator system (Hu et al., 2015). This combination offers strong operability, clear logic, and practical applicability. Therefore, this study employs this integrated approach to classify the landscape genes in the Meishan area into four categories: environmental, architectural, cultural, and layout characteristic genes.

In line with this classification, this study conducted three comprehensive field surveys in Meishan from January 2020 to January 2023. The data collection was an extensive process that included field research, literature reviews, semi-structured interviews, and information gathered from village committees. The field research involved on-site observations and assessments of the landscape, while the literature review helped contextualize these findings within the broader academic and historical framework. Semi-structured interviews were particularly crucial

in understanding the local perspective. Conducted with a diverse group of stakeholders, including residents, local authorities, and cultural experts, these interviews provided deeper insights into the cultural significance and perceptions of the landscape features. Information provided by village committees further enriched our understanding, offering data on socio-economic factors and local governance impacting the landscape.

The integration of these data collection methods with the landscape gene classification approach provided a thorough understanding of Meishan's rural cultural landscape. This multi-faceted approach enabled a detailed analysis of the region's cultural and ecological diversity, illustrating how these elements work together to shape Meishan's unique landscape. The results of this analysis were used to identify 16 key landscape genes, which were widely recognized by both the villagers and experts consulted during the study. These 16 landscape genes, detailed in Table 1, were derived through a rigorous process of expert consultations and semi-structured interviews with local villagers, ensuring that the classification was not only scientifically grounded but also deeply connected to the lived experiences and cultural identity of the local community.

Table 1. Landscape genes

Overall target	Landscape genes		Photos
Sequencing of landscape genes in the construction of rural cultural landscape	Environmental gene	Topography	
		Landscape	
		Land resource	
		Transportation	–
	Layout gene	Spatial layout	–
		Building style	
		Street layout	
		River layout	
	Architecture gene	Building structure	
		Building material	

End of Table 1

Overall target	Landscape genes		Photos
Sequencing of landscape genes in the construction of rural cultural landscape	Architecture gene	Building color	
		Building decoration	
	Cultural genes	Traditional culture	
		Folk customs	–
		Festival celebration	
		Traditional skills	

3.3. Rural cultural landscape evaluation

In the pursuit of evaluating the rural cultural landscape of Meishan with scientific accuracy and depth, this study implemented the Analytical Hierarchy Process (AHP), as initially proposed by Saaty in 1980 (Saaty, 1989). AHP is renowned for its ability to integrate both qualitative and quantitative elements in multi-criteria and multi-objective decision-making (Bhyan et al., 2023; Seyedmohammadi et al., 2018, 2019a). This method is particularly suited for the hierarchical nature of the evaluation factor system used in this study. An expert panel of 15 professionals was carefully selected to ensure diversity in expertise. The panel consisted of five experts from landscape architecture, five from urban planning, and five from architecture, all with over 10 years of experience. These experts were identified through academic networks and professional associations, ensuring their deep knowledge of rural cultural landscapes.

A two-part questionnaire was developed for data collection. The first section gathered demographic and background information, such as the expert's qualifications and familiarity with the Meishan area. The second section focused on pairwise comparisons of landscape gene categories (environmental, architectural, cultural, and layout genes), using Saaty's 9-point scale to assess their relative importance. This structure ensured comprehensive and reliable input from experts, which laid the foundation for the AHP analysis. The AHP analysis followed a structured process, beginning with the construction of pairwise comparison matrices based on expert judgments. A hierarchical model was first developed to classify the main criteria and sub-criteria relevant to the evaluation of the rural cultural landscape in Meishan. The 15 experts conducted pairwise comparisons using Saaty's 9-point scale to evaluate the relative importance of the criteria. Next, the relative

weights of the criteria were calculated using the row average method, which normalizes each row of the comparison matrix and computes the average value. To validate the robustness of the expert evaluations, the Consistency Index (*CI*) and Consistency Ratio (*CR*) were calculated using the following equations:

