

A Quantitative Method for Cultural Landscape Zoning in Traditional Chinese Villages and Its Applications: A Case Study Based on Chongqing

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ABSTRACT: In China, the traditional village is an important agricultural civilization legacy in its rural cultural landscape. Influenced by multiple factors like physical geography and human society, cultural landscape characteristics in traditional villages have obvious intraregional similarities and interregional differences within a particular space. To examine spatial differentiation in cultural landscapes in traditional villages and determine their spatial distribution characteristics and historical evolutionary paths, the cultural landscape zoning method in traditional villages was explored in this study. The goal was to facilitate systematic regional protection, development, and use of traditional villages.

First, the cultural landscape factor system in traditional villages was decomposed into 21 types of cultural landscape factors. Those factors belonged to four classes: natural environment, spatial form, dwelling type, and social culture. Second, the data on cultural landscape factors were collected and analyzed. Quantitative factors were normalized by the Statistical Package for the Social Sciences (SPSS) software. Third, Principal Component Analysis (PCA) was used to quantitatively analyze the quantitative factors to extract principal components and perform hierarchical clustering. Finally, cultural landscape zoning in traditional villages was achieved with a GIS map expression method by combining the qualitative sensory impressions of descriptive factors. Also, 320 traditional villages in Chongqing City were chosen as research objects, and the proposed zoning method was empirically applied.

Results demonstrated the following: (1) A systematic cultural landscape zoning method in traditional villages was formed. That method comprised factor decomposition, data acquisition and processing, principal component extraction, and hierarchical clustering-zoning. (2) Cultural landscape characteristics in traditional villages in Chongqing can be divided into four zones: a commercial culture dominant type in the west, an immigrant-culture dominant type in the center, a defense-culture dominant type in the northeast, and an ethnic cultural integration type in the southeast.

Chongqing was chosen as the study area, and 320 traditional villages covering the entire Chongqing City were chosen as research objects in the empirical study. Results showed that an optimized zoning method that combines quantitative and qualitative analyses of “principal component extraction combined with hierarchical clustering” was feasible and had high operability. Also, optimization of the traditional village zoning method was manifested in two main aspects. On one hand, the information retention rate of the “zoning factor” increased significantly from the traditional 20%-30% to at least 80%. This refines and enhances the dominant expression of cultural landscape characteristics and decreases the loss of “non-dominant factor” information. It also decreases the subjectivity of the zoning outcome. The extracted principal factors were gained from recombining cultural landscape factors in various traditional villages according to a weight relation. Such a weight relation was calculated by the SPSS software according to pure mathematical statistical relations, and reduced the subjectivity associated with weight determination in the traditional “expert

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scoring method.”

In future studies, the migration paths of cultural landscape factors among different zones in traditional villages, their evolutionary mechanism and influencing characteristics, and the macro-, meso-, and micro-applications of zoning outcomes must be further examined.

KEYWORDS: traditional villages; cultural landscape; zoning; principal component analysis; hierarchical clustering method; Chongqing

Introduction

Traditional villages, as both historical witnesses and important heritage of China's agricultural civilization, are one of the important cultural landscapes created by humankind throughout their historical evolution [1]. The concept of “traditional village cultural landscapes” derives from “cultural landscapes,” a category of cultural heritage introduced within the World Heritage framework in 1992. Synthesizing domestic and international research, Tang Maolin defines “cultural landscapes” as landscapes formed by human utilization of natural materials to satisfy specific needs, essentially superimposing the results of human activities onto natural landscapes [2]. In China, this concept was first comprehensively elucidated in the *Guiyang Recommendation*, which describes it as the “joint work of long-term interaction between nature and humanity.” It is characterized as a significant type of cultural landscape that is not only created by human action but also encompasses that action itself. This landscape embodies the diverse survival wisdom possessed by village societies and ethnic groups, reflects the intrinsic connection between humanity and nature, and represents the crystallization of agrarian civilization. It is distinct from both landscapes intentionally designed by humans and natural landscapes bearing few traces of human modification [3]. Influenced by natural geography and human society, the cultural landscape of traditional villages exhibits marked spatial differentiation, manifesting as similarities within certain regions and differences between them. Zoning is an effective method for exploring the spatio-temporal differentiation characteristics and evolution paths of traditional village cultural landscapes.

The study of traditional villages can be divided into three major stages: the initial stage (prior to 1996), dominated by descriptive studies; the developmental stage (1996-2005), characterized by the continuous expansion of research methods and depth; and the active stage (post-2005), featuring the coexistence of traditional themes with

“soft” factors such as place identity and organizational behavior [4]. In recent years, with the integration of multiple disciplines such as human geography, ethnology, architecture, and urban and rural planning, studies have progressively moved towards the typology and zoning of traditional villages [1]. Regarding the content of research on traditional village cultural landscapes zoning, the focus has shifted from a single cultural landscape element to a more comprehensive cultural landscape zoning approach. Studies focusing on single elements mainly concentrate on village morphology [5], dwellings [6], landscapes [7], ethnicity [8], and infrastructure [9]. In contrast, comprehensive cultural landscape zoning involves the regional division of whole villages [10] or settlements [11] covering multiple elements, as well as research on regional formation mechanisms [12]. In terms of research scale, macro and meso scales are dominant, while research at the micro-scale is gradually increasing. The macro-level focuses on the whole country [13], the meso-level studies concern regions [14], provinces [15], cities [16], and the micro-level concentrates on localities [12] and counties [17]. In terms of research methods, qualitative research is the main approach, and quantitative research is gradually integrated on the basis of qualitative research. Qualitative research is most commonly conducted using descriptive methods [18], multi-factor overlay methods [19], dominant factor methods [10], and historical-geographical methods [20]. Descriptive methods are largely obsolete due to their strong subjectivity and lack of standardization, while the other methods are still commonly used. Integrated quantitative methods involve correlation analysis and extraction of dominant factors [1]; determining factor weights via “expert scoring method” to standardize elements; and calculating village similarity for clustering [21]. This also includes using cluster analysis to group factors by type, followed by correlation analysis for categorical zoning [22]. An overview of current research reveals that the

