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RESEARCH ARTICLE

Investigation on the Space Patterns and Influential Factors for Distribution of Traditional Villages in Sichuan

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ABSTRACT - Traditional villages encapsulate the core of traditional culture and represent an indispensable element for rural revitalization. Nevertheless, over the past few decades, the continuous expansion of urban areas has resulted in the destruction of these villages. It holds immense importance to scrutinize the spatial arrangement and factors influencing the safeguarding and advancement of traditional villages. Previous research has predominantly concentrated on the value and protective mechanisms of traditional villages, overlooking their spatial distribution attributes and influencing factors. Hence, The paper focus on 396 traditional villages in Sichuan. Google Earth was utilized to rectify the longitude and latitude coordinates of villages. ArcGIS 10.8 and Geo-detector 2015 software was employed to examine the geographical distribution and influencing factors of traditional villages in Sichuan. The findings revealed that: (1) Sichuan traditional villages exhibit a clustered distribution, with the highest concentration found in Bazhong and Guangyuan cities in northeast Sichuan. Following closely are Li County of Aba Prefecture, Danba County of Ganzi Prefecture in northwest Sichuan, the junctions of Zigong, Neijiang, and Luzhou in southern Sichuan, and the junctions of Ya'an, Meishan, and Leshan in the Chengdu Plain. (2) Traditional villages in Sichuan are impacted by natural environmental and socio-economic factors, with temperature, altitude, precipitation, and distance from cities significantly affecting their distribution. (3) Approaches for the conservation and advancement of those villages include supporting spontaneously organized eco-friendly and sustainable agricultural projects by farmers, as well as planning the development of concentrated and contiguous tourism industries while protecting the ecological environment.

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1. INTRODUCTION

Traditional villages are defined as villages that possess material and intangible cultural heritage imbued with historical, cultural, scientific, artistic, and socioeconomic significance. Six rounds of evaluations were conducted, identifying 8155 traditional villages in China. They are a fusion of material and non-material culture in the river of cultural history, holding significant value. However, some rural areas have suffered varying degrees of damage [1]. Studying the spatial arrangement and examining the influencing elements is crucial for enhancing the organization and promoting the conservation [2, 3]. Previous research has encompassed various scopes. Several investigations have concentrated on particular individual instances, resulting in challenges such as a restricted number of sample points and regional uniqueness in qualitative examination. Certain studies have placed particular emphasis on distinct geographical settings, such as the Qinghai-Tibet Plateau and areas rocky desertification area, but this may not be conducive to providing references for government decision-making [4]. Other studies have often utilized administrative provincial area, such as Yunnan, Shaanxi, and Guangxi, but lack research on distribution patterns and influential factors of traditional villages in Sichuan [5, 6]. The aim of this study is to address the following objectives to remedy this deficiency: (1) Describe and analyse the spatial patterns of Sichuan traditional villages. (2) Analyse their influencing factors, evaluate their significance, and explain which factors dominate. (3) Propose protection and development strategies. Sichuan Province covers a total area of 492,400 square kilometres, accounting for 5.13% of China [7]. The topography of Sichuan is dominated by basins, mountains and plateaus, and the terrain gradually slows down from northwest to southeast, with 15.9°C as the average yearly temperature. It has around 1,400 rivers, and there are 84 million people living in 2022 [8]. Sichuan is a multi-ethnic province, with a total of 14 ethnic minorities, Tibetan, Yi, Miao, Qiang, Tujia, etc [9]. A total of 5.69 million people, Sichuan's unique geographical location has created a long Bashu culture and rich ethnic culture, but also gave birth to many traditional villages with local characteristics and different forms [10].

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2. MATERIALS AND METHOD

2.1 Data source

The data information of the research collected in this article comes from three sources: (1) Chinese Traditional Village Digital Museum (https://www.dmctv.cn/), including 396 in Sichuan. (2) Each village was regarded as a point in space, and they were determined using Google Earth (Figure 1). The coordinates of villages were obtained from Google Maps (The coordinate system was wgs84). Digital elevation model (DEM) data for Sichuan was extracted from the Geographic Spatial Data Cloud Platform (https://www.gscloud.cn). Additionally, data on water systems, transportation, temperature, precipitation, etc., were obtained from the National Earth System Science Data Centre (http://www.geodata.cn/). (3) Socio-economic data were sourced from the Sichuan Statistical Yearbook published on the website of the Sichuan Provincial Bureau of Statistics [11, 12].