$$CI = \frac{\left(\lambda_{max} - n\right)}{\left(n-1\right)}; \quad (1)$$

$$CR = \frac{CI}{RI}, \quad (2)$$

where λ_{max} is the maximum eigenvalue, n is the number of indicators, and *RI* is the Random Index obtained from Saaty's table. A *CR* value below 0.1 was considered acceptable, confirming a reasonable level of consistency (Seyedmohammadi & Navidi, 2022). In this study, YAAHP software was used to analyze the 16-order judgment matrix, handling expert input, constructing judgment matrices, and calculating the weights and consistency ratios. The software efficiently handled the input of expert judgments, constructed the judgment matrices, and calculated the weights and consistency ratios (Miao et al., 2024b). The weights for each factor at various levels were determined based on expert assessments, as presented in Table 2. The maximum eigenvalue obtained was 16.340, resulting in a Consistency Index (*CI*) of 0.023 and a *CR* of 0.014. Since the *CR* was below 0.1, the matrix satisfied the consistency requirements, thereby confirming the reliability of the calculated weights.

It can be seen from Table 2 that architectural genes account for the largest proportion in the criterion layer, followed by cultural genes and environmental genes. A total of 16 indicators participated in the evaluation in the sub-criterion layers, and the top 5 were Building materials, Folk customs, Topography, Building decoration, and Festival celebration. It can be seen that the improvement of the landscape of traditional settlements should start with the architectural style, followed by the cultural and environmental characteristics. Therefore, in the development of rural cultural landscapes, the architectural gene should be taken as the focus of upgrading, and the structure, decoration, color, material and other elements of buildings should be fully excavated to highlight the characteristics of human living.

3.4. A fuzzy comprehensive evaluation of rural cultural landscape

This study employs the Fuzzy Comprehensive Evaluation (FCE) method to assess the rural cultural landscape of Meicheng Town. FCE is particularly suited for situations involving subjective judgment and uncertainty, such as evaluating residents' satisfaction with cultural landscapes. The adoption of fuzzy sets is essential because it allows for the handling of imprecision and vagueness inherent in human perceptions and judgments (Liu & Lai, 2009; Seyedmohammadi et al., 2019b; Unwin, 1986). By converting qualitative assessments into quantitative data, fuzzification captures the variations in individual perceptions and accommodates the ambiguity inherent in human evaluations, providing a more nuanced analysis than deterministic methods alone (Dubois, 1980; Klir & Yuan, 1996).

In this study, residents' satisfaction with the cultural landscape of Meicheng Town was measured using a 5-point Likert scale (5 = very satisfied, 4 = satisfied, 3 = neutral, 2 = dissatisfied, 1 = very dissatisfied). The fuzzification process involves mapping these Likert scale values onto fuzzy membership functions to more accurately reflect the degree of satisfaction. This approach ensures that the evaluation accounts for subtle differences

Table 2. Subjective weights based on the analytical hierarchy process method

Overall target	Criterion layers		Weight	Sub-criterion layers		Weight
Sequencing of landscape genes in the construction of rural cultural landscape	A1	Environmental gene	23.26%	B1	Topography	7.56%
				B2	Landscape	5.08%
				B3	Land resource	5.07%
				B4	Transportation	5.55%
	A2	Layout gene	22.55%	B5	Spatial layout	5.46%
				B6	Building style	5.80%
				B7	Street layout	6.07%
				B8	River layout	5.22%
	A3	Architecture gene	27.83%	B9	Building structure	5.85%
				B10	Building material	7.71%
				B11	Building color	6.81%
				B12	Building decoration	7.46%
	A4	Cultural genes	26.35%	B13	Traditional culture	7.02%
				B14	Folk customs	7.65%
				B15	Festival celebration	7.05%
				B16	Traditional skills	4.63%

in satisfaction levels that may not be fully captured by traditional deterministic methods.