content has become increasingly rich and in-depth, the research scales have been gradually refined, and the research methods have strengthened quantitative analysis. However, quantitative analysis still has certain shortcomings. First, regarding the selection of “dominant factors,” although quantitative research has been explored, it often still involves pre-determining a factor as an independent or dependent variable and then analyzing its correlation with other factors to verify the correctness of the selection. Furthermore, the dominant factor method retains only about 30% of the information¹⁾, resulting in a significant loss of information from non-dominant factors. This method is actually a dominant factor-based zoning, rather than a zoning of the “overall characteristics of cultural landscape”. Second, regarding methods like multi-factor overlay and similarity clustering, although they attempt to move away from purely subjective weight assignment, methods such as the Delphi method or Analytic Hierarchy Process (AHP) still rely heavily on human judgment. This leads to subjective bias in the zoning process and a lack of objectivity in the results. Therefore, drawing on the aforementioned methods, this paper introduces a quantitative analysis method combining Principal Component Analysis (PCA) for dimensionality reduction with hierarchical clustering, which not only fully reflects the characteristics of cultural landscapes but also avoids the subjective influence of weighting values. By combining quantitative and qualitative methods, this paper explores a more comprehensive, objective, and accurate method for zoning traditional villages.

Chongqing borders Shaanxi, Sichuan, Guizhou, Hunan, and Hubei provinces, and its unique natural and cultural environments have shaped the diversity and complexity of its traditional villages. To better grasp the characteristics of Chongqing’s traditional village cultural landscape system, this study selected 320 “traditional villages”²⁾ listed by the national and Chongqing municipal governments as research subjects. An attribute system of cultural landscape factors was constructed, and SPSS was used to extract principal component factors and perform cluster analysis on quantitative indicators. Based on the clustering results, zoning was carried out in combination with descriptive indicators and qualitative sensory impressions to re-

veal the spatial differentiation characteristics of traditional villages in Chongqing. This work aims to improve the methods of zoning traditional villages and to provide a foundation for subsequent research on their protection and development.

1 Studyarea and data sources

1.1 Overview of the study area

Chongqing is located in the eastern part of Southwest China, bordering Hubei and Hunan to the east, Sichuan to the west, Guizhou to the south, and Sichuan and Shaanxi to the north. It covers an area of approximately 82,400 km² and administers 38 county-level divisions, including 26 districts, 8 counties, and 4 autonomous counties, with which collectively contain 8,015 village committees [23]. Located in the eastern part of the Sichuan Basin, the terrain descends from east to west, with complex and diverse landforms, a well-developed water system, and a climate that combines the characteristics of mountainous and valley areas. Historically, Chongqing has served as an intersection for the “Ba,” “Shu,” and “Chu” cultures, and its administrative divisions have undergone numerous splits and mergers over time.

1.2 Data sources

The research data were obtained from three sources: (1) Research samples. A total of 110 villages in Chongqing have been listed in the five batches of “Traditional Chinese Villages Lists” by national ministries, including the Ministry of Housing and Urban-Rural Development (MOHURD). Furthermore, the Chongqing municipal authorities have designated 22 municipal-level traditional villages, 45 historic and cultural villages (across two batches), and 444 villages hosting protected cultural relics protection units (across three batches). After removing duplicates and villages in highly urbanized areas, a total of 320 village samples were obtained (Figure 1). (2) Documentary data. This includes official announcements on traditional villages from the MOHURD, archives on traditional villages from the Chongqing Municipal Commission of Housing and Urban-Rural Development, promotional materials on historical and cultural villages from the Municipal Planning and Natural Resources Bureau, and the list of cultural relics

Table 1 Attributes of cultural landscape factors in traditional villages of Chongqing

Category	Cultural landscape Factor type	Subtype of cultural landscape factors	Data type
Natural environment	Landforms	Low-altitude plains, medium-altitude plains, low-altitude plateaus, medium-altitude plateaus, high-altitude plateaus, low-altitude hills, medium-altitude hills, high-altitude hills, gently undulating low mountains, gently undulating medium mountains, gently undulating high mountains	Quantitative
	Elevation	$H < 500$ m, $500 \text{ m} \leq H < 1000$ m, $1000 \text{ m} \leq H < 3500$ m	
	Watershed Scale	Micro($S < 100 \text{ km}^2$), small ($100 \text{ km}^2 \leq S < 500 \text{ km}^2$), medium-sized ($500 \text{ km}^2 \leq S < 1000 \text{ km}^2$), large ($1000 \text{ km}^2 \leq S$)	
	Site Selection ³⁾	Near mountains and near water, near mountains and far from water, far from mountains and near water, far from mountains and far from water	
	Relation to Mountains	Flatland, hillside, foothill, mountainside, mountaintop	
	Relation to Water	No adjacent water, point-type, single-sided, double-sided, through-type, and ring-type	
	Proximity to Rivers	Adjacent ($D < 300$ m), near ($300 \text{ m} \leq D < 600$ m), far ($600 \text{ m} \leq D < 900$ m), none ($900 \text{ m} \leq D$)	
Spatial form	Grouping Pattern	Clustered, strip-shaped, grouped, scattered	Quantitative
	Morphological type	Punctate, strip, tiered, compact, centripetal, free-form, enclosed	
	Village environment	Feng shui forest & pond, feng shui forest (no pond), pond (no feng shui forest), none (no forest, no pond)	
	Village orientation ⁴⁾	Backed by mountains and facing water, with multiple directions of mountain support, one direction of mountain support, multiple directions of road support, and one direction of core area.	
Dwelling form	Dwelling type	Traditional Chinese courtyard houses, stilted houses, shop-houses, watchtowers, Western-style houses, and fortified manor houses	Descriptive
	Building materials	Rammed earth, adobe bricks, bamboo-wattle and daub, wooden boards, stone strips, rubble, blue bricks, red bricks, etc.	
	Facade features	Tripartite facade proportion, entrance, eaves, gate tower, roof ridge ornaments, etc.	
	Roof form	Overhanging gable, flush gable, hip-and-gable, fire gable wall, pyramidal, hip roof	
	Building-Ground Interface	Ground-level, semi-stilted (Diaojiailou), and fully stilted (Ganlan)	
	Typical buildings	Basic building information recording, planimetric survey, and elevation survey	
Social culture	Era of construction	Yuan Dynasty and earlier, Ming Dynasty, Qing Dynasty, Republic of China period and later	Quantitative
	Ethnicity	Han, Tujia, Miao, Gelao, etc.	
	Intangible cultural heritage	Ethnic songs, handicrafts, folk activities, traditional customs, clan order, village planning wisdom, etc.	Descriptive
	Dominant culture	Industrial-commercial culture, agricultural culture, immigrant culture, defense culture, salt culture, ethnic culture, etc.	