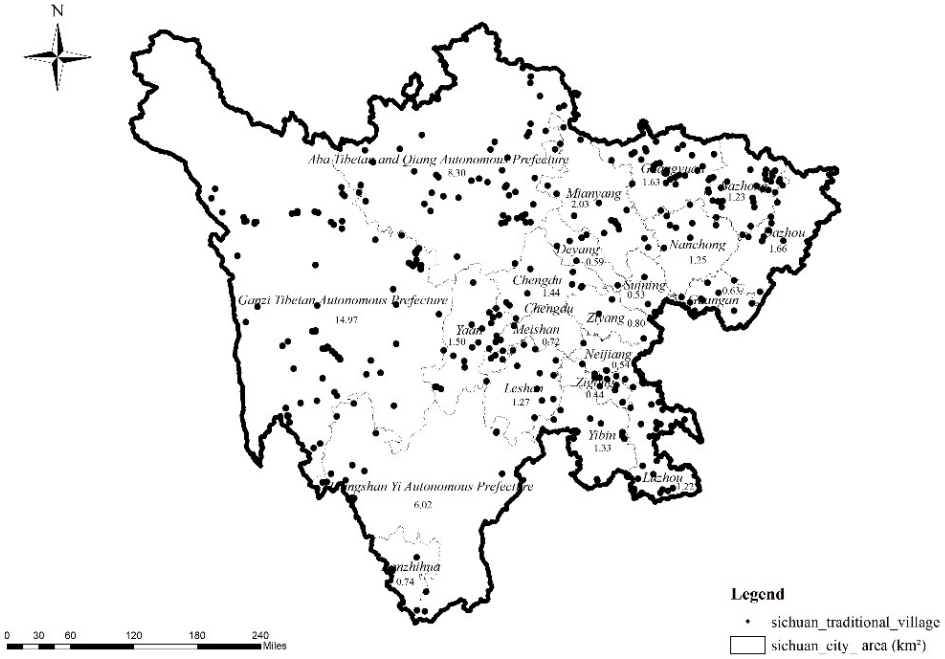

Figure 1. Sichuan traditional villages' spatial distribution map

2.2 Methods

Research on distribution characteristics refers to parameters. Average Nearest Neighbour Index and Voronoi diagram are used to reflect types of distribution. Kernel density, Geographical Concentration Index, and Moran's I are used to reflect the density of distribution. The Imbalance Index and Lorentz curve are used to reflect the degree of equilibrium of distribution [13, 14]. The Average Nearest Neighbour Index is a geographic indicator used to represent the proximity of point features in geographic space. By measuring the distance r_i between each traditional village point feature and its nearest neighbouring village, the actual nearest neighbour distance is obtained as the average value $\overline{r_1}$. Voronoi Diagram measures the relative degree of spatial variation of an element. Each cell in the Voronoi diagram represents the region closest to a given point compared to all other points. Kernel Density measures the concentration of point features. It uses a kernel function to estimate the density of points in certain area, highlighting regions of high and low concentration. Geographical Concentration Index is an important metric for assessing the degree of spatial concentration of traditional villages in a study area. It quantifies how concentrated or dispersed the villages are. Moran's I assesses the overall trend and variability of spatial autocorrelation of a variable across the entire study area. It indicates whether similar values are clustered or dispersed in space. Imbalance Index reflects the balance or imbalance of traditional villages across certain areas. It measures how evenly or unevenly the villages are distributed in different regions. Lorentz Curve shows the degree of deviation from uniform distribution. The distance and curvature of the Lorentz curve from the line of equality indicate the degree of balance in the distribution of traditional villages across the region.

Excel 365 and the ArcGIS 10.8 are used to objectively analyse the spatial distribution of traditional villages in Sichuan [15]. Additionally, Geo-Detector 2015 utilizes both single-factor and interaction factor methods to evaluate the influence of various factors [16]. Furthermore, through Geo-Detector 2015, these methods are employed to evaluate the extent of influence of different factors on traditional village distribution.