A fuzzy evaluation matrix was constructed based on the responses of 110 villagers, from which 100 valid questionnaires were collected. Table 3 presents the results of the survey. Each criterion is represented by a fuzzy set describing varying satisfaction levels. The fuzzy sets were weighted according to their importance, determined through the Analytic Hierarchy Process (AHP). This approach combines expert-driven evaluations (through AHP) with non-expert perspectives (through FCE), ensuring a holistic assessment that integrates both technical and local knowledge. The fuzzy evaluation result vector is then converted into a specific value using a weighted average formula, resulting in an overall evaluation score E, calculated as follows:

$$E = 0.235 \times 5 + 0.271 \times 4 + 0.279 \times 3 + 0.147 \times 2 + 0.068 \times 1 = 3.458. \quad (3)$$

The formula aggregates the weighted fuzzy scores, providing a comprehensive evaluation of residents' satisfaction with the cultural landscape.

4. Discussion and results

According to the evaluation results of each gene (Table 3), the scores and weights of Meicheng Town landscape gene evaluation indicators were analyzed by a four-quadrant diagram (Figure 4). This four-quadrant diagram model, also known as the important factor derivation model, is a diagnostic tool biased toward qualitative research. The abscissa represents the importance of the evaluation index, derived from the weights listed in Table 3, while the ordinate reflects the current score of the evaluation index, directly correlating with the 'Combined Score' column from Table 3.

Area A in the analysis results is the dominant area (high weight, high score), including topography (B1) and building decoration (B12). Area B is the maintenance area (low weight, high score), including 5 indicators: land resource (B3), spatial layout (B5), street layout (B7), river layout (B8), building structure (B9). Area C is an opportunity area (low weight, low score), including landscape (B2), transportation (B4), building style (B6), traditional skills (B16). Area D is an improvement area (high weight, low score), including 5 indicators: building material (B10), building color (B11), traditional culture (B13), folk customs (B14), and festival celebration (B15). It can be seen that the cultural landscape and architectural landscape in the improvement area (Area D) is the most prominent, followed by the environmental landscape gene such as landscape pattern and transportation in the opportunity area (Area C).

Meicheng Town is a famous cultural town with a long history. There are 81 villages in Meicheng Town, which is the birthplace of Meishan Culture. The current rural cultural landscape is generally good. The streets of Meicheng

Table 3. Evaluation on rural cultural landscape in Meicheng Town

Criterion layers		Sub-criterion layers		Weight	Very satisfied	Satisfied	Neither satisfied nor dissatisfied	Dissatisfied	Very dissatisfied	Combined Score
A1	Environmental gene	B1	Topography	7.56%	0.45	0.2	0.2	0.15	0	3.95
		B2	Landscape	5.08%	0.1	0.3	0.29	0.21	0.1	3.09
		B3	Land resource	5.07%	0.22	0.31	0.22	0.24	0.01	3.49
		B4	Transportation	5.55%	0.23	0.24	0.35	0.08	0.1	3.42
A2	Layout gene	B5	Spatial layout	5.46%	0.45	0.3	0.2	0.05	0	4.15
		B6	Building style	5.80%	0.12	0.41	0.22	0.12	0.13	3.27
		B7	Street layout	6.07%	0.3	0.2	0.35	0.09	0.06	3.59
		B8	River layout	5.22%	0.41	0.3	0.22	0.07	0	4.05
A3	Architecture gene	B9	Building structure	5.85%	0.23	0.23	0.34	0.2	0	3.49
		B10	Building material	7.71%	0.17	0.25	0.28	0.17	0.13	3.16
		B11	Building color	6.81%	0.12	0.33	0.12	0.21	0.22	2.92
		B12	Building decoration	7.46%	0.31	0.25	0.26	0.18	0	3.69
A4	Cultural genes	B13	Traditional culture	7.02%	0.15	0.32	0.32	0.12	0.09	3.32
		B14	Folk customs	7.65%	0.15	0.22	0.36	0.2	0.07	3.18
		B15	Festival celebration	7.05%	0.22	0.21	0.33	0.15	0.09	3.32
		B16	Traditional skills	4.63%	0.12	0.34	0.43	0.06	0.05	3.42