2.2 Data collection and standardization processing

For descriptive factors, the Rapid Ethnographic Assessment Procedure (REAP) was employed, employing methods such as photography, field surveying, questionnaires, and interviews to collect data, archive photographs, and organize qualitative descriptions. For quantitative factors, one approach is to use REAP to collect statistical data from literature and survey materials. Second, the Tianditu platform was used to search for place names and employed

visual interpretation to identify and statistically analyze relevant factor information. Third, villages were abstracted as points by selecting the geometric centers of their representative architectural clusters to determine longitude and latitude coordinates. These coordinates were then imported into ArcGIS for vectorization [26] and integrated with Digital Elevation Model (DEM) data to conduct analysis and statistics on the geospatial information associated with the factors.

Data-based factors cannot be directly statistically analyzed due to differences in information type and dimension. Standardization is required to eliminate the influence of dimension on the analysis [27].

(1) Construction of the original data sample matrix X of village cultural landscape factors:

$$X = \begin{bmatrix} x_1^T \\ x_2^T \\ \vdots \\ x_n^T \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix}$$

Here, x_{ij} is the value of the j -th cultural landscape factor variable in the i -th village, n is the number of village samples, p is the number of cultural landscape factor types, and $n > p$.

(2) Normalization. The matrix X is normalized to obtain the matrix Z . Use SPSS data transcoding to resolve inconsistencies in the types and dimensions of indicators in matrix X :

$$Z = \begin{bmatrix} z_1^T \\ z_2^T \\ \vdots \\ z_n^T \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1p} \\ z_{21} & z_{22} & \cdots & z_{2p} \\ \vdots & \vdots & & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{np} \end{bmatrix}$$

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}, \text{ and here, } \bar{x}_j \text{ is the arithmetic mean of}$$

$$x_j, s_j \text{ is the standard deviation of } x_j. \bar{x}_j = \frac{1}{n} \sum_{i=1}^n x_{ij}, s_j =$$

$$\frac{1}{n-1} \sum_{i=1}^n (x_{ij} - \bar{x}_j)^2.$$

2.3 Principal component analysis

Principal component analysis is a method that simplifies the structure of a dataset by using the concept of dimensionality reduction [28]. Principal component analysis of village cultural landscape factors involves transforming multiple factors that were originally correlated with each other using SPSS to extract a small number of uncorrelated principal components (PCs) that comprehensively reflect the information carried by the original multiple factors. These principal component factors are the principal components of the original multiple factors. Characterized by their small number, mutual uncorrelation, and retention of over 80% of the original information content, these principal components achieve the goal of dimensionality

reduction when they replace the original set of factors in analysis [29]. The extraction steps are as follows:

(1) Calculate the correlation coefficient matrix R for matrix Z :

$$R = [r_{ij}]_{n \times p} = \frac{Z^T Z}{n-1}$$

(2) Calculate the eigenvalues of the correlation coefficient matrix R :

$$|R - \lambda I_p| = 0$$

Solving this yields p eigenvalues, where $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_p \geq 0$.

(3) Determine the value of m such that the cumulative variance contribution rate of the principal components exceeds 80%:

$$\frac{\sum_{j=1}^m \lambda_j}{\sum_{j=1}^p \lambda_j} \geq 0.8$$

For each $\lambda_j (j=1, 2, \dots, m)$, solve the system of equations $Rb = \lambda_j b$, thus obtaining the unit vector $b_j^0 = \frac{b_j}{\|b_j\|}$.

(4) Calculate the m component score coefficients $u_{ij} = z_i^T b_j^0$ (for $j=1, 2, \dots, m$) of $z_i = (z_{i1}, z_{i2}, \dots, z_{ip})^T$ to obtain the coefficient matrix U :

$$U = \begin{bmatrix} u_1^T \\ u_2^T \\ \vdots \\ u_p^T \end{bmatrix} = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1m} \\ u_{21} & u_{22} & \cdots & u_{2m} \\ \vdots & \vdots & & \vdots \\ u_{p1} & u_{p2} & \cdots & u_{pm} \end{bmatrix}$$

Where u_i represents the principal component vector of the i -th variable.

(5) Establish the principal component extraction model:

$$\begin{cases} F_1 = u_{11}X_1 + u_{21}X_2 + \cdots + u_{m1}X_m \\ F_2 = u_{12}X_1 + u_{22}X_2 + \cdots + u_{m2}X_m \\ \vdots \\ F_m = u_{1m}X_1 + u_{2m}X_2 + \cdots + u_{mm}X_m \end{cases}$$

Here, F_1, F_2, \dots, F_m denote the m extracted principal components; u_{ij} represents the coefficients from the decision matrix U ; and X_1, X_2, \dots, X_p are the standardized values of the original factors.

2.4 Hierarchical clustering analysis

Hierarchical clustering is a method that progressively merges clusters from many to few based on inter-cluster

distances at different levels[27]. In the hierarchical clustering of principal components derived from village cultural landscape factors, the information carried by the principal component factors serves as the attribute set. Initially, each village is treated as a distinct cluster, constituting the first level. Using the “inter-village distance” (village similarity) as the statistic, the villages with the smallest “inter-class distance” are merged into a new cluster, forming the second level. Subsequently, the new clusters from the second level are grouped based on inter-class distances. This process is repeated recursively until all villages are aggregated into a single large cluster. The final “number of clusters” can be pre-specified according to practical needs or determined by evaluating the reasonableness of sample attribution using expert judgment [30].

