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Coupling Coordination Relationship between Cultural Landscape Conservation and Socio-Economic System in Ethnic Villages of Southeast Guizhou

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Abstract: Amidst the transition from agriculture to tourism, ethnic villages are facing issues of "misalignment" and "disequilibrium" between economic growth and cultural heritage conservation. Previous research has often isolated the effects of cultural heritage conservation or socio-economic development, neglecting their reciprocal influences within the coupling coordination. This study addresses this gap by assessing 43 villages in Leishan County, quantifying the preservation status of the cultural landscape (PSCL) and socio-economic level (SEL) using a comprehensive evaluation model and revealing the coupling coordination relationship between PSCL and SEL in each village with the coupling coordination degree (CCD) model. Spatial autocorrelation and the geographical detector model reveal the spatial agglomeration characteristics and influential factors of the CCD. The results highlight three findings. (1) The majority of villages (93%) are in a moderate imbalance stage or a serious imbalance stage, underscoring an urgent need for targeted policies. (2) Spatial autocorrelation analysis exposes significant clustering, with the northwest corner exhibiting the most pronounced high-value aggregation, which contrasts with the southern region's low-value clustering. A 'low–high' clustering pattern is observed in the northern region, while the southwestern corner presents a 'high–low' distribution. (3) Key determinants affecting the CCD include the tourism revenue, tourist volume, resident participation in tourism, village hollowing level, and number of historical buildings. The interactions between driving factors show non-linear and two-factor enhancement effects. This study concludes with policy recommendations advocating for context-specific strategies to enhance the CCD, emphasizing the importance of aligning cultural preservation with economic progress in ethnic villages.

Keywords: cultural landscape; socio-economic; coupling coordination degree; ethnic villages

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1. Introduction

Ethnic cultures are integral to the rich tapestry of global cultural diversity. Their preservation and dissemination not only enrich the world's cultural heritage but also facilitate communication and learning between different cultures [1]. Ethnic villages are vital repositories of ethnic cultures; often called "village museums" or "open-air museums", they encapsulate rich historical and cultural landscapes [2]. Ethnic village tourism, as a business model, plays a pivotal role in alleviating rural poverty, catalyzing the diversification of rural economies [3], providing a sustainable livelihood for local residents [4], and promoting the resurgence of indigenous cultural practices, contributing to the industrialized utilization of rural cultural heritage resources [5]. The region of southeast Guizhou deserves special attention due to its numerous ethnic villages and rich cultural landscapes [6]. A total of 30 villages in southeast Guizhou have been recognized by the World Tourism Organization as World-Class Rural Tourism Villages, and an additional 536 villages are listed as national

and provincial ethnic villages. However, ethnic villages in these regions face various challenges; some have seen a decline in their ethnic characteristics due to over-tourism, while others suffer from long-term poverty resulting from inadequate transportation and obsolete infrastructure.

The growth of tourism has become a double-edged sword for ethnic villages, driving economic progress while threatening cultural landscapes. As tourist volumes surged, the spatial expanse of villages rapidly expands, resulting in the encroachment upon farmland and ecological green spaces by tourism facilities and infrastructure [7]. The influx has also brought contemporary architectural styles and external cultural influences that have intensified the damage to ethnic architecture and heritage sites, risking the assimilation and potential extinction of ethnic cultures [8]. In the quest for a balance between the protection and development of ethnic villages, policymakers have typically approached the issue from isolated perspectives. The tourism department has focused on enhancing infrastructure to invigorate the economy [9], while the heritage conservation department has aimed at preserving historical features and cultural heritages [10]. Concurrently, the environmental protection department has advocated for the conservation and sustainable use of natural resources [11]. Therefore, it is an urgent priority to improve the unity and coordination of policies across departments and regions, creating a unified strategy aimed at the development and protection of ethnic villages.

Currently, a multitude of studies have investigated the relationship between the protection of cultural landscapes and socio-economic development in ethnic villages, considering aspects such as tourism-driven poverty alleviation, cultural authenticity [12], and the landscape pattern evolution [13]. These studies suggested that efforts to preserve cultural landscapes significantly promote the development of local cultural tourism, establish a robust industrial base, improve infrastructure, increase employment, and catalyze the transformation of traditional subsistence practices [14]. However, the rapid socio-economic development carries the potential to endanger cultural landscapes. The overexploitation of tourism led to the erosion of traditional architectural heritage [15], induced community conflicts [16], and disrupted the ecological balance [17]. This situation undermines the authenticity of regional features, risking the erosion of ethnic identity and cultural uniqueness [18]. Although the current literature has exhibited a trend toward diversification, it has primarily focused on the unidirectional impacts of the preservation status of the cultural landscape (PSCL) and socio-economic level (SEL) in ethnic villages, neglecting their interdependent dynamics and quantitative analysis of their interrelationships [19].

The coupling coordination degree (CCD) model effectively assesses the coordination quality of interdependent systems, quantifying their harmonious and consistent levels. It has been widely adopted to study various interlinkages, including those between the economy and tourism [20], tourism and ecology [21], and economy and environment [22]. When integrated with spatial Durbin models, the findings has been utilized to examine the extent of green transformation and its determinants [23]. Additionally, its combination with geographically weighted regression has shed light on the ecological implications of urbanization [24]. Collectively, these applications have confirmed the model's utility in quantifying the levels of coordination among different systems.

The geographical detector model is designed to identify the underlying drivers of geographical phenomena [25]. It features a "factor detector" that evaluates the impact of each factor as well as an "interaction detector" that analyzes the synergistic or antagonistic effects on change [26]. This study has integrated the geographical detector model with the CCD model to conduct an in-depth analysis of the forces that shape the diverse manifestations of CCD between the PSCL and SEL in ethnic villages [27]. The insights gained are pivotal for policymakers in devising strategic interventions that align with the unique geographic and resource endowments of ethnic villages, aiming to achieve an optimal level of coupling coordination.

This study offers a novel perspective that extends beyond the traditional focus on unidirectional impacts between cultural conservation and economic development, examining

the coupling coordination relationship between the PSCL and SEL. It explores and visualizes the spatial differentiation in the levels of coupling and coordination within ethnic villages, considering variations in geographical location and resource endowment. Drawing on the key determinants of CCD, the study aims to inform targeted funding allocation and policy strategies tailored to villages with different types of CCD, reducing the risks of urbanization and commercialization that could dilute cultural values.

2. Materials and Methods

2.1. Study Area and Data Sources

This study focused on Leishan County, located in southeast Guizhou, which is renowned for its diverse ethnic villages and unique karst topography. Situated between 26°02′ N to 26°34′ N and 107°55′ E to 108°22′ E (Figure 1), it is home to 61 villages recognized as national and provincial ethnic villages. To ensure a representative analysis, we utilized a random sampling method, selecting 43 provincial-level and above ethnic villages as sample points, achieving a sampling rate of approximately 70.49%. Leishan County has leveraged local festivals to promote tourism, benefiting both the economy and its residents. However, interventions by local governments and developers have resulted in a decline in indigenous cultures, highlighting a conservation–development conflict. As such, Leishan County serves as a significant and typically representative region for discussions on the sustainable development of minority regions under the influence of tourism.