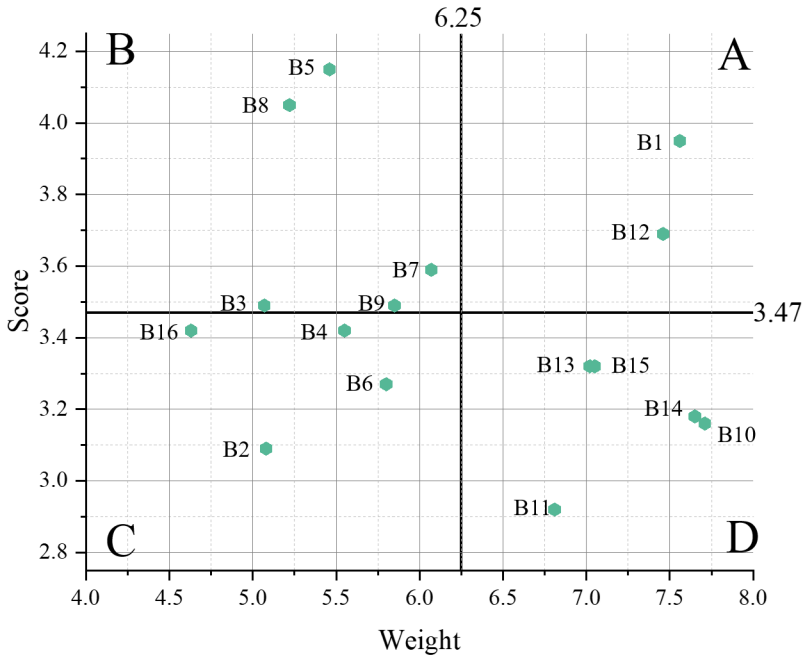

Figure 4. Four-quadrant diagram of Meicheng Town landscape evaluation

Town are distributed along the river from east to west as a whole. The road structure in the villages and towns is clear. The roads are mainly arranged according to the trend of mountains and rivers, which embodies the ideology of conforming to nature and harmonious coexistence. Xinmei Street is the core of the landscape of the entire region and is well-preserved. However, challenges persist: crucial buildings lie in disrepair, village entrances lack distinction, and the river landscape requires enhancement.

To optimize the architectural landscape, it's imperative that design echoes the uniqueness, harmony, and aesthetic beauty of the Meishan region. Architects and designers should harness Meicheng's distinctive regional elements, ensuring their preservation and innovative incorporation into architectural designs and renovations.

Further, traditional Confucian culture can be actively disseminated in constructing the cultural landscape through the maintenance of ancestral halls, the construction of Confucius schools, and the increase of Confucian cultural program performances. At the same time, the village committee can rely on the most representative activities in Meicheng Town to organize folk activities to visit and experience. In addition, the display of folk customs can also be used throughout daily life, and specific groups of people can be organized to perform in a particular stage in the village, as well as touring in the village.

The current environment and layout of Meicheng Town are generally good, but the recognition of the village entrance is not high, and the river and road landscape needs to be optimized. Therefore, it is necessary to focus on building the village entrance landscape and river landscape, and highlight the rural cultural landscape characteristics of Meicheng Town. For example, when repairing damaged villages or streets, landscape genes can be extracted, and combined with materials, colors, forms and other genes into the landscape construction, so that the traditional style can be preserved and continued.

At the same time, in the process of optimizing and protecting the landscape of traditional settlements in Meishan, it is necessary to preserve the actual appearance of buildings, traditional villages, ancient towns and history as much as possible, and protect the inherent planning and layout of traditional villages or historical blocks.