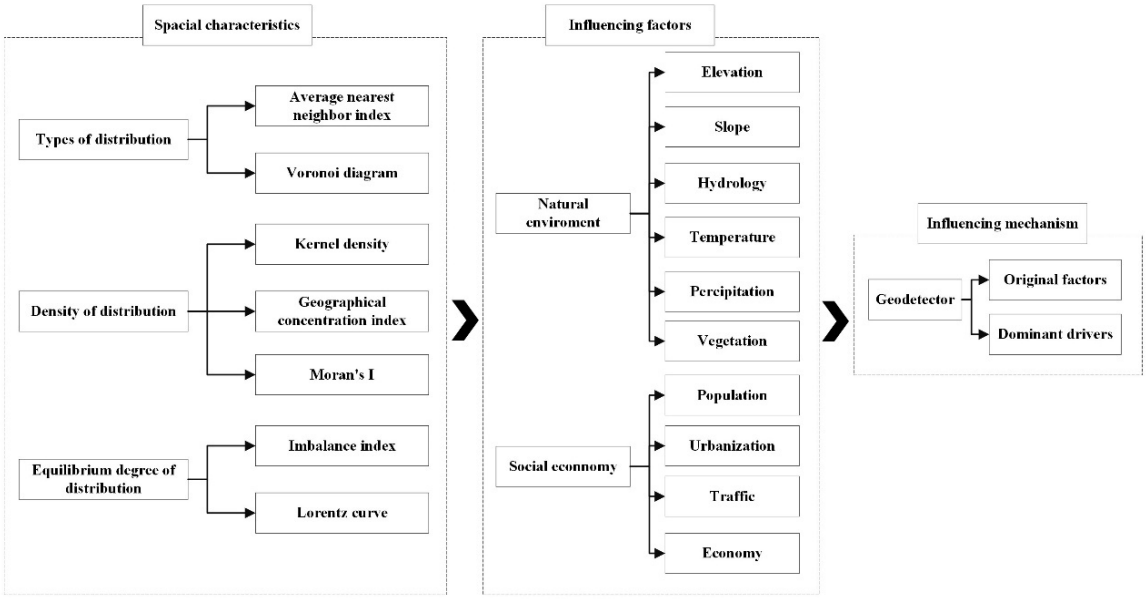

Figure 2. Sichuan traditional villages' spatial distribution map

Table 1. Statistical analysis models

Indicator	Formula	Definition	Interpretation
Average nearest neighbor index	$R = \overline{r_1}/r_E$	$\overline{r_1}$ is the average actual nearest Neighbour distance of the village; r_E is the theoretical nearest neighbour distance of the village.	If R<1 means that the sample is centrally clustered. The sample is considered random if R=1. R>1 denotes that the sample is dispersed. R=0 denotes a fully clustered sample.
Voronoi diagram	$CV = R/\bar{s}$	R is the Voronoi diagram's area standard deviation. $\bar{s}$ represents the Voronoi diagram's area average value.	When 33%<CV<64%, the point features are random, when CV>64%, the samples exhibit clustered, and when CV<33%, the samples are dispersed.
Kernel density	$\widehat{\lambda_h}(S) = \sum_{i=1}^{n} \frac{3}{\pi h^4}[1 - \frac{(S - S_i)}{h^2}]^2$	S is the traditional village's location; Si is a traditional village centred around S and h is the i-th traditional village's position within the radius space.	The larger the f (x) value, the denser the distribution of point.
Geographical concentration index	$G = 100 \times \sqrt{\sum_{i=1}^{n} (\frac{x_i}{T})^2}$	x_i is the quantity of traditional villages within the i-th city, the quantity of cities is n. T represents the total quantity of traditional villages.	G ranges from 0 to 100, Greater concentration is indicated by larger values, whereas greater dispersion is shown by lower values.
Moran's I	$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}\sum_{i=1}^{n}(x_i - \bar{x})^2}$	x_i and x_j are the quantity of point elements in i region and j region, $\bar{x}$ is average value of x_1, x_2, …, x_n, w_{ij} is the weight matrix spatially, n is the quantity of spatial elements.	I is between -1 and 1, if I > 0, it means that there is a positive spatial autocorrelation, if I < 0, it means that there is a negative spatial autocorrelation, and if I= 0, it means that there is no spatial autocorrelation.
Imbalance Index	$S = \frac{\sum_{i=1}^{n} Y_i - 50(n+1)}{100n - (n+1)}$	The quantity of cities is n, and Yi is accumulated percentage of the i-th digit, obtained by ranking the percentage of the number of traditional villages from large to small.	S is between 0 and 1, and higher S values indicate higher imbalance. When the traditional villages are evenly distributed in each city, S = 0. When all the traditional villages are concentrated in one city, S=1.
Average nearest neighbor index	$R = \overline{r_1}/r_E$	$\overline{r_1}$ is the average actual nearest Neighbour distance of the village; r_E is the theoretical nearest neighbour distance of the village.	If R<1 means that the sample is centrally clustered. The sample is considered random if R=1. R>1 denotes that the sample is dispersed. R=0 denotes a fully clustered sample.

3. RESULT

3.1 Spatial Distribution Characteristics

3.1.1 Province and city distribution

There are 396 traditional villages in Sichuan, ranking ninth in China, accounting for 4.86%, and the density of 8 traditional villages per 10,000 km², same as the national average, ranking 19th in China. Therefore, the quantity of Sichuan traditional villages is large, and the spatial distribution range is wide. ArcGIS 10.8 was used to classify the cities according to the number of villages, and divided them into five grades, the area's more traditional villages are represented by the darker colour band in the city. There are more than 30 traditional villages in Ganzi Prefecture, Aba Prefecture, Luzhou, and Guangyuan cities. 210 traditional villages are located in the four cities, and most of the traditional villages are located at the provincial or city borders, which are limited by urbanization and modernization (Figure 3).