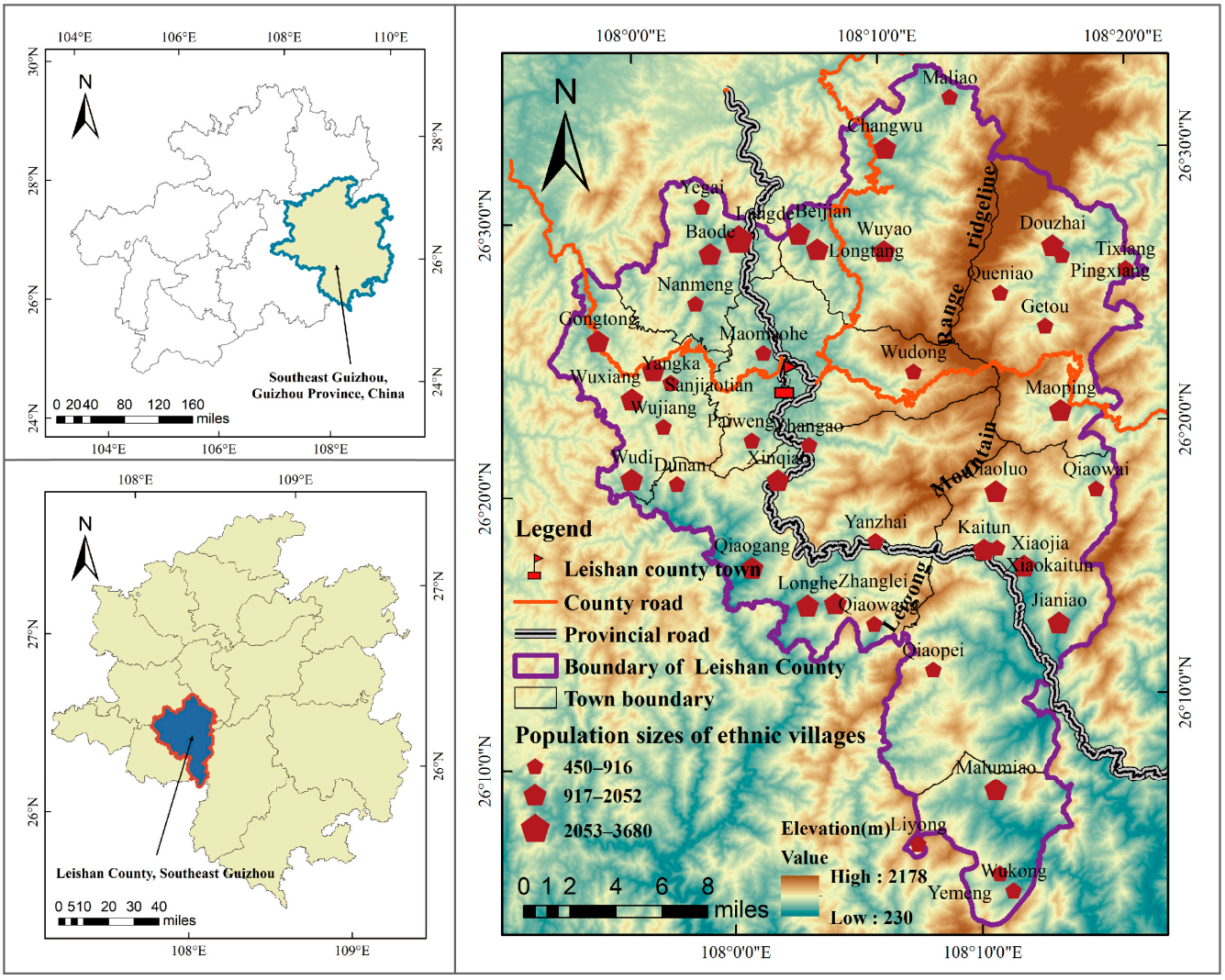


Figure 1. Location of the study area, showing 43 ethnic villages, town boundaries, and altitude.

In July 2023, we conducted a rural survey, covering 43 distinct settlements. At the county level, visits were made to the Housing and Urban–Rural Development Bureau, the Cultural Tourism Bureau, the Rural Revitalization Bureau, and the Statistics Bureau. Archives related to the protection and management of ethnic villages at the provincial level and above, as well as rural social and economic statistics, intangible cultural heritage catalogues, and records of government investments in the protection of ethnic villages over the years were collected. At the town and village levels, field visits and surveys were conducted in 8 town governments and the village committees of the 43 ethnic villages under their jurisdiction. Data collected included village statistical bulletins, lists of festival activities, and rural community management regulations.

2.2. Evaluation Index System

The evaluation index system for the CCD in ethnic villages is structured around four key dimensions (Table 1), which were chosen for their relevance to the region and the data's accessibility and reliability.

Table 1. Evaluation index system.

Subsystem	Indicator	Variable	Definition	Direction	Reference
Preservation status of cultural landscape	Tangible cultural landscape	Preservation degree of ethnic architecture	Ratio of the number of traditional ethnic buildings to the total number of buildings in the village	+	[28]
		Number of historical environment elements	Number of ancient bridges, pavilions, wells, old trees, etc., within the village	+	[29]
		Number of historical buildings	The number of historic buildings recognized by the governments as county-level and above	+	[30]
		Forest coverage	Ratio of the forest square measure to the village area square measure	+	[31]
		Ecological landscape diversity	The number of ecological patches such as water systems, lakes, forests, and wetlands within the village	+	[32]
	Intangible cultural landscape	Proportion of ethnic minority population	Proportion of the minority ethnic population to the village's household registered population	+	[33]
		Quantity of intangible cultural heritage	The number of intangible cultural heritage items with the characteristics of ethnic minorities at the county level or above	+	[34]
		Number of craftsmen in heritage transmission	The number of individuals who actively perpetuate and practice traditional crafts with the characteristics of ethnic minorities	+	[35]
		Folk festival activities held	The number of various festive events held with the characteristics of ethnic minorities by the village each year	+	[35]
		Participation in folk activities	Ratio of the number of participants in festival activities with the characteristics of ethnic minorities to the total population of village	+	[36]

Table 1. *Cont.*

Subsystem	Indicator	Variable	Definition	Direction	Reference
Socio-economic level	Social development level	Total population	Total population of village areas	+	[33]
		Agricultural population	Labor force engaged in agricultural production with agriculture as the main source of income	+	[37]
		Village hollowing level	The ratio of the population permanently residing outside the village to the village's household registered population	−	[38]
		Resident participation in tourism	Number of households in the village engaged in tourism reception	+	[37]
		Public facility completeness	Number of facility types, such as schools, clinics, fitness centers, and markets	+	[39]
	Economic development level	Disposable income of residents	Annual per capita disposable income of rural residents	+	[40]
		Grain production	Average annual grain production	+	[41]
		Diversity index of industries	Composition of various industries in overall village production	+	[3,42]
		Tourism revenue	The total monetary income obtained by the region through tourism activities during a certain period of time	+	[43]
		Conservation fund investment	Amount of special protection funds invested by the county-level government in the village in the past 5 years	+	[3,44]
		Tourist volume	Average annual tourist volume	+	[45]

The "+" indicates a positive contribution to the coupling coordination degree (CCD), while the "−" indicates a potential negative impact or a factor to minimize.

In 1992, the UNESCO World Heritage Convention internationally codified the term "cultural landscape" as the "combined works of nature and of man" [46], signifying a complex and integrating concept with both tangible and intangible cultural heritages [47]. The tangible aspect encompasses the visible, physical cultural expressions such as historical buildings, natural landscapes, traditional villages [34]. Conversely, the intangible aspect comprises the non-physical cultural elements like languages, festival activities and traditional handicrafts [48,49].

This study evaluated the preservation status of the tangible cultural landscape in ethnic villages through the preservation degree of ethnic architecture, number of historical environment elements, number of historical buildings, forest coverage, and ecological landscape diversity. Additionally, the preservation status of the intangible cultural landscape is gauged by the proportion of ethnic minority population, quantity of intangible cultural heritage, number of craftsmen in heritage transmission, folk festival activities held, and participation in folk activities.

For the SEL indicators, the selection was guided by principles of representativeness and measurability, as informed by literature reviews [50–52]. The social development level considers the total population, agricultural population, village hollowing level, resident participation in tourism, and public facility completeness in its calculation. Economic development level factors include the disposable income of residents, grain production, diversity index of industries, tourism revenue, conservation fund investment and tourist volume.