5. Conclusions

Based on the principles of landscape gene theory and detailed field research, the study has developed an evaluative index system. By integrating the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE), the research systematically ranked 16 landscape sub-categories within four main categories, offering a clear framework to prioritize key elements for enhancing rural cultural identity.

The exploration of Meicheng Town's cultural landscape provided both an in-depth evaluation and practical recommendations for improvement. The four-quadrant analysis highlighted topography and building decoration as dominant features that should be preserved and further emphasized. In contrast, building materials, traditional culture, and folk customs were identified as areas needing significant improvement to better align with the town's cultural heritage. Furthermore, the river and road landscapes were identified as opportunities for enhancement to improve overall recognition and aesthetic quality.

The findings underscore the importance of preserving Meicheng's distinctiveness by incorporating traditional materials, forms, and colors into future landscape designs. This study not only offers a nuanced evaluation of Meicheng Town's landscape but also provides practical insights for balancing cultural preservation with modern development needs. This innovative approach addresses a critical gap in the academic literature on settlement landscape genes, particularly for rural areas, and contributes valuable strategies for the sustainable development of rural cultural landscapes.

References

Bhyan, P., Shrivastava, B., & Kumar, N. (2023). Allocating weightage to sustainability criteria's for performance assessment of group housing developments: Using fuzzy analytic hierarchy process. *Journal of Building Engineering*, *65*, Article 105684. https://doi.org/10.1016/j.jobe.2022.105684

Blackmore, S. J. (2000). *The meme machine* (Vol. 25). Oxford Paperbacks.

Cadieux, K. V., & Hurley, P. T. (2011). Amenity migration, exurbia, and emerging rural landscapes: Global natural amenity as place and as process. *GeoJournal*, *76*, 297–302. https://doi.org/10.1007/s10708-009-9335-0

Churchill, F. B. (1974). William Johannsen and the genotype concept. *Journal of the History of Biology*, *7*, 5–30. https://doi.org/10.1007/BF00179291

Conzen, M. R. (2004). *Thinking about urban form: Papers on urban morphology, 1932-1998*. Peter Lang.

Dang, A., Zhao, D., Chen, Y., & Wang, C. (2020). Conservation of cave-dwelling village using Cultural Landscape Gene Theory. In *Spatial synthesis: Computational social science and humanities* (pp. 97–105). Springer. https://doi.org/10.1007/978-3-030-52734-1_8

Dawkins, R. (2016). *The selfish gene*. Oxford University Press. https://doi.org/10.4324/9781912281251

Dubois, D. J. (1980). *Fuzzy sets and systems: Theory and applications* (Vol. 144). Academic Press.

Feng, S., & Xu, L. D. (1999). Decision support for fuzzy comprehensive evaluation of urban development. *Fuzzy Sets and Systems*, *105*(1), 1–12. https://doi.org/10.1016/S0165-0114(97)00229-7

Gullino, P., Devecchi, M., & Larcher, F. (2018). How can different stakeholders contribute to rural landscape planning policy? The case study of Pralormo municipality (Italy). *Journal of Rural Studies*, *57*, 99–109. https://doi.org/10.1016/j.jrurstud.2017.12.002

Guo, Z.-H. (2022). Local revitalization: Support from local residents. *Sustainability*, *14*(14), Article 8298. https://doi.org/10.3390/su14148298

Hu, Z., Liu, P., Deng, Y., & Zheng, W. (2015). A novel method for identifying and separating landscape genes from traditional settlements. *Scientia Geographica Sinica*, *35*(12), 1518–1524.

Hu, Z., Strobl, J., Min, Q., Tan, M., & Chen, F. (2021). Visualizing the cultural landscape gene of traditional settlements in China: A semiotic perspective. *Heritage Science*, *9*(1), 1–19. https://doi.org/10.1186/s40494-021-00589-y

Jing, L., & Hua, H. C. (n.d.). *Anhua traditional residential architecture design method of regeneration*.