2.5 Zoning of traditional village cultural landscapes

The zoning of traditional villages falls within the category of “formal cultural regions,” referring to the distribution range of people or landscapes possessing shared cultural attributes that are formed naturally without external imposition [31]. However, due to the processes of spatial transition and regional variations, there exists a degree of long-distance dispersal of villages with similar characteristics and short-range intermixing of villages with different characteristics. Therefore, based on the principal component clustering of quantitative factors, it is necessary to combine the regional differences described by descriptive factors such as building materials, facade features, roof forms, building-ground interface, typical building documentation, intangible cultural heritage, and dominant culture. Based on principles such as similarity of cultural landscape characteristics, geographic contiguity, convergence of development processes, equal development levels, distinct core and peripheral areas, and county and district administrative divisions as boundaries⁵⁾, spatial overlay should be carried out to seek commonalities and refine boundaries. the cultural landscape regions of traditional villages are delineated by combining quantitative and qualitative methods.

3 Analysis and results

3.1 Spatial distribution of cultural landscape factors

Based on the aforementioned framework for deconstructing traditional village cultural landscape factors and the corre-

sponding data collection methods, the collected and organized 14 quantitative factor information items were processed by ArcGIS to form corresponding spatial distribution maps, which intuitively express the spatial distribution characteristics of the quantitative factors (Figure 2).

3.2 Extraction of principal component factors

3.2.1 Model validation

A strong correlation between factor variables is a prerequisite for principal component analysis, so it is necessary to test whether the model is suitable. The KMO value shown in Table 2 is 0.853, which is much greater than 0.5 (the value ranges from 0 to 1, and the closer it is to 1, the stronger the correlation) [29], indicating that the correlation between the factors is relatively strong. Meanwhile, the approximate chi-square distribution value of Bartlett’s test for sphericity is 4223.528, with 91 degrees of freedom and a significance of 0.000, which is much smaller than 0.001 [29]. Therefore, the data model, through the KMO and Bartlett’s double test of sphericity, can effectively summarize the interrelationships and common characteristics among cultural landscape factors, indicating that the sample data meet the analysis conditions.

Table 2 Correlation test between KMO and Bartlett

KMO sampling suitability measures		0.853
Bartlett’s test for sphericity	Approximate Chi-Square	4223.528
	Degrees of freedom (df)	91
	Significance (Sig.)	0.000

3.2.2 Eigenvalues and contribution rates

The principal component eigenvalues and contribution rates are the basis for selecting the number of principal components[27]. The principal component eigenvalues and variance contribution rates of the village cultural landscape factors are shown in Table 3. Based on the criterion of eigenvalues $\lambda \geq 1$ [27], five principal components were extracted. Their cumulative variance contribution rate reached 84.845%, satisfying the statistical requirement that the cumulative contribution rate exceed 80%. This accounts for 84.845% of the information content of the original factors. Therefore, the first 5 principal components were selected to replace the original 14 quantitative factors for analysis.

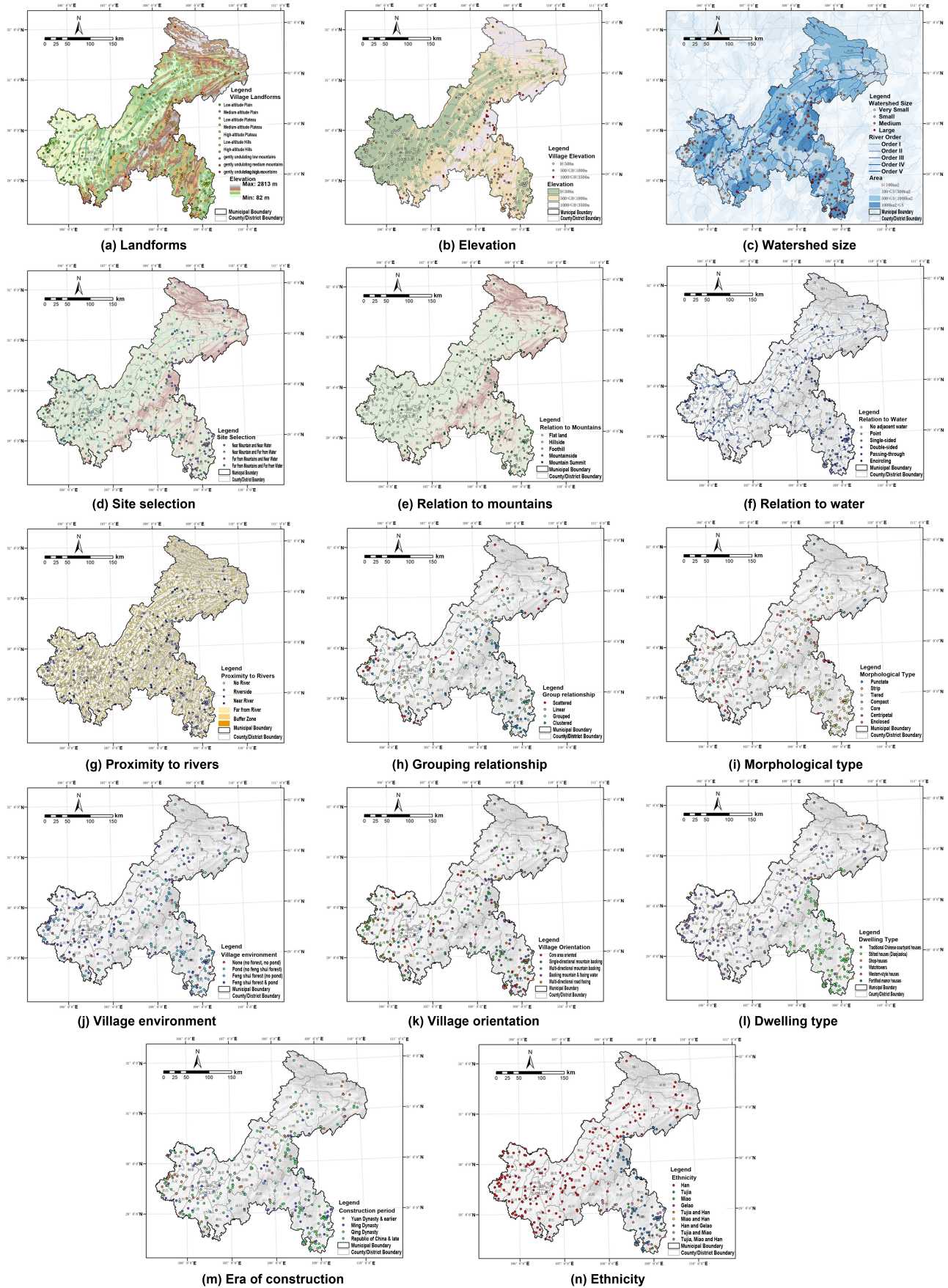


Figure 2 Spatial distribution characteristics of quantitative cultural landscapes in traditional villages of Chongqing based on subtypes