2.3. Data Standardization

To standardize the diverse indicators selected for this study, which vary in dimension and unit, we applied the extremum method to convert all values into a common positive framework. This method eliminates the differences in data scale under the index system, facilitating a fair comparison across indicators [53]. For benefit indicators, the normalization formula is as shown in Equation (1). For cost indicators, the normalization formula is as shown in Equation (2).

$$Y_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})} \quad (1)$$

$$Y_{ij} = \frac{Max(X_{ij}) - X_{ij}}{Max(X_{ij}) - Min(X_{ij})} \quad (2)$$

where Y_{ij} is the original value of the index, X_{ij} is the original value of the index, and $Min(X_{ij})$ and $Max(X_{ij})$ represent the maximum and minimum values of each sequence parameter, respectively.

2.4. Entropy Method

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \quad (3)$$

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \quad (4)$$

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \quad (5)$$

where P_{ij} is the proportion of X_{ij} to the sum of X_{ij}, E_j is the entropy, and W_j is the weight. m is the total number of samples, and n is the number of indicators.

2.5. Comprehensive Evaluation Model

The weights of each indicator are multiplied by their standardized values and summed to obtain the comprehensive evaluation score of each system. The score is used to measure the comprehensive level of each system.

$$U_j = \sum_{j=1}^{n} W_{ij} \times X_{ij} \quad (6)$$

where U_j is the comprehensive level of the ith system, W_{ij} is the weight of second-grade indexes of systems, and X_{ij} is the standardized value of second-grade indexes of systems. n is the number of indicators of the ith system.

The study classified ethnic villages based on comparing the comprehensive evaluation scores of the SEL and the PSCL. Villages are labeled as 'PSCL-lagging' when the comprehensive level of the PSCL is less than SEL and 'SEL-lagging' in the opposite scenario.

2.6. CCD Model

2.6.1. Coupling Degree Calculation

The coupling degree (CD) model is used to determine the intensity of the mutual influence between the PSCL and SEL. The value range is [0, 1], and the calculation formula is as follows:

$$C = \sqrt{\frac{U_1 \times U_2}{[(U_1 + U_2)/2]^2}} \quad (7)$$

where C represents the CD index between the PSCL and SEL, and U_1 and U_2 correspond to the comprehensive level of the PSCL and SEL in the study area.

2.6.2. CCD Calculation

As the CD alone fails to indicate the consistency and synergistic effects between PSCL and SEL [54], this study employed the CCD model, with a value range is [0, 1], as detailed in Table 2.

$$D = \sqrt{C \times T} \quad (T = \alpha U_1 + \beta U_2) \tag{8}$$

where D represents the CCD index, with a value range of [0, 1], and α and β are coefficients to be determined. C is the CD index. T is the comprehensive coordination index. For the PSCL and SEL of the study area in this work, the intensity of the mutual influence and interaction was relatively balanced; therefore, α and β were each set to 0.5. U_1 and U_2 correspond to the comprehensive level of the PSCL and SEL in the study area.

Table 2. Classification of the CCD.

Coupling Coordination Level	CCD Value Range	Type of CCD
1	$CC_d \in (0.801, 1.000)$	High coordination
2	$CC_d \in (0.601, 0.800)$	Moderate coordination
3	$CC_d \in (0.401, 0.600)$	Basic coordination
4	$CC_d \in (0.201, 0.400)$	Moderate imbalance
5	$CC_d \in (0.000, 0.200)$	Serious imbalance

This study comprehensively referenced relevant research [55–58] and adhered to the principles of data availability and scientific rigor. The CCD was categorized into 5 levels.

2.7. Spatial Autocorrelation Analysis

2.7.1. Global Spatial Autocorrelation

Spatial autocorrelation was used to assess the potential interdependence between a phenomenon within a region and the same phenomenon in neighboring regional units. The Global Moran's I index was utilized to quantify this spatial autocorrelation, which was calculated as follows:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(P_i - \overline{x})(P_j - \overline{x})}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\right) \times \sum_{i=1}^{n}(P_i - \overline{x})^2} \tag{9}$$

where I represents the Global Moran's I index; n is the number of subjects under study; P_i and P_j are the CCD for the ith and jth sample villages; $\overline{x}$ is the mean value of the indices; and w_{ij} denotes the spatial weight matrix. The range of Moran's I is $[-1, 1]$, with positive values indicating spatial clustering, negative values suggesting dispersion, and a value of zero implying spatial randomness.

2.7.2. Local Spatial Autocorrelation

The Local Moran's I was used to identify areas with high significance levels for the CCD, revealing local spatial agglomeration patterns. The local indicators of the spatial association (LISA) map classify spatial patterns into four quadrants: high–high (H–H), low–low (L–L), low–high (L–H), and high–low (H–L). H–H and L–L represent areas where the observed values are similar to their surroundings. H–L and L–H denote areas where the observed values are dissimilar to their surroundings.

$$Local\ Moran's\ I = \frac{n(P_i - \overline{x})}{\sum_{i=1}^{n}(P_i - \overline{x})^2}\sum_{j=1}^{m} w_{ij}(P_j - \overline{x}) \tag{10}$$

The following variables were used in the calculation: P_i and P_j represent the CCD for the ith and jth sample villages, n denotes the number of regions, $\overline{x}$ is the mean value of the indices, w_{ij} represents the spatial weight matrix, and m corresponds to the number of Thiessen polygons adjacent to the ith spatial unit.

2.8. Geographical Detector Model

The geographical detector model was used to accurately identify and analyze the drivers behind various geographic phenomena [27]. This model is equipped with factor and interaction detectors, which assess the explanatory power of factors for CCD changes and their potential antagonistic or synergistic interactions.

Factor detectors assess the extent to which a given indicator explains the spatial variation of attribute CCD across different regions and the entire study area. This is quantified by the (q) value, as detailed below:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{11}$$

$$SSW = \sum_{h=1}^{L} N_h \sigma_h^2 \quad SST = N\sigma^2 \tag{12}$$

where h represents the strata of the variable CCD or factor X; N_h and N are the numbers of units in layer h and the entire area; σ_h^2 and σ^2 are the variances of the CCD values in layer h and the entire area; and L is the number of classification categories (zones) of the factor X. SSW is the within sum of squares, and SST is the total sum of squares. The range of q is [0, 1]; the q-value represents the explanatory force of X on CCD.

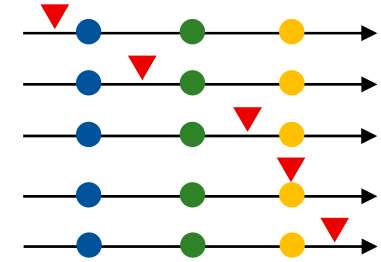
$$F = \frac{N-L}{L-1}\frac{q}{1-q} \sim F(L-1, N-L; \lambda) \tag{13}$$

$$\lambda = \frac{1}{\sigma^2}\left[\sum_{h=1}^{L} \overline{Y}_h^2 - \frac{1}{N}\left(\sum_{h=1}^{l} \sqrt{N_h}\,\overline{Y}_h\right)^2\right] \tag{14}$$

Here, λ is the non-central parameter, and $\overline{Y}_h$ represents the mean value of stratum h. An F test can be used to identify whether X significantly explains the spatial distribution of CCD. N_h and N are the numbers of units in layer h and the entire area. L is the number of classification categories (zones) of the factor X. σ_h^2 is the variances of the CCD values in layer h. q represents the explanatory force of X to CCD.

Interaction detectors analyze the interplay among factors to determine whether their combined influence on the dependent variable CCD is synergistic, antagonistic, or independent. The outcomes are categorized into five distinct types, as illustrated in Table 3.