Jongman, R. H. (2002). Homogenisation and fragmentation of the European landscape: Ecological consequences and solutions. *Landscape and Urban Planning*, *58*(2–4), 211–221. https://doi.org/10.1016/S0169-2046(01)00222-5

Klir, G. J., & Yuan, B. (1996). Fuzzy sets and fuzzy logic: Theory and applications. *Possibility Theory Versus Probability Theory*, *32*(2), 207–208.

Krummel, J., Gardner, R., Sugihara, G., O'Neill, R., & Coleman, P. (1987). Landscape patterns in a disturbed environment. *Oikos*, *48*(3), 321–324. https://doi.org/10.2307/3565520

Lee, J.-A., Lee, Y.-K., Lee, S.-W., & Chon, J.-H. (2011). Landscape resources evaluation strategy of rural waterfront villages – An application to a rural waterfront village along the Han river. *Journal of Korean Society of Rural Planning*, *17*(3), 91–101. https://doi.org/10.7851/ksrp.2011.17.3.091

Liu, K. F., & Lai, J.-H. (2009). Decision-support for environmental impact assessment: A hybrid approach using fuzzy logic and fuzzy analytic network process. *Expert Systems with Applications*, *36*(3), 5119–5136. https://doi.org/10.1016/j.eswa.2008.06.045

Liu, P. (2014). *Traditional settlement cultural landscape gene: A precise interpretation for traditional settlement landscape gene's maps*. The Commercial Press.

Liu, P., Zeng, C., & Liu, R. (2023). Environmental adaptation of traditional Chinese settlement patterns and its landscape gene mapping. *Habitat International*, *135*, Article 102808. https://doi.org/10.1016/j.habitatint.2023.102808

Liu, S., Wu, L., Xiang, C., & Dai, W. (2024). Revitalizing rural landscapes: Applying cultural landscape gene theory for sustainable spatial planning in Linpu Village. *Buildings*, *14*(8), Article 2396. https://doi.org/10.3390/buildings14082396

Liu, Y., Meng, Q., Zhang, J., Zhang, L., Allam, M., Hu, X., & Zhan, C. (2022). Evaluation of urban spatial structure from the perspective of socioeconomic benefits based on 3D urban landscape measurements: A case study of Beijing, China. *Remote Sensing*, *14*(21), Article 5511. https://doi.org/10.3390/rs14215511

Luo, J., & Chen, F. (2016). Preservation of traditional culture in modern society: A case study of China Meishan cultural park. *International Journal of Sustainable Development and Planning*, *11*(3), 416–425. https://doi.org/10.2495/SDP-V11-N3-416-425

Miao, Y., Liu, P., Fu, I. C. S., Lei, Q., Lau, S. S. Y., & Tao, Y. (2022). The study of architectural geometry and shape in the energy balance of glazed roofs. *Buildings*, *12*(10), Article 1550. https://doi.org/10.3390/buildings12101550

Miao, Y., Ye, T., Xiao, J., Lau, S. S. Y., & Zhou, Z. (2024a). Investigation on alkali-activated insulation mortar containing high-volume recycled concrete powder for energy-efficient buildings. *Energy and Buildings*, *303*, Article 113825. https://doi.org/10.1016/j.enbuild.2023.113825

Miao, Y., Yu, D. S. F., Tan, W., Lau, S. S. Y., Lau, S. S. Y., & Tao, Y. (2024b). Crafting sustainable healthcare environments using green building ratings for aging societies. *Sustainability*, *16*(5), Article 1954. https://doi.org/10.3390/su16051954

O'Neill, R. V., Krummel, J., R., Gardner, R. H., Sugihara, G., Jackson, B., DeAngelis, D. L., Milne, B. T., Turner, M. G., Zygmunt, B., Christensen, S. W., Dale, V. H., & Graham, R. L. (1988). Indices of landscape pattern. *Landscape Ecology*, *1*(3), 153–162. https://doi.org/10.1007/BF00162741

Parks, L. C., Wallin, D. O., Cushman, S. A., & McRae, B. H. (2015). Landscape-level analysis of mountain goat population connectivity in Washington and southern British Columbia. *Conservation Genetics*, *16*(5), 1195–1207. https://doi.org/10.1007/s10592-015-0732-2

Peilin, L. (2015). Theories and practices of remembering nostalgia in new urbanization. *Journal of Landscape Research*, *7*(6), Article 53.