Table 3 Eigenvalues and variance contribution rates of principal components of cultural landscape factors

Principal component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	Percentage of variance	Cumulative%	Total	Percentage of variance	Cumulative%
1	6.196	44.261	44.261	6.196	44.261	44.261
2	2.297	16.405	60.666	2.297	16.405	60.666
3	1.212	8.657	69.323	1.212	8.657	69.323
4	1.161	8.291	77.614	1.161	8.291	77.614
5	1.012	7.231	84.845	1.012	7.231	84.845
6	0.700	4.997	89.842	—	—	—
7	0.380	2.715	92.557	—	—	—
8	0.353	2.521	95.078	—	—	—
9	0.278	1.984	97.063	—	—	—
10	0.119	0.847	97.909	—	—	—
11	0.108	0.774	98.683	—	—	—
12	0.082	0.587	99.270	—	—	—
13	0.060	0.431	99.701	—	—	—
14	0.042	0.299	100.000	—	—	—

3.2.3 Principal component function

Five principal components were selected as principal component factors for analysis. Their factor loading matrices are shown in Table 4. The factor loading vectors represent the contributions of factors to each principal component. The principal component function is expressed as the standardized values of the 14 original variables multiplied by the coefficients of the decision matrix, and then summed⁹⁾. The five principal component functions are:

$$F_1 = 0.025X_1 + 0.029X_2 + 0.006X_3 - 0.032X_4 + 0.060X_5 + 0.052X_6 + 0.058X_7 + 0.001X_8 + 0.060X_9 + 0.058X_{10} - 0.007X_{11} - 0.043X_{12} - 0.059X_{13} + 0.037X_{14}$$

$$F_2 = -0.231X_1 - 0.231X_2 - 0.007X_3 + 0.199X_4 + 0.031X_5 + 0.051X_6 + 0.068X_7 + 0.022X_8 + 0.070X_9 + 0.084X_{10} - 0.081X_{11} + 0.026X_{12} + 0.087X_{13} - 0.087X_{14}$$

$$F_3 = 0.144X_1 + 0.141X_2 + 0.157X_3 + 0.075X_4 + 0.049X_5 + 0.046X_6 + 0.136X_7 + 0.270X_8 + 0.086X_9 + 0.112X_{10} + 0.409X_{11} + 0.414X_{12} + 0.064X_{13} - 0.390X_{14}$$

$$F_4 = 0.083X_1 + 0.081X_2 + 0.266X_3 + 0.002X_4 - 0.071X_5 - 0.002X_6 - 0.006X_7 + 0.636X_8 - 0.086X_9 - 0.037X_{10} - 0.454X_{11} - 0.161X_{12} - 0.028X_{13} - 0.084X_{14}$$

$$F_5 = -0.169X_1 - 0.138X_2 + 0.869X_3 - 0.058X_4 - 0.022X_5 - 0.174X_6 + 0.011X_7 - 0.162X_8 + 0.029X_9 - 0.009X_{10} + 0.230X_{11} - 0.118X_{12} - 0.026X_{13} + 0.210X_{14}$$

As can be seen from Table 4, X₅, X₉, X₁₃, X₇, and X₁₀

exhibit the highest factor loadings on F₁ and are positively correlated, mainly reflecting the influence of relation to mountains, grouping patterns, era of construction, proximity to rivers, and spatial forms. On component F₂, variables X₂, X₁, and X₄ show the most significant loadings; specifically, X₂ and X₁ are negatively correlated, whereas X₄ is positively correlated. These factors primarily reflect the influence of elevation and landform. Variables X₁₂, X₁₁, and X₁₄ have the highest loadings on F₃, with X₁₂ and X₁₁ showing positive correlations and X₁₄ showing a negative correlation. This component primarily embodies the influence of dwelling type and village environment. Variable X₈ exhibits the highest loading on F₄ with a positive correlation, mainly reflecting the influence of village orientation. Finally, variable X₃ has the highest loading on F₅ and is positively correlated, primarily reflecting the influence of the Watershed Size.

3.3 Hierarchical clustering of principal components

Each of the 320 villages was considered as a cluster, with the five principal component factors as its attributes. SPSS cluster analysis was performed using the between-groups linkage method and squared Euclidean distance as the distance measure. No predetermined range was set for the number of clusters, and a cluster dendrogram was drawn. As shown in Figure 3, at the distance coefficient

$d= 5$, it clusters into 81 clusters; $d= 10$, clusters into 20 clusters; $d= 15$, clusters into 7 clusters; $d= 20$, clusters into 3 clusters; and $d= 25$, clusters into 1 cluster. It can be seen that different distance coefficients correspond to different numbers of clusters. The number of clusters was set to 2-10 for further analysis. The corresponding area codes of each village in each cluster were obtained. The area codes were imported into the corresponding village attribute table in ArcGIS. Spatial geographic maps of clusters 2-10 were drawn and compared. It was found that the spatial distribution of villages in clusters 2-3 was too fragmented and inter-mixed. If divided into 2-3 characteristic areas, these solutions would show clear deficiencies in terms of intra-regional cultural landscape similarity, distinctiveness between core and pe-

ripheral areas, convergence in developmental processes, and comparability in development levels. The spatial distribution of villages in clusters 5-10 shows that a small number of villages are now clustered together. The main reason for this is that they are located in areas of ethnic integration, typical immigrant areas, and areas on the edge of municipal boundaries. This result is suitable for reference in the next step of sub-region division. Based on the influence of Chongqing’s topography, hydrology, climate, and other natural environment and human environment, such as population migration and social organization, on the characteristics of village cultural landscape [25, 32], it was determined that a cut-off distance of $d= 16$ yields a reasonable clustering of the 320 villages into 4 categories.