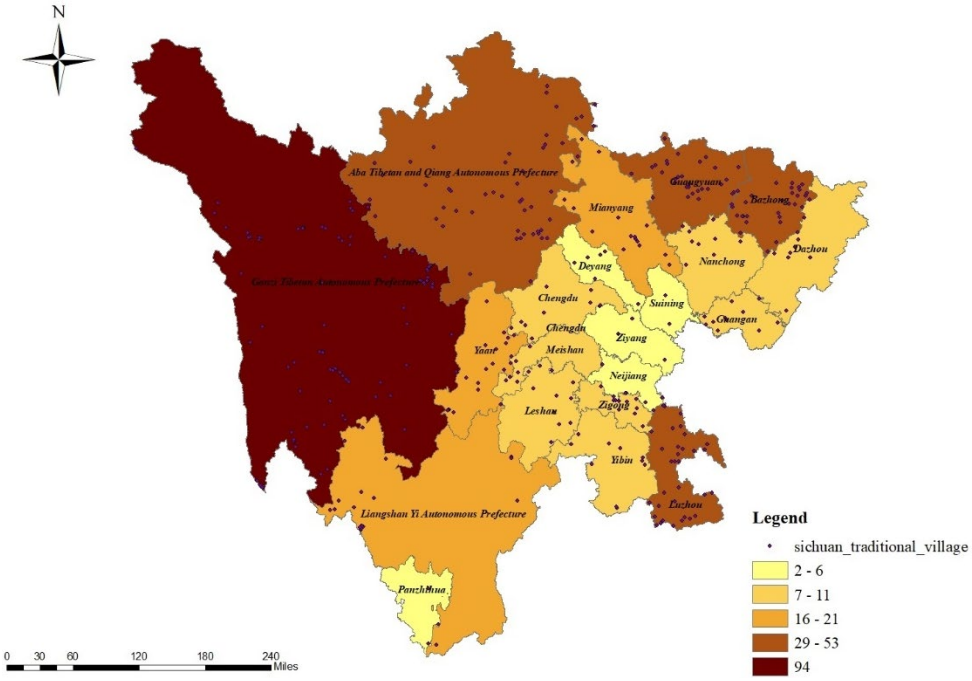

Figure 3. Sichuan traditional villages' spatial distribution map

3.1.2 The type of spatial distribution

Three categories may be distinguished in the geographical distribution of point groups: clustered, random, dispersed [17]. In this study, the research model of the nearest Neighbour index R is used to determine the spatial distribution, and the average nearest Neighbour in Spatial Statistics Tools of ArcGIS 10.8 is used to calculate: the expected average distance of traditional villages in Sichuan is measured to be 21. 863 kilometres, the average observation distance is 13. 080 km. The nearest exponential ruler is 0.598, which is less than 1. Strong significance is shown by the test parameters' Z-value of -15.29 and P-value of 0 respectively. It is evident that Sichuan's village spatial distribution is clustered.

The variation index (CV) was calculated to research spatial distribution types [18]. Sichuan traditional village Voronoi diagram were created using ArcGIS 10.8, and CV was 145.89% (＞64%), implying that Sichuan's traditional villages were clustered and further verified the previous results.

3.1.3 The density of spatial distribution

Utilize the Kernel Density tool Spatial Analyst in ArcGIS 10.8 to acquire the distribution map of kernel density (Figure 6). There are multiple high-density and sub-high-density centres in the border area of Ganzi Prefecture and Aba Prefecture, Chengdu Plain, northeast Sichuan and southern Sichuan, forming a concentrated and contiguous trend. The specific distribution is as follows: the high-density core areas are distributed in Bazhong and Guangyuan cities in northeast Sichuan, and the sub-high-density areas are located in Li County of Aba Prefecture, Danba County of Ganzi Prefecture in northwest Sichuan, the junctions of Zigong, Neijiang and Luzhou in southern Sichuan, and the junctions of Ya'an, Meishan and Leshan in Chengdu Plain.