Table 3. Types of interactions.

Diagram	Basis for Judgment	Types of the Interaction
	q(X1∩X2) < Min(q(X1), q(X2))	Non-linear attenuation
	Min(q(X1)), q(X2)) < q(X1∩X2) < Max(q(X1), q(X2))	Single-factor nonlinearity attenuation
	q(X1∩X2) > Max(q(X1), q(X2))	Two-factor enhancement
	q(X1∩X2) = q(X1) + q(X2)	Independent
	q(X1∩X2) > q(X1) + q(X2)	Non-linear attenuation
Min(q(X1), q(X2)): Take the minimum value between q(X1) and q(X2)		q(X1) + q(X2): Summation of q(X1) and q(X2)
Max(q(X1), q(X2)): Take the maximum value between q(X1) and q(X2)		q(X1∩X2): Interaction between q(X1) and q(X2)

3. Results

3.1. Comprehensive Measurements and Spatial Distribution of the PSCL and SEL

3.1.1. Comprehensive Measurements and Spatial Distribution of the PSCL

The study presents a comprehensive assessment of the Preservation Status of PSCL and the SEL across various villages in Leishan County, revealing distinct spatial patterns. The comprehensive evaluation scores of the PSCL are depicted in Figure 2. The comprehensive level of the PSCL was found to be higher in the northwest and lower in the southeast (Figure 3a), showing a correlation between higher scores and the proximity to the Leishan County government, which is likely due to earlier conservation investments.

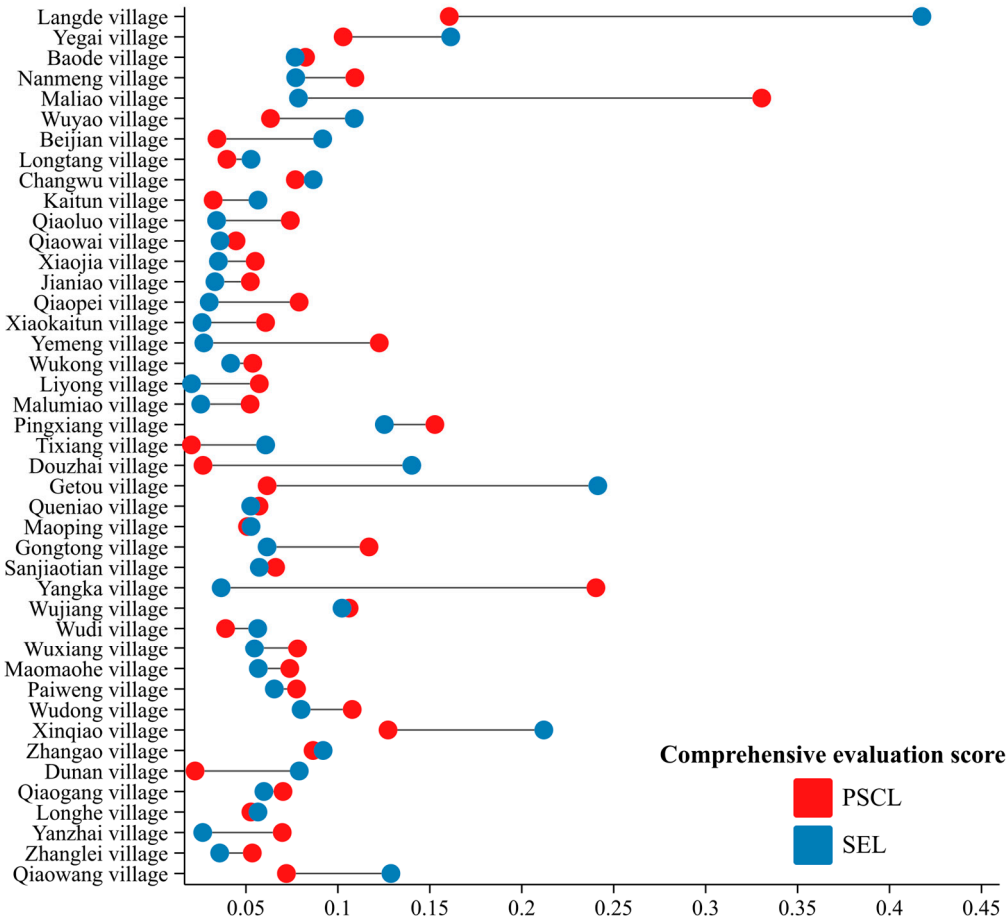


Figure 2. Comprehensive evaluation scores of the preservation status of the cultural landscape (PSCL) and socio-economic level (SEL).

3.1.2. Comprehensive Measurements and Spatial Distribution of SEL

The comprehensive evaluation score of the PSCL is shown in Figure 2. Similarly, the comprehensive level of the SEL exhibits a "north-to-south" gradient, with the highest levels of SEL observed in the northern region, as shown in Figure 3b. This region benefits from significant resident participation in tourism, a high volume of tourists, and a high diversity index of industries. Notably, the northeastern part of the county, which is the core area of the Leigongshan National Nature Reserve, has seen favorable economic conditions due to conservation fund investments. In contrast, the southern part of the county, characterized by poor transportation infrastructure, faces constraints in economic development.

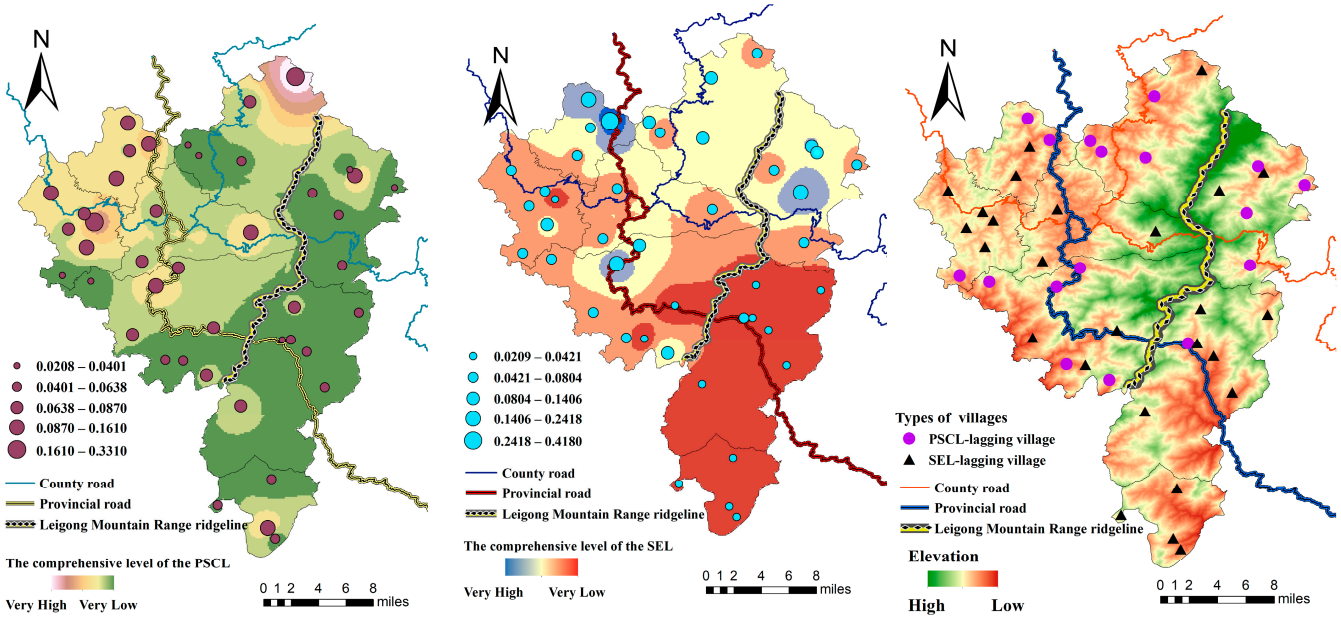


Figure 3. (**a**) Spatial distribution of comprehensive levels of the PSCL. (**b**) Spatial distribution of comprehensive levels of the SEL. (**c**) Spatial distribution of PSCL-lagging and SEL-lagging villages.