Table 4 Principal component factor loading matrix

Cultural landscape factors	Principal component F ₁	Principal component F ₂	Principal component F ₃	Principal component F ₄	Principal component F ₅
X ₁ (Landforms)	0.062	-0.350	0.158	0.089	-0.170
X ₂ (Elevation)	0.073	-0.351	0.155	0.087	-0.139
X ₃ (Watershed Size)	0.015	-0.010	0.173	0.286	0.874
X ₄ (Site Selection)	-0.080	0.301	0.082	0.003	-0.059
X ₅ (Relation to Mountains)	0.150	0.046	0.053	-0.077	-0.022
X ₆ (Relation to Water)	0.129	0.077	0.050	-0.002	-0.175
X ₇ (Proximity to Rivers)	0.145	0.104	0.150	-0.006	0.011
X ₈ (Village orientation)	0.002	0.033	0.297	0.685	-0.163
X ₉ (Group Relationship)	0.150	0.107	0.095	-0.092	0.029
X ₁₀ (Morphological type)	0.145	0.128	0.123	-0.040	-0.009
X ₁₁ (Village Environment)	-0.018	-0.122	0.450	-0.489	0.232
X ₁₂ (Types of dwellings)	-0.106	0.039	0.456	-0.173	-0.119
X ₁₃ (Era of construction)	0.147	0.132	0.070	-0.030	-0.026
X ₁₄ (Ethnicity)	0.093	-0.132	-0.429	-0.090	0.212

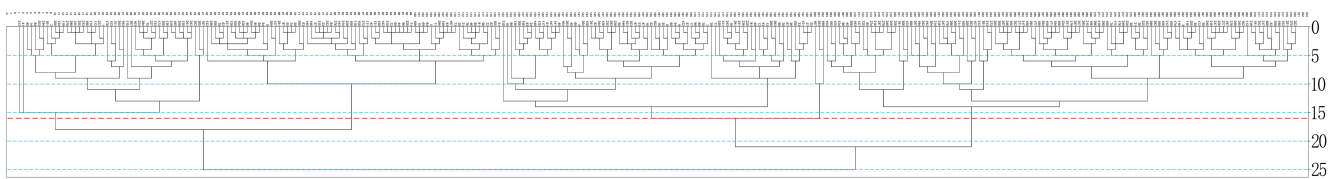


Figure 3 Clustering dendrogram of principal component factors

3.4 Results and typical characteristics of cultural landscape zoning in traditional villages

3.4.1 Results of cultural landscape zoning in traditional villages

By combining quantitative factor clustering results with descriptive factors such as architecture, ethnicity, and

dominant culture to identify common features, spatial overlay and boundary fine-tuning were performed, ultimately dividing Chongqing’s traditional villages into four cultural landscape zones. Drawing on the “tripartite” naming convention [33], the zones were named according to the structure: “Geographic Location — Dominant or Blended

Culture Type — Common Name.” The four major traditional village cultural landscape areas in Chongqing are: the Western Commercial Culture-Dominated Traditional Village Landscape Zone, the Central Immigrant Culture-

Dominated Traditional Village Landscape Zone⁷⁾, the Northeastern Defense Culture-Dominated Traditional Village Landscape Zone, and the Southeastern Ethnic Culture Integration Traditional Village Landscape Zone (Figure 4).