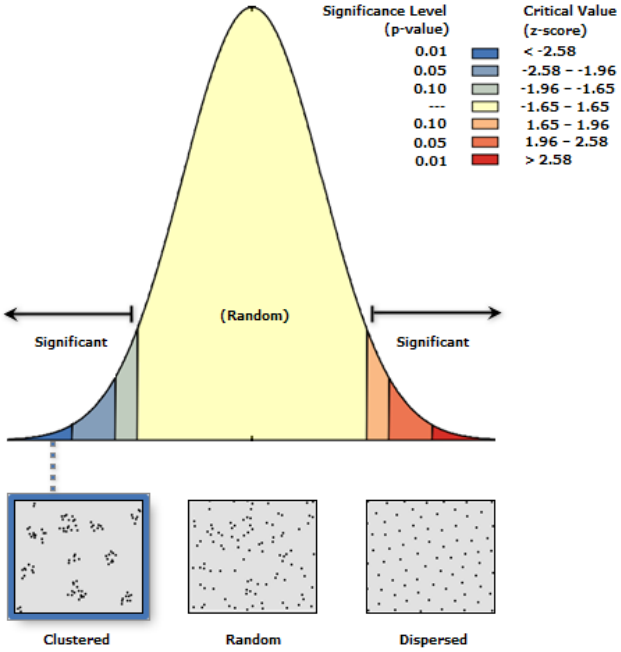

Figure 4. Average nearest neighbour report

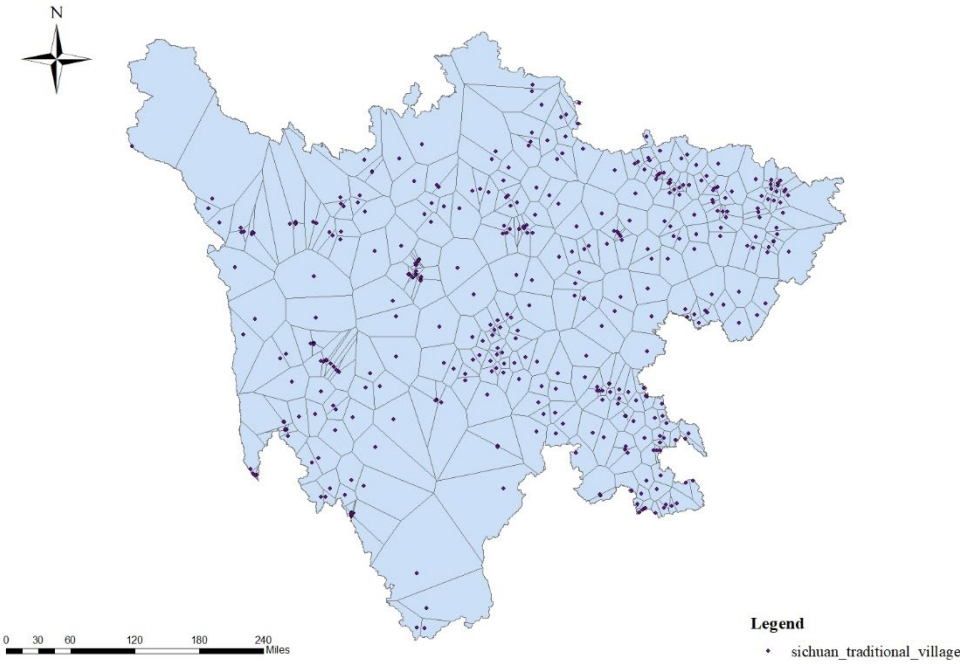

Figure 5. Voronoi diagram of traditional villages in Sichuan

The geographical concentration index G was used to examine the concentration of traditional villages in Sichuan [19]. The number of traditional villages in each city is calculated, and they have a geographical concentration index G of 32.418. Given an equal distribution of traditional villages across cities, the geographical concentration index G' = 21. 822. G > G' demonstrates that the Sichuan traditional village distribution is relatively concentrated at the city scales.

ArcGIS 10.8 was employed for calculating the global Moran's I index of traditional villages in Sichuan [20]. Z-value and P-value were 2.37 and 0.0178, indicating that the index showed significance. The Moran' I index was 0.213 (I＞0), demonstrating that the spatial distribution was not completely random, but showed a significant positive spatial correlation.