3.1.3. Spatial Distribution of PSCL-Lagging and SEL-Lagging Villages

Upon comparing the comprehensive evaluation scores between PSCL and SEL across 43 sample villages, 17 were identified as PSCL-lagging villages, and 26 were considered SEL-lagging villages (Figure 3c). The PSCL-lagging villages are notably clustered in the northern, western, and eastern parts, while SEL-lagging villages display less pronounced signs of spatial aggregation. The spatial clustering of PSCL-lagging villages is attributed to their significant locational advantages; they are primarily located near provincial and county roads and have benefited from well-developed public infrastructure. This has positioned them at the forefront of ethnic village tourism, where they have surpassed other villages in terms of tourist volume. However, despite the higher comprehensive level of SEL in these villages compared to PSCL, the progress of ethnic village tourism requires careful management. This is to prevent the adverse effects of over-commercialization, including the commodification of culture, the fragmentation of cultural landscapes, and environmental pollution.

To elucidate these concepts, consider Maliao, an SEL-lagging village in the north of Leishan County that is rich in Maliao cultural heritage and known for its 600-year-old silversmithing tradition. With government support, Maliao has established a heritage center and academy, fostering a new generation of artisans. Despite the economic gains achieved through a "company + cooperative" model that expanded the reach of its crafts, the village faces challenges due to its reliance on a single craft and logistical issues posed by the karst terrain, thus hindering further market expansion and resulting in an SEL that lags behind PSCL.

Similarly, Langde village, a PSCL-lagging village in the northwest, has seen its economy bolstered by tourism. In response to tourist demand, traditional Miao stilt houses have been converted into modern accommodations and retail spaces. and the village's traditional Miao songs and dances have been adapted into commercial shows. The commercialization has resulted in a focus on revenue generation from performances, often at the expense of the preservation and transmission of cultural practices. Consequently, while Langde village has achieved notable economic gains, its cultural preservation efforts have not been commensurate.

3.2. Measurement Results and Spatial Characteristics of CCD

3.2.1. Measurement Results and Spatial Distribution of CCD

The analysis results indicated in Figure 4 that among the 43 villages assessed, only three were classified in the stage of basic coordination stage (>0.401), 37 were in the stage of moderate imbalance (>0.201), and 3 were identified as having a serious imbalance (<0.201). There was a significant spatial differentiation in the CCD of the PSCL and SEL in various ethnic villages within the study area. Villages located north of the Leigong Mountain range exhibited a high CCD, while those to the south displayed a low CCD (Figure 5a). All the villages with CCD indexes belonging to the basic coordination stage were located in the north part of the Leigong Mountain (Figure 5b). These villages have benefited from improved transportation and have received early policy protection and financial investment because they were among the first and second batches of recognized national and provincial ethnic villages, which has fostered well-developed tourism.

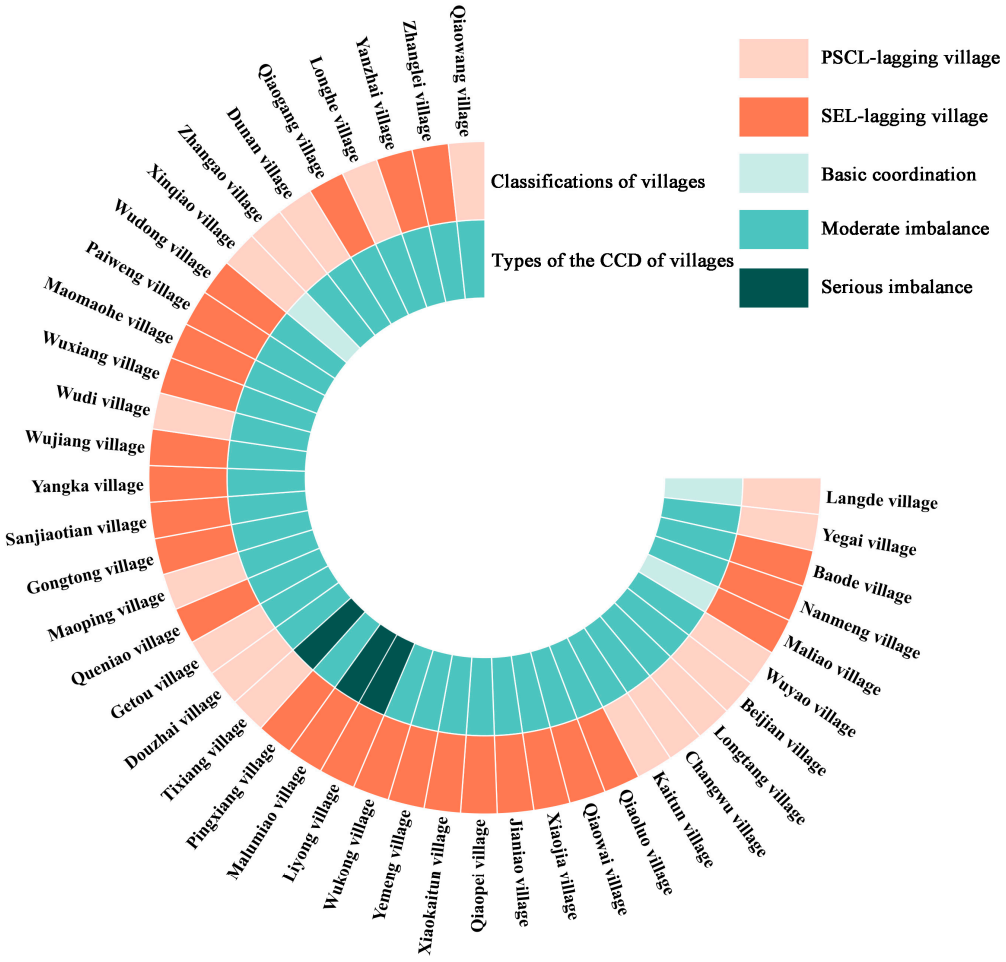


Figure 4. Classifications of villages.

Interestingly, 15 PSCL-lagging villages were found in the imbalance stage (Figure 4), primarily situated near areas with advanced tourism and a higher comprehensive level of SEL (Figure 5c), with a larger resident participation in tourism and higher disposable income among residents. This indicates that while developed tourism has the potential to catalyze growth in neighboring villages, the cultural landscape has suffered due to inexperience, lack of guidance, and external capital intrusion, causing a misalignment in the development of PSCL and SEL. Two PSCL-lagging villages in the basic coordination stage showed below-average forest coverage of 65% and a preservation degree of ethnic architecture of 39%, indicating a possible negative impact of tourism development on the cultural landscape. However, these villages have managed to achieved a balance between protection

and development. In contrast, 23 SEL-lagging villages in the moderate imbalance stage (Figure 4), which were predominantly concentrated south of the Leigong Mountain range, were characterized by low grain production and a high level of village hollowing, which was likely due to inadequate transportation and underdeveloped tourism. Notably, the sole SEL-lagging village in the basic coordination stage, with over 300 craftsmen engaged in heritage transmission, particularly in silver jewelry making, has benefited significantly from conservation fund investment. This investment has substantially contributed to there being a higher comprehensive level of the PSCL.