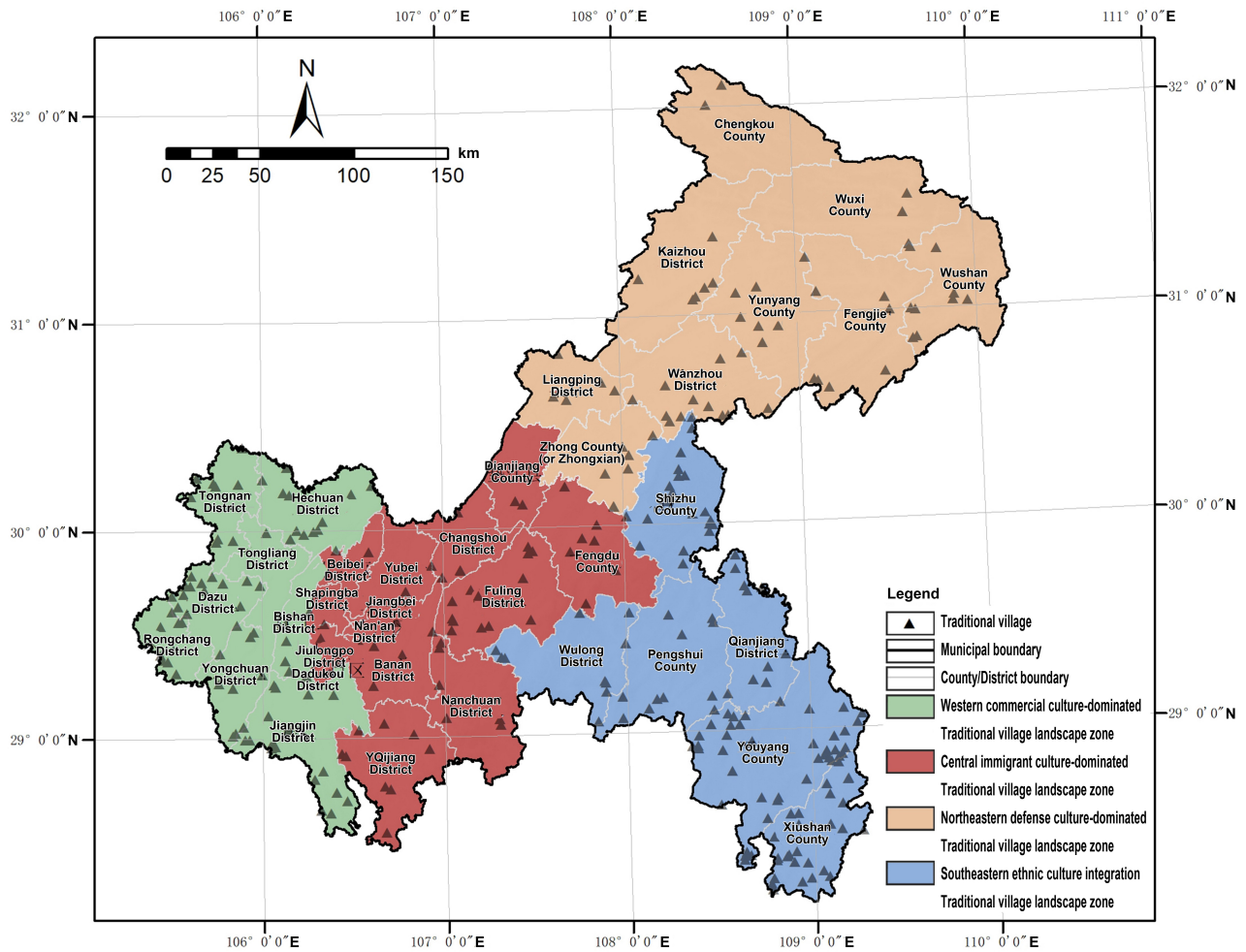


Figure 4 Division of traditional villages in Chongqing

3.4.2 Typical characteristics of traditional village cultural landscape zones

The Western Commercial Culture-Dominated Traditional Village Landscape Zone encompasses eight districts and counties, including Hechuan and Jiangjin. The terrain is mainly plains and plateaus. Villages are commonly located in plains and typically near water or rivers. The spatial form of villages is most characterized by clusters and strips. Commercial villages rarely have feng shui forests or ponds, while feng shui forests are more common than ponds in agricultural villages. The houses are mostly oriented towards roads or mountains; the types of dwellings are diverse, with both ground-level and stilted Building-

Ground Interfaces, and the shophouses and Western-style houses are the most distinctive; the ethnic group is mainly Han Chinese. The social culture includes industrial and commercial culture, hilly agricultural culture, Hakka immigrant culture, and Buddhist and Taoist stone carving culture, with commercial culture being the most prominent. Social organizations are mainly composed of guilds (Huiguan) based on trade and regional ties.

The Central Immigrant Culture-Dominated Traditional Village Landscape Zone includes 15 districts and counties such as Qijiang and Fuling. The terrain is mainly hilly and low mountainous, a typical parallel ridge-and-valley region. Villages are often located in hilly areas, close to



mountains and water; the spatial form of villages is mainly clustered, dense, and centripetal. Most of them have feng shui forests, while ponds are relatively rare. Houses are mostly oriented backed by mountains, and are divided into single-direction and multi-directional based on the terrain. Dwelling types are diverse, with ground-level dwellings being the most common. The traditional Chinese courtyard houses are the most prominent, while the walled houses are the most distinctive. The watchtowers are made of a combination of earth and stone. The ethnic group is Han, with some ethnic minorities present in the southern area bordering Guizhou. Social culture includes migration culture, hilly and mountainous agricultural culture, and military defense culture, with migration culture being the most prominent. With clans as the basic social structure, the size of the clan determines the size of the village, and there are close connections within the clan.

The Northeastern Defense Culture-Dominated Traditional Village Landscape Zone comprises nine districts and counties, including Wushan and Wanzhou. The terrain and landforms are diverse, ranging from hills, low mountains, medium mountains, and high mountains from south to north. Villages tend to be located near mountains or water, often situated at the foot or summit of mountains. The most common spatial forms of villages are clustered, dense, and centripetal. Villages generally have feng shui forests, but few ponds. The houses are mostly oriented towards the mountains; the style of dwellings is relatively simple, and the ground-level approach is the most common. Chinese-style houses and watchtowers are the most common. In the Zhongshan area, they are mostly in a straight line. Courtyard houses are mostly located in low mountains and hilly areas. Watchtowers are mainly made

























of stone, and in the Dabashan area, stone is used for walls and roof tiles. The ethnic group is mainly Han, with Tujia as a secondary ethnic group. Social culture includes defensive culture, salt culture, immigrant culture, Ba-Chu culture, agricultural culture, goddess culture, and Wu (Shamanic) culture, with defensive culture being the most prominent. Villages are based on clans as their basic social structure, with strong clan blood ties.

The Southeastern Ethnic Culture Integration Traditional Village Landscape Zone encompasses six districts and counties, including Youyang and Xiushan. The terrain is dominated by low mountains and hills, making it a typical mountainous area. Villages tend to be located near mountains or water, often situated at the foot or mountainside; their spatial forms are most distinctive in clusters and strips. The village environment is based on feng shui forests, and there are often ponds in the flatter areas. The orientation is determined by the mountain as a backdrop, or by the water if there is water nearby, and if there is no water, the orientation is determined by considering both the mountain behind and the direction facing the mountain. The dwellings are characterized by their distinctive features, especially the stilted houses. The stilted houses of the Tujia, Miao, and Gelao ethnic groups have their own unique features in terms of terrain utilization, shape, stilt structure, details, and roofs, due to the influence of their geographical environment and the degree of integration with other ethnic groups. The ethnic groups are mainly Tujia and Miao, with Han and Gelao as secondary groups. Social culture includes agricultural culture, immigrant culture, commercial culture, and ethnic culture, with minority cultures being the most prominent. Villages are built together by clan blood ties, and there are also a small number of contractual clan-type villages (Table 5).

Table 5 Comparison of typical characteristics of traditional village cultural landscape zones in Chongqing

Category	Western commercial culture-dominated traditional village landscape feature zone	Central immigrant culture-dominated traditional village landscape feature zone	Northeastern defense culture-dominated traditional village landscape feature zone	Southeastern ethnic culture integration type traditional village landscape feature zone
Natural Environment	 Dazu Hongxing Community	 Dashun Village, Fuling	 Longxi Village, Wushan	 Ranjiawan Village, Wulong

(Continued)

Category	Western commercial culture-dominated traditional village landscape feature zone	Central immigrant culture-dominated traditional village landscape feature zone	Northeastern defense culture-dominated traditional village landscape feature zone	Southeastern ethnic culture integration type traditional village landscape feature zone
Village Panorama	 Xingjia Village, Jiangjin	 Anzhen Village, Fuling	 Dongyan Ancient Village, Zhongxian County	 Yangjiashai Village, Youyang
Street and Alley Spaces	 Jiguang Village, Dazu	 Anzhen Village, Fuling	 Ximao Village, Liangping	 Dazhai Village, Xiushan
Residential Buildings	 Songjiang Village, Yongchuan	 Anzhen Village, Fuling	 Yongping Village, Wanzhou	 Yongxiang Village, Youyang
Intangible Cultural Heritage	 Songjiang Village, Yongchuan	 Fengyang Village, Fuling	 Dongyan Ancient Village, Zhongxian County	 Dazhai Village, Xiushan
Residential Buildings	 Songjiang Village, Yongchuan	 Anzhen Village, Fuling	 Yongping Village, Wanzhou	 Yongxiang Village, Youyang
Intangible Cultural Heritage	 Songjiang Village, Yongchuan	 Fengyang Village, Fuling	 Dongyan Ancient Village, Zhongxian County	 Dazhai Village, Xiushan