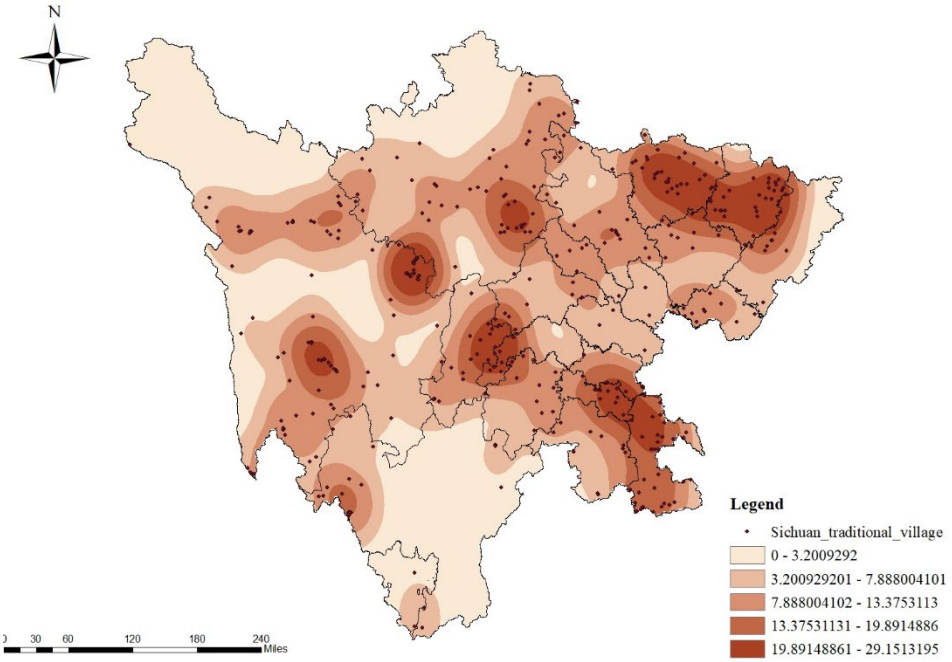

Figure 6. Kernel density analysis traditional villages in Sichuan

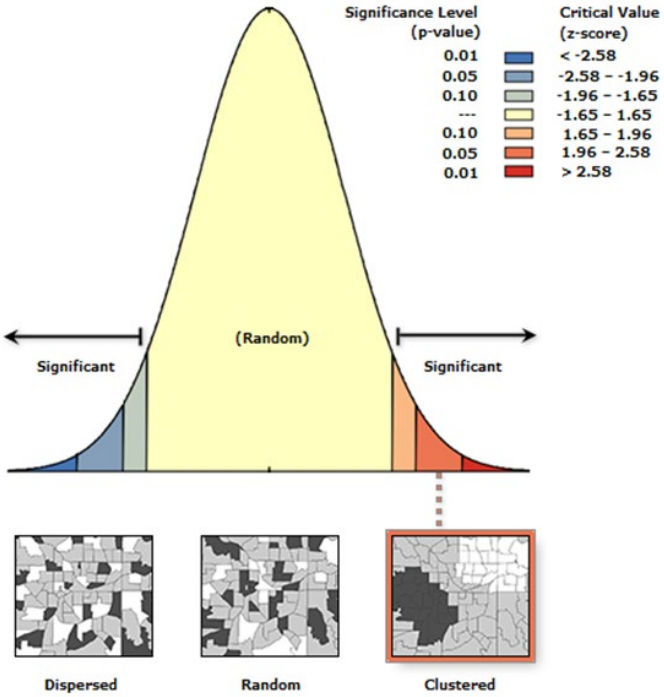

Figure 7. Spatial autocorrelation report

3.1.4 The equilibrium degree of spatial distribution

The equilibrium degree of dispersion was analysed using the imbalance index S. S = 0.520, it demonstrates the uneven distribution of traditional villages across 21 cities. Examining the Lorenz curve, it can also be found that the Lorenz curve shows a significant upward convex trend, and the traditional villages in Sichuan are mainly distributed in Aba, Ganzi, Luzhou, Guangyuan.