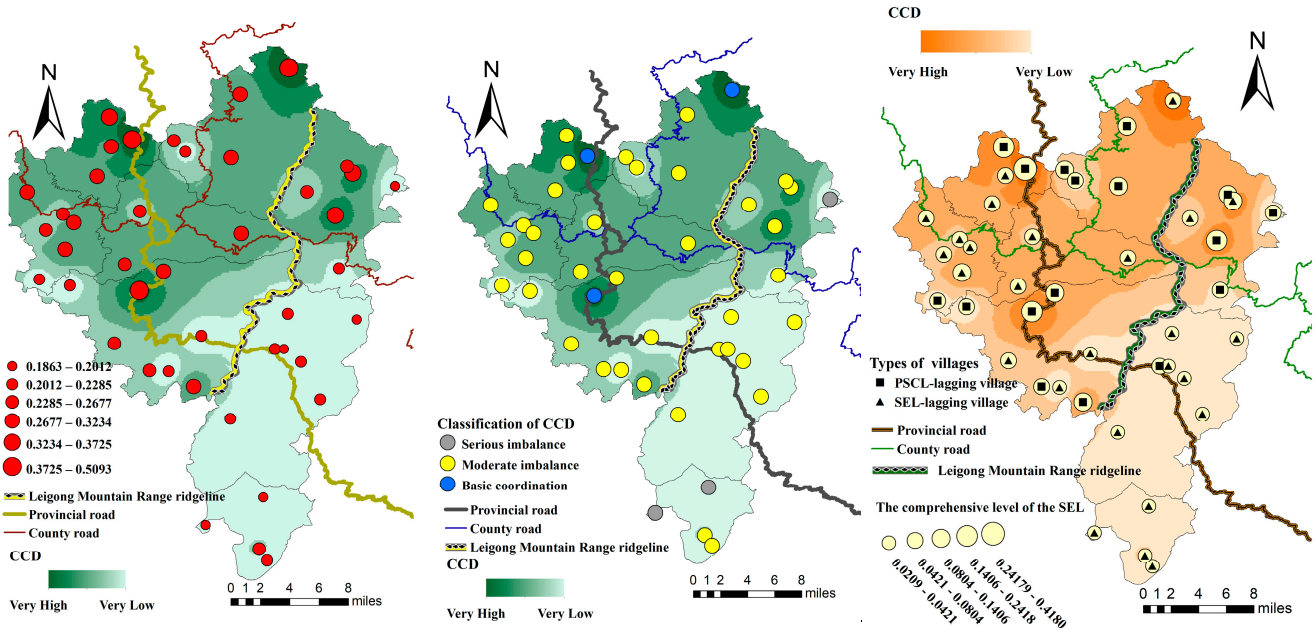
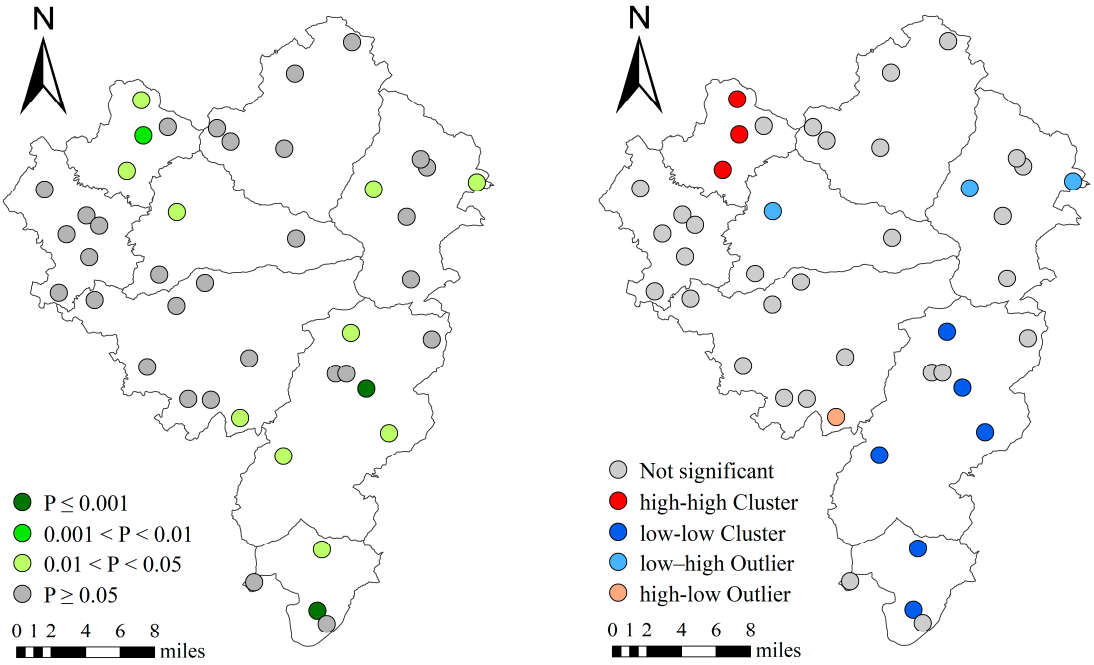


Figure 5. (**a**) Spatial distribution of CCD. (**b**) Spatial distribution of types of CCD. (**c**) Spatial distribution of PSCL-lagging and SEL-lagging villages.

3.2.2. Spatial Association and Aggregation of CCD

Moran's I for the CCD, calculated at 0.142, signifies a positive spatial correlation within the study area, highlighting the area's strongest spatial clustering characteristics.

The Local Indicators of Spatial Association (LISA) maps for the CCD revealed distinct clustering patterns (Figure 6a,b). The southern region concentrated low-value clusters, which were characterized by a high village hollowing level, scant historical environment elements, and few craftsmen engaged in heritage transmission. In contrast, a 'high–low' clustering pattern emerged in the southwestern corner, where the village with a higher diversity index of industries, a large number of historical environment elements, and tourism revenue stood out against neighboring villages. In the northern region, a 'low–high' clustering pattern emerged, and the CCD in the northwest corner showed the strongest high-value clustering, which was likely due to its strategic location near the Leishan County government.



(**a**) (**b**)

Figure 6. (**a**) Significance map of CCD. (**b**) Spatial autocorrelation cluster map of CCD.

3.3. Influential Factors of CCD

Utilizing the K-means clustering method within the IBM SPSS statistics 21 software, we discretized the values of 21 indicators and subsequently applied the geographical detector model for factor detection and interaction detection, aiming to comprehensively identify key determinants influencing the CCD and to reveal synergistic and antagonistic interactions among these determinants with respect to the CCD.

3.3.1. Key Influential Factors of CCD

The factor detection leveraged the q-value metric to evaluate the explanatory power of indicators influencing the CCD, as detailed in Table 4. The q-value is in the range [0, 1], which indicates higher values for a more significant contribution to spatial variations in CCD. This study prioritized tourism revenue (0.620), tourist volume (0.536), village hollowing level (0.482), resident participation in tourism (0.460) and number of historical buildings (0.397) as the principal factors affecting the CCD.

Specifically, regarding the tourism revenue, Leishan County's strategic use of ethnic culture and ecological resources has significantly boosted tourism revenue. This increase has seen an annual growth of over 30% since 2011, contributing 41.5% to the GDP and promoting the coordinated development of cultural protection and socio-economic development in ethnic villages, fostering unique agricultural and intangible cultural heritage sites.

High collinearity existed between tourist volume and revenue, where an increase in visitor numbers markedly elevated the economic income of ethnic villages. This growth also drove infrastructure improvements and the spread of culture. However, a sharp surge in tourism also had strained local ecosystems and overburdened facilities, threatening the sustainable development of ethnic village tourism.

Table 4. q-value of driving factors for CCD.