Conclusion

The study of cultural landscape zoning in traditional villages and its methods represents a direction worthy of in-depth exploration in the cultural geography of tradi-

tional villages. This paper optimizes the zoning method by combining Principal Component Analysis (PCA) with hierarchical clustering. The new method was then applied to the zoning of the traditional village cultural landscape in

Chongqing to verify its feasibility. The main conclusions are as follows: (1) A comprehensive zoning method for traditional village cultural landscapes was established, characterized by the workflow: “Factor Deconstruction — Data Collection and Processing — PCA and Hierarchical Clustering — Zoning.” First, cultural landscape factors were deconstructed and selected from four aspects: natural environment, spatial form, dwelling type, and social culture. Secondly, factor information was collected, and SPSS was used to standardize the quantitative factors. Next, SPSS was used to extract principal component factors and perform hierarchical clustering. Finally, combining descriptive factors with qualitative impressions, ArcGIS was used to delineate the cultural landscape zoning of traditional villages. (2) The traditional village cultural landscapes in Chongqing can be classified into four zones: the Western Commercial Culture-Dominated Traditional Village Cultural Landscape Zone, the Central Immigrant Culture-Dominated Traditional Village Landscape Zone, the Northeastern Defense Culture-Dominated Traditional Village Cultural Landscape Zone, and the Southeastern Ethnic Culture Integration Type Traditional Village Cultural Landscape Zone. The characteristics of each zone in terms of natural environment, spatial form, dwelling type, and social culture have been summarized.

By optimizing the quantitative zoning method through “Principal Component Analysis combined with hierarchical clustering”, this paper explores and validates a more objective, reasonable, and accurate approach for characterizing traditional village cultural landscapes. This represents a further advancement in traditional village cultural geography research and quantitative zoning studies. The new method increases the information retention rate of the zoning factors and reduces the subjectivity of assigning weights among the zoning factors. Specifically, the retained information content was elevated from 20%-30% to over 80%, enhancing the explicit expression of characteristics from “non-dominant factors.” Principal components are obtained by combining the factors according to the weight relationships determined by SPSS software based on pure mathematical statistics, which reduces the subjectivity of the traditional “expert scoring method” in

determining weight values. Future research should further examine the migration paths, evolution mechanisms, and impact characteristics of traditional village cultural landscape factors in different regions, as well as the application of zoning results at macro, meso, and micro scales.

Sources of Figures and Tables

Figures 1-4 in the text were created by the author.

Table 1 in the text was compiled by the author, and Tables 2-4 are the results calculated and derived by the author using SPSS software based on the data. The images in Table 5, including the second and third photos of the natural environment, the first aerial view of the village, the first and third photos of the street and alley spaces, the third photo of residential buildings, and the second and third photos of intangible cultural heritage, are from “Archives of Traditional Chinese Villages”. The remaining photos were taken by the author.

Notes

1) Traditional zoning analysis typically involves 10 to 15 cultural landscape factors. However, usually only 2-3 “dominant factors” are selected for zoning, resulting in an information retention rate of only approximately 20%-30%. This paper focuses on the study of “natural villages.” For entries in the official “lists” that are designated as administrative villages, their representative natural villages were selected as the research subjects.

2) This paper focuses on the study of “natural villages.” For entries in the official “lists” that are designated as administrative villages, their representative natural villages were selected as the research subjects.

3) Traditional village siting is influenced by feng shui philosophy, emphasizing the principle of “backing the yin and embracing the yang (Fu Yin Bao Yang), and backing mountains while facing water” to adapt to and utilize nature; thus, mountains and water become the most critical factors. The method for judging the distance between villages and mountains and rivers is as follows: the distance between villages and mountains and rivers is measured by the farming radius (the article takes agricultural villages as the main research object). The two-dimensional farming

radius is calculated by ideal, normal, and extreme walking times. Considering the rugged terrain, the accessible radius within a given travel time in a three-dimensional landscape is significantly smaller than the theoretical radius on a two-dimensional map. Therefore, it is necessary to introduce the topographic position index, traffic conditions, etc., to adjust the two-dimensional farming radius. After correction, the equivalent radius on a two-dimensional map corresponding to the actual three-dimensional travel distance is approximately 300 m, 600 m, and 900 m. This paper adopts 600 m as the critical threshold for distinguishing between “far” and “near.” Detailed calculation methods are available in Reference [16].

4) Village orientation determines visual conditions, lighting, and settlement microclimate, making it a crucial consideration for siting and settlement.

Chongqing is located in the southwestern mountains, with abundant sunshine and varied terrain. The orientation of villages in Chongqing is unlike other parts of China, where a single dominant orientation prevails. Instead, they follow the terrain. This article divides the orientation of villages based on factors such as mountains, water, and roads. For a detailed orientation model diagram, please refer to the reference [16].

5) Using the administrative boundaries of districts and counties as the boundaries of cultural zones is to facilitate the practical needs of subsequent protection, development, and management work based on the zoning results.

6) It should be noted that the Principal Component Analysis in SPSS yields the initial factor loadings $f_{i,j}$ not the coefficients u_{ij} of the decision matrix U . The relationship between the two is: $u_{ij} = \frac{f_{ij}}{\sqrt{\lambda_i}}$, for $j=1, 2, \dots, m$.

7) Due to high urbanization in the “Nine Districts of the Central City” (main urban area) of this region, a large number of traditional villages have vanished. This study involves only a small sample size, which cannot fully demonstrate its cultural landscape characteristics. However, to maintain the integrity of the cultural regions, these areas have been incorporated into the Central Traditional Village Cultural Region of Chongqing.

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