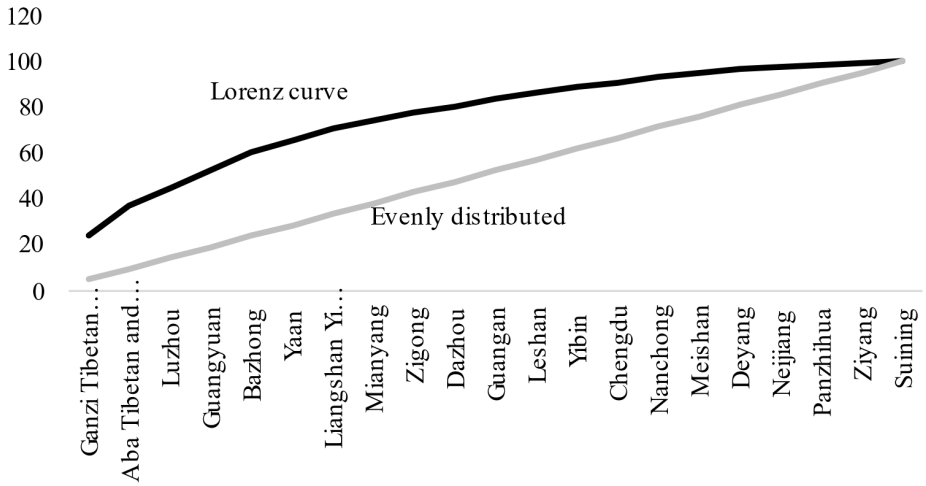

Figure 8. Lorenz curve of a traditional village in Sichuan

3.2 Analysis of Influencing Factors

3.2.1 Evaluation factor

The elevation of an area dictates the geographical features of traditional villages, giving rise to unique village forms based on varied terrains. Additionally, elevation affects village accessibility and economic progress, resulting in limited external connections and enhancing of villages. Using the Digital Elevation Model (DEM) elevation data of Sichuan as a basis, the elevation of Sichuan traditional villages was extracted. According to the Chinese mountain classification standard, the elevation data was divided into four types: plains (<200m), hilly (200m~500m), low mountain (500m-1000m), middle mountain (1000m~3500m), high mountain (>3500m), the altitude distribution map of traditional villages in Sichuan was acquired (Figure 8).The average elevation of traditional villages in Sichuan is 1566m, the lowest altitude is Xiaba Village, Xianshi Town, Hejiang County, Luzhou City, with an altitude of 198m, and the highest altitude is Shuiwa Village, Shuiwa Township, Xiangcheng County, Ganzi Tibetan Autonomous Prefecture, with an altitude of 4346m.

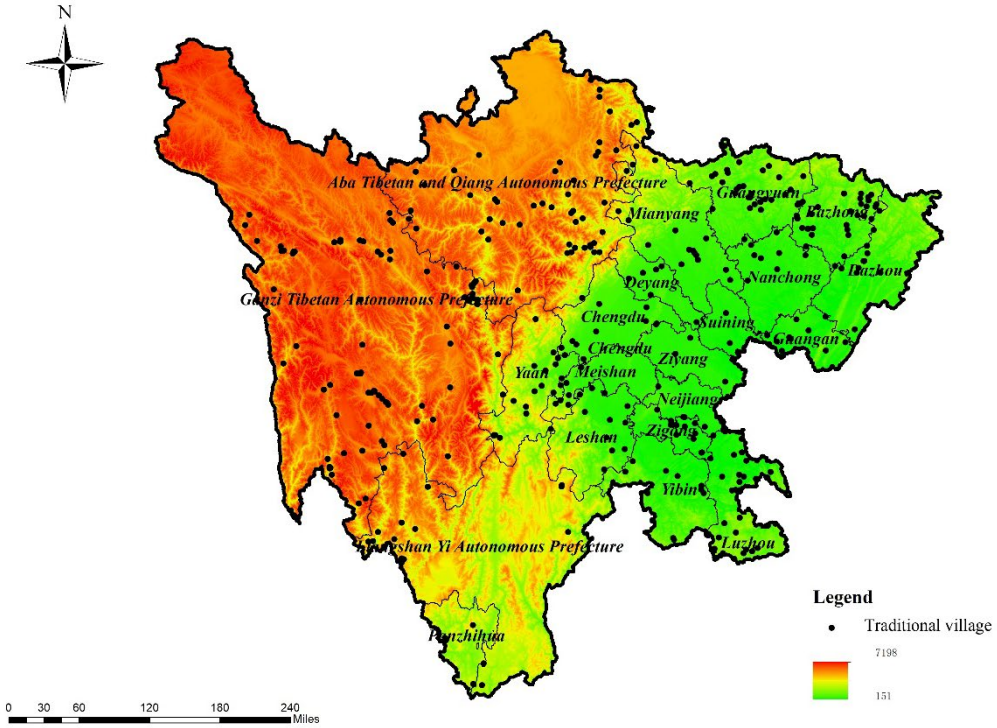

Figure 9. Elevation distribution map of traditional villages in Sichuan

The distribution of traditional villages in Sichuan is more concentrated in the eastern region and sparser in the western region, and the east is dense and the west is sparse. There is 1 traditional village in the elevation range of the plain (below 200m), 113 villages are in elevation range of the hilly (200~500m), accounting for 28.5%, 86 villages are in elevation range of the low mountain (500~1000m), accounting for 21.7%, and the quantity of traditional villages in the elevation

range of the middle mountain (1000~3500m) is the largest, with 161, accounting for 40.7%, The amount of traditional villages in the altitude range of the high mountain (＞3500m) is relatively small, only 37, accounting for 8.8%. Most traditional villages are observed to be situated within the altitude range of 200 to 3500 meters, that is, the altitude range of hills, low mountains and middle mountains.

3.2.2 Slope orientation factor

By analysing the slope orientation of the DEM elevation map of Sichuan Province, eight slope orientations are delineated in 45-degree intervals clockwise from true north (0° or 360°): (1) North-facing slope (0° to 22° 30', 337° 30' to 360°). (2) Northeast-facing slope (22° 30' to 67° 30'). (3) East-facing slope (67° 30' to 112° 30'). (4) Southeast-facing slope (112° 30' to 157° 30'). (5) South-facing slope (157° 30' to 202° 30'). (6) Southwest-facing slope (202° 30' to 247° 30'). (7) West-facing slope (247° 30' to 292° 30'). (8) Northwest-facing slope (292° 30' to 337° 30').