Driving Factors	q-Value	Driving Factors	q-Value
Tourism revenue	0.620	Agricultural population	0.081
Tourist volume	0.536	Conservation fund investment	0.079
Village hollowing level	0.482	Number of craftsmen in heritage transmission	0.069
Resident participation in tourism	0.460	Preservation degree of ethnic architecture	0.069
Number of historical buildings	0.397	Folk festival activities held	0.067
Total population	0.362	Number of historical environment elements	0.053
Grain production	0.361	Proportion of ethnic minority population	0.039
Disposable income of residents	0.332	Participation in folk activities	0.039
Quantity of intangible cultural heritage	0.308	Ecological landscape diversity	0.029
Diversity index of industries	0.160	Public facility completeness	0.001
Forest coverage	0.156		

The village hollowing level emerged as a key factor leading to the decline in cultural landscapes and economic stagnation. Capital investments drew low-income groups toward regional growth poles, exacerbating land resource waste, cultural disruption, and the loss of traditional skills and successors in less commercially viable villages [59]. Consequently, a significant negative correlation exists between the village hollowing level and the low CCD.

Regarding resident participation in tourism, the county's priority employment mechanism for impoverished households has integrated residents into the tourism industry, particularly in formats like silver jewelry crafting, embroidery, and ethnic cuisine. This participation not only safeguards cultural heritage but also enhances local income and wealth.

The integrity of ethnic villages' historical appearance, indicated by the number of preserved historical buildings, is vital for local culture exhibition and inheritance, offering a unique tourism attraction. A greater number of intact historical buildings correlates with stronger ethnic characteristics, attracting more capital and investment from entrepreneurs into the ethnic culture industry, aiding in the socio-economic development of these villages.

3.3.2. Synergistic Effect of the Influential Factors of CCD

The analysis evaluated whether explanatory power would increase from the interaction effect between two driving factors of the CCD. The joint influence of any two factors typically surpassed the impact of individual factors with slightly more two-factor enhancements (101 groups) than non-linear enhancements (109 groups) observed (Figure 7).

Notably, in terms of two-factor enhancements, the best enhancement of the joint explanatory power of 80.9%was observed for the combination of tourism revenue and number of historical buildings. This was followed by the joint effect of resident participation in tourism and number of historical buildings, accounting for a joint explanatory power of 78.5%. Third was the combination of total population and village hollowing level with an explanatory power of 77.2%.

For non-linear enhancements, the most significant enhancement of the explanatory power of 80.6% was that observed for the combination of village hollowing level and agricultural population. This was followed by the combination of tourism revenue and conservation fund investment, contributing to an explanatory power of 77.0%. The combination of tourism revenue and number of craftsmen in heritage transmission had an explanatory power of 75.0%.

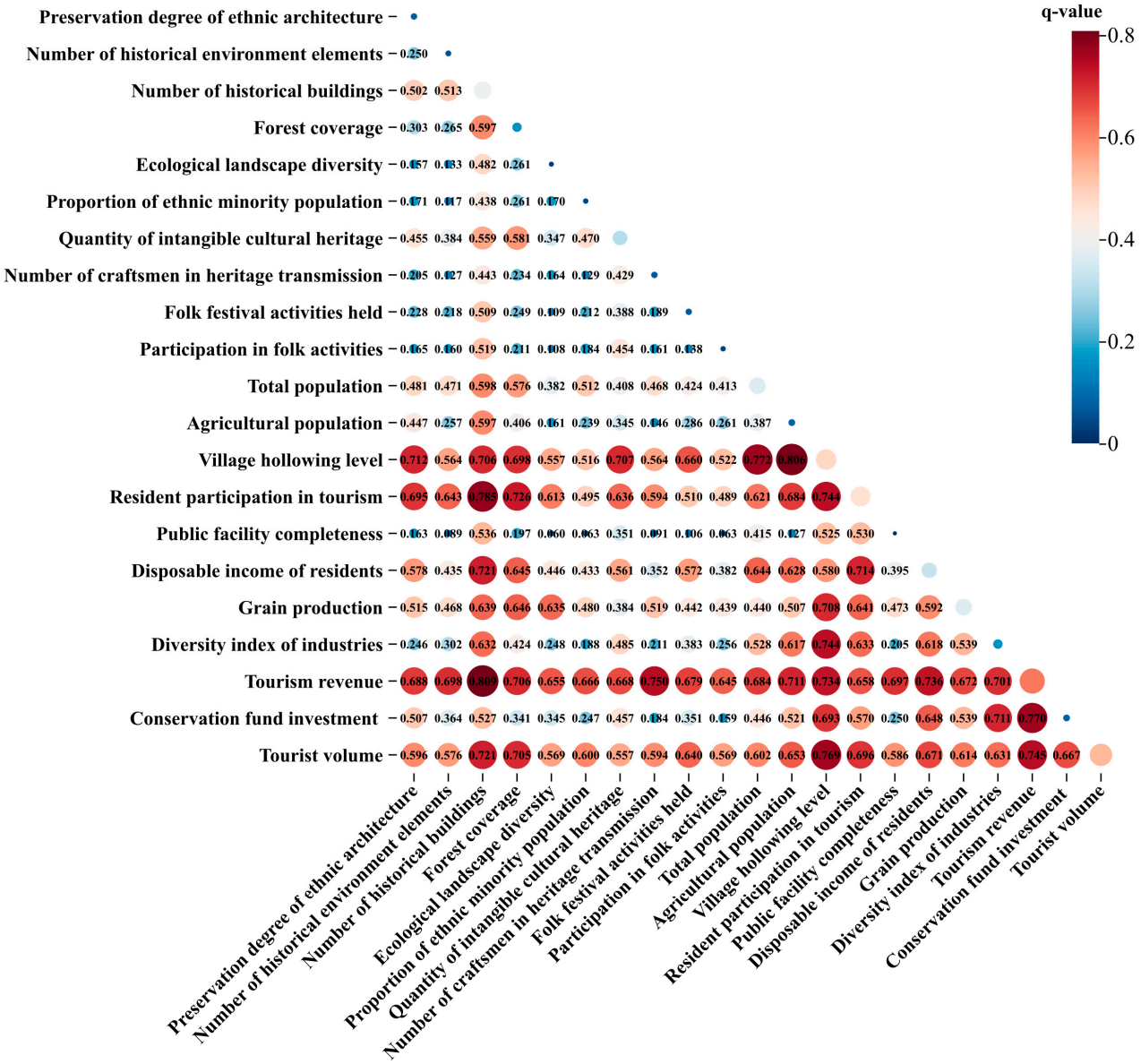


Figure 7. Interaction detection results for each indicator.

4. Discussion and Policy Recommendations

4.1. Comparison with Previous Studies

Existing research has made significant strides in balancing heritage conservation with socio-economic development in ethnic villages. For instance, resilience theory has been used to reveal the ability of villages to resist tourism disturbances [60], cultural landscape genetics theory has been applied to propose classification protection strategies [61], and organic renewal theory has suggested a combination of static and dynamic protection strategies [62]. However, these studies have predominantly focused on unidirectional impacts [63], attempting to find an effective yet somewhat universal approach. A one-size-fits-all policy has led to a convergence in the development models of rural tourism in heritage areas, which has not yielded satisfactory results [64]. This study adopts a comprehensive perspective to analyze the coupling coordination degree (CCD) between socio-economic development and heritage conservation, aiming to find a balance between rural tourism development and heritage protection. Additionally, we use LISA clustering maps to geographically visualize the analysis results, revealing the spatial distribution patterns of villages with different levels of CCD, which aids in formulating strategies

tailored to local conditions. Moreover, the geographical detector model not only identifies the dominant influencers of CCD but also provides deep insights into the complex synergies and antagonisms among factors, thus enhancing our understanding of the overall trend in CCD changes. The findings offer a policy basis for government departments that aligns with the distinctive attributes of local contexts.