Pinto-Correia, T., & Kristensen, L. (2013). Linking research to practice: The landscape as the basis for integrating social and

ecological perspectives of the rural. *Landscape and Urban Planning*, *120*, 248–256. https://doi.org/10.1016/j.landurbplan.2013.07.005

Plexida, S. G., Sfougaris, A. I., Ispikoudis, I. P., & Papanastasis, V. P. (2014). Selecting landscape metrics as indicators of spatial heterogeneity–A comparison among Greek landscapes. *International Journal of Applied Earth Observation and Geoinformation*, *26*, 26–35. https://doi.org/10.1016/j.jag.2013.05.001

Qiu, Y., & Chen, F. (2016). Research on ancestral hall stages in meishan area: A case study of the Lei family's ancestral hall stage in Changtang Town, Anhua County. In *5th International Conference on Sustainable Energy and Environment Engineering (ICSEEE 2016)* (pp. 905–910). Atlantis Press. https://doi.org/10.2991/icseee-16.2016.162

Ren, X., Kang, J., Zhu, P., & Wang, S. (2018). Effects of soundscape on rural landscape evaluations. *Environmental Impact Assessment Review*, *70*, 45–56. https://doi.org/10.1016/j.eiar.2018.03.003

Risser, P. G. (1990). The ecological importance of land-water ecotones. *The Ecology and Management of Aquatic-Terrestrial Ecotones*, *4*, 7–22.

Saaty, T. L. (1989). Group decision making and the AHP. In *The analytic hierarchy process* (pp. 59–67). Springer. https://doi.org/10.1007/978-3-642-50244-6_4

Schwarzbach, E., Smýkal, P., Dostál, O., Jarkovská, M., & Valová, S. (2014). Gregor J. Mendel – genetics founding father. *Czech Journal of Genetics and Plant Breeding*, *50*(2), 43–51. https://doi.org/10.17221/54/2014-CJGPB

Semple, E. C. (1911). *Influences of geographic environment, on the basis of Ratzel's System of Anthropo-geography*. H. Holt.

Seyedmohammadi, J., & Navidi, M. N. (2022). Applying fuzzy inference system and analytic network process based on GIS to determine land suitability potential for agricultural. *Environmental Monitoring and Assessment*, *194*(10), Article 712. https://doi.org/10.1007/s10661-022-10327-x

Seyedmohammadi, J., Sarmadian, F., Jafarzadeh, A. A., & McDowell, R. W. (2019a). Development of a model using matter element, AHP and GIS techniques to assess the suitability of land for agriculture. *Geoderma*, *352*, 80–95. https://doi.org/10.1016/j.geoderma.2019.05.046

Seyedmohammadi, J., Sarmadian, F., Jafarzadeh, A. A., & McDowell, R. W. (2019b). Integration of ANP and Fuzzy set techniques for land suitability assessment based on remote sensing and GIS for irrigated maize cultivation. *Archives of Agronomy and Soil Science*, *65*(8), 1063–1079. https://doi.org/10.1080/03650340.2018.1549363

Seyedmohammadi, J., Sarmadian, F., Jafarzadeh, A. A., Ghorbani, M. A., & Shahbazi, F. (2018). Application of SAW, TOPSIS and fuzzy TOPSIS models in cultivation priority planning for maize, rapeseed and soybean crops. *Geoderma*, *310*, 178–190. https://doi.org/10.1016/j.geoderma.2017.09.012

Unwin, S. D. (1986). A fuzzy set theoretic foundation for vagueness in uncertainty analysis. *Risk Analysis*, *6*(1), 27–34. https://doi.org/10.1111/j.1539-6924.1986.tb00191.x

Vetter, S. (2013). Development and sustainable management of rangeland commons–aligning policy with the realities of South Africa's rural landscape. *African Journal of Range & Forage Science*, *30*(1–2), 1–9. https://doi.org/10.2989/10220119.2012.750628

Wagner, H. H., & Fortin, M.-J. (2005). Spatial analysis of landscapes: Concepts and statistics. *Ecology*, *86*(8), 1975–1987. https://doi.org/10.1890/04-0914

Wang, W., Li, W., Pan, J., Deng, X., & Xiao, H. (2023). Research progress and prospect of landscape gene theory in China. *Journal of Yunnan Agricultural University (Social Science)*, *17*(6), 122–130.

Wang, W., Shi, Q., & Wang, G. (2024). Analysis of performance and genetic characteristics of cultural landscapes in traditional villages along the Jinzhong section of the Wanli Tea Road from a landscape gene information chain perspective: A case study of Xiamen Village. *Sustainability*, *16*(18), Article 8131. https://doi.org/10.3390/su16188131

Wang, Y., & Fan, J. (2020). Multi-scale analysis of the spatial structure of China's major function zoning. *Journal of Geographical Sciences*, *30*, 197–211. https://doi.org/10.1007/s11442-020-1723-x

Xiang, L., Cao, M., Qin, J., & Wu, C. (2020). Study of traditional rural settlements landscape genetic variability in Shaanxi province based on accurate-restoration. *Progress in Geography*, *39*(9), 1544–1556. https://doi.org/10.18306/dlkxjz.2020.09.011

Xiao, H., Li, L., Zhang, Q., Liu, M., & Yu, Z. (2013). Ecological evaluation and reconstruction of fine-scale rural landscape. *Zhongguo Shengtai Nongye Xuebao/Chinese Journal of Eco-Agriculture*, *21*(12), 1554–1564. https://doi.org/10.3724/SP.J.1011.2013.30565

Yang, X., & Lo, C. (2003). Modelling urban growth and landscape changes in the Atlanta metropolitan area. *International Journal of Geographical Information Science*, *17*(5), 463–488. https://doi.org/10.1080/1365881031000086965

Yang, Z.-w., Chen, J., Duan, J.-y., & Liu, B.-t. (2021). Evaluation of vernacular landscape attraction for traditional village tourism: A case study of Yongfeng Village in Lanzhou. *E3S Web of Conferences*, *292*, Article 03058. https://doi.org/10.1051/e3sconf/202129203058

Yong, F., & Xiang, J. (2024). Spatial gene extraction and regional overall protection of traditional villages. In *Urban construction and management engineering IV* (pp. 1076–1084). CRC Press. https://doi.org/10.1201/9781032626444-138

Zhang, L., & Chen, F. (2014). Landscape diachrony in the design expression for meishan culture park: A survey. *Journal of Asian Architecture and Building Engineering*, *13*(1), 157–162. https://doi.org/10.3130/jaabe.13.157

Zhao, Z., Ji, C., Xiao, J., Yao, L., Lin, C., Ding, T., & Ye, T. (2023). A critical review on reducing the environmental impact of 3D printing concrete: Material preparation, construction process and structure level. *Construction and Building Materials*, *409*, Article 133887. https://doi.org/10.1016/j.conbuildmat.2023.133887

Zhong, Y., & Chen, F. (2015). Study on the uncertainty in meishan culture park construction and art's randomness. In *5th International Conference on Civil Engineering and Transportation* (pp. 1366–1370). Atlantis Press.

Zou, Y. (2008). *Anhua traditional architecture with Meishan culture*. Changsha.

Zui, H., Peilin, L., Yunyuan, D., & Wenwu, Z. (2015). A novel method for identifying and separating landscape genes from traditional settlements. *Scientia Geographica Sinica*, *35*(12), 1518–1524.