The study's findings indicate a higher comprehensive level of the PSCL in the northwest region, where villages have benefited from early investment in conservation funding and a lower level in the southeast with villages characterized by outdated transportation infrastructure and pronounced depopulation. This discovery validates that the notion of a closed traffic environment being favorable for heritage preservation is inapplicable to the karst regions of southeast Guizhou. On the contrary, an environment with more accessible transportation is capable of enhancing both the conservation of cultural heritage and the impetus for economic growth [65]. The SEL follows a similar pattern, being higher in the north and lower in the southeast, The findings support the concept that affirmative cultural capital and governmental investment in cultural landscapes were conducive to economic growth, which is a principle that is applicable to both urban areas and ethnic villages [66]. Conversely, most villages are characterized by poor transportation infrastructure [67]; despite a lack of direct human-induced damage, the cultural landscapes in these regions had been exposed to the weathering and the passage of time, leading to their abandonment [68], and these characteristics were particularly evident in karst regions.

The research outcomes, delineated by the Lei Gongshan Mountain Range, indicated a high CCD in the northern villages, where the terrain is notably flat. In contrast, the southeast region, predominantly characterized by rugged mountainous terrain, exhibited a comparatively low CCD. LISA aggregation maps revealed significant clusters of low CCD values in the southern region, while the northwest region demonstrated clusters of high CCD values. The findings showed a significant positive correlation between the CCD index and the transport location of villages. The northern villages exhibited a "low–high" pattern, which was characterized by considerable resident participation in tourism. However, they concurrently experienced severe population depopulation. This phenomenon substantiates that the siphon effect triggered by the tourism had exacerbated regional disparities [69] and led to an over-concentration of resources and labor force in the growth poles of the county economy [70]. In contrast, the villages in the southwest corner exhibited a "high–low" pattern, where tourism revenue and the diversity index of industries are prominent among surrounding villages, confirming that selective capital investment could widen the wealth gaps between villages [71].

Contrasting with previous research that emphasized the importance of industry linkage [72], heritage protection [73], public participation [74], and ecological engineering [75] in either cultural preservation or socio-economic development, this study employs the factor detector to demonstrate that tourism revenue, tourist volume, the extent of village hollowing, resident participation in tourism, and the number of historical buildings are critical factors in achieving coordinated development between the two. While prior studies have shown a trend toward diversification, the policy strategies they proposed were more general, covering a wide range of areas. In contrast, the policies suggested in this study are more nuanced and are designed to be more readily implementable. Unlike previous research that has often used models such as the geographically weighted regression model, regression model, and obstacle diagnosis model [76–78] to merely list influencing factors without considering their interactions, this study introduces the geographical detector model. This model not only identifies the primary drivers of the CCD but also provides insights into the complex synergies and antagonisms among these factors, thereby enhancing our understanding of the broader trends in CCD dynamics. The findings thus offer a policy foundation for government departments that is tailored to the unique characteristics of local contexts.

4.2. Policy Recommendations

To achieve a balance between economic development and cultural landscape preservation in the spatial reconstruction of ethnic villages, the following policy recommendations are proposed. These recommendations are based on the key factors influencing the CCD and the synergistic and antagonistic dynamics among influential factors. Consideration is given to how land use planning can play a pivotal role in regulating the key factors that impact the CCD, which is tailored for ethnic villages with different CCD classifications.

For PSCL-lagging villages, particularly those in the moderate imbalance stage and serious imbalance stage, there was a notable concentration near villages with advanced tourism development. Lacking due consideration, these villages have begun to emulate successful tourism business models, resulting in an increased participation of residents in tourism [79]. The development of tourism requires additional facilities and activity spaces, contributing to changes in land use and land cover, such as an increase in construction land and a decrease in forest and grassland areas [80], While the economic level of these villages has indeed improved to some extent, the change in land use patterns poses challenges for the existence of some land-dependent historical and cultural heritages, potentially leading to their complete disappearance. Consequently, it is urgent for PSCL-lagging villages to assess the location characteristics and risks of cultural landscapes under land use changes [81], protect existing cultural landscapes, and enhance the cultural value of the villages by cultivating craftsmen skilled in heritage transmission.

SEL-lagging villages in the moderate imbalance stage and serious imbalance stage are notably characterized by advanced rural depopulation. The outflow of rural populations led to shifts in land use, including increased numbers of vacant residences, abandoned lands, and environmental degradation [82]. Therefore, it is imperative for these SEL-lagging villages to intertwine rural depopulation strategies with land use policies. In the context of population migration, which leads to the disconnection between people and the land, it is essential to unleash the potential of rural land resources. This includes streamlining the rural land transfer process, amplifying the scale of land transfers, and transitioning toward large-scale, efficient agricultural production operations. The evolution of agricultural management must transcend the conventional farmer-centric model to encompass a spectrum of innovative and diverse agricultural practices [83]. Such a paradigm shift is essential for catalyzing the swift economic revitalization.

PSCL-lagging villages identified with basic coordination in CCD have experienced positive tourism growth and achieved a state of relative ideality concerning CCD. However, a prevalent trend exists for sacrificing rural cultural landscapes for the sake of enhancing tourism revenue. Consequently, it is imperative to regulate the pace of commercial development with stringent regulatory measures. The government must enact well-considered and efficacious policies to govern commercial development, precluding detrimental construction endeavors that could disrupt the harmonious progression of land use and economic growth [84]. Furthermore, increasing financial allocations to conservation funds in PSCL-lagging villages serves as an essential policy instrument. Instituting and enforcing more rigorous protective regulations for cultural landscapes is vital to averting their destruction by development activities [85]. This proactive approach is instrumental in facilitating equitable land use planning that integrates economic advancement with the imperative of cultural heritage conservation.

In SEL-lagging villages with basic coordination, significant investments have been allocated toward preserving their cultural landscapes. Yet, the dominance of a single industry sector poses a significant barrier to their economic advancement. Strategic optimization of the industrial structure is vital for reshaping the land use configuration within these communities, facilitating a more balanced allocation of land resources across a spectrum of economic sectors. This transformation is instrumental in establishing a land use pattern that is orderly, efficient, and in harmony with the principles of sustainable development [86]. Moreover, refining the land use structure is likely to generate a wider array of employment opportunities, stimulating the return of the out-migrated population.

This influx of returning residents is anticipated to revitalize the socio-economic vitality of these rural settlements [87].

These policy recommendations aim to help village residents share the fruits of development and promote high-quality development in ethnic villages, ensuring that the benefits of tourism and economic growth are balanced with the protection and enhancement of cultural landscapes.

5. Conclusions

The application of coupling theory in this study effectively elucidates the interconnected dynamics between the PSCL and SEL within the ethnic minority villages of Leishan County, Qiandongnan. The spatial autocorrelation and LISA mapping techniques revealed a 'high–low' CCD pattern in the southwest and a 'low–high' in the north with the northwest corner exhibiting the densest high-value clusters and a low-value cluster observed in the southern region.

Our findings indicate that only three villages have achieved a basic coordination stage with 37 in the stage of moderate imbalance and three in the serious imbalance stage. The geographical detector model identified key influencers, including tourism revenue, tourist volume, village hollowing level, resident participation in tourism and the number of preserved historical buildings; then, it revealed the consistency and synergistic effects among influential factors, emphasizing the complexity of the coupling coordination relationship.

This research provides a fundamental methodology for the assessing the dynamic interrelationships between cultural landscape preservation and socio-economic development. It offers valuable insights for policymakers to devise precise and locally relevant strategies. These strategies should aim to mitigate potential threats to the cultural landscape of ethnic villages posed by urbanization, hollowing out, and tourism development, promoting sustainable and high-quality development in these regions.

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Abbreviations

PSCL	preservation status of the cultural landscape
SEL	socio-economic level
CD	coupling degree
CCD	coupling coordination degree

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