The analysis of traditional village distribution based on slope orientation reveals that villages predominantly face southeast, south, and southwest directions, accounting for 47.73%. Conversely, the number of villages facing north is the lowest, with only 29 villages. Considering a broader classification into sunlit slopes (90° to 270°) and shaded slopes (0° to 90°, 270° to 360°), it is found that there are 248 villages on sunlit slopes and 148 villages on shaded slopes, indicating that the quantity of villages on sunlit slopes is 1.67 times that on shaded slopes. Moreover, overlay analysis with elevation reveals that the average elevation of villages on sunlit slopes and shaded slopes is 1516m and 1649m, respectively. Villages on sunlit slopes benefit from ample sunlight radiation, along with lower elevations, gentle terrain, and favourable production conditions.

Table 2. Quantity statistics of different slope orientation

Slope orientation	Quantity of traditional village
North	29
Northeast	40
East	50
Southeast	61
South	67
Southwest	61
West	47
Northwest	41

3.2.3 Hydrology factors

In Sichuan, there are major river, such as the Jinsha River, Min River, and Fu River. To further examine the influence of watershed characteristics on the spatial arrangement, the hydrological analysis tool within the Spatial Analyst module of ArcGIS 10.8 was employed to delineate the distribution of water systems. It becomes evident that traditional villages in Sichuan demonstrate a distinct trend of being situated along riversides.

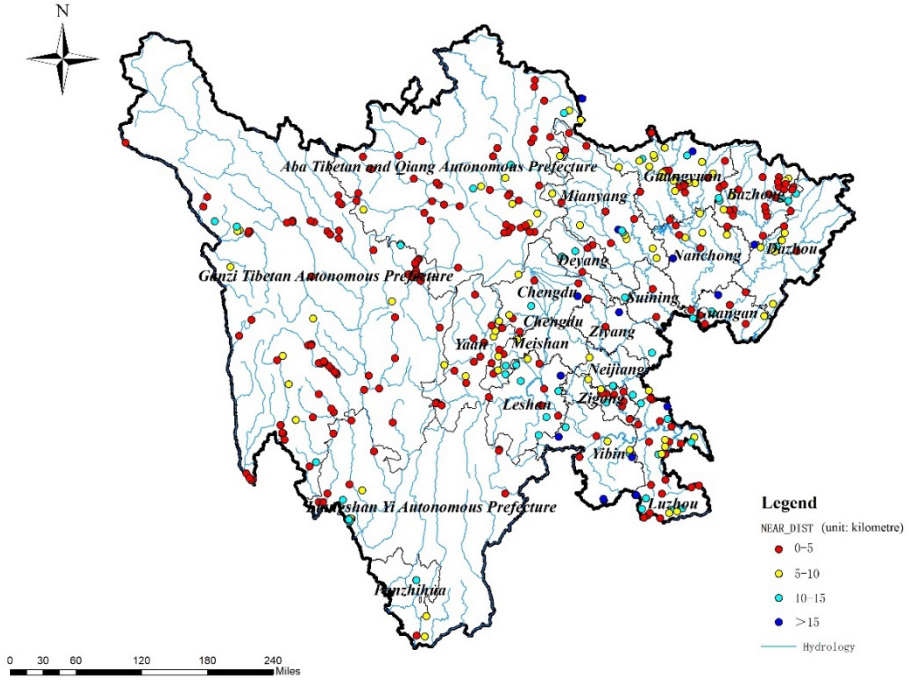

Figure 10. Hydrology distribution of traditional villages in Sichuan

Rivers serve not only as sources of water for daily activities and agriculture but also facilitate land levelling and transportation through waterways. Proximity analysis are used in ArcGIS 10.8. These analyses categorized distances from major rivers into four zones (unit: kilometre): 0-5, 5-10, 10-15, and ＞15. By assessing the amounts of traditional villages within each distance category. The majority of traditional villages (243 villages, or 61.36%) are located within 0-5 kilometres from rivers.

3.2.4 Climate factors

Climate affects both the comfort of the living environment and agricultural production. Using ArcGIS 10.8, an assessment of two key climate factors, the data of annual average temperature and annual precipitation, is conducted. These data are overlaid with the village's locations. The result reveals: (1) The yearly mean temperature in the area shows a tendency to rise from the northwest to the southeast. Likewise, the overall annual rainfall gradually rises from the west to the east, peaking in Luzhou and Ya'an. (2) it was found that the majority of villages (206 villages, or 52.02% of the total) are located in areas with annual average temperatures ranging from 15°C to 20°C. The temperature range is pleasant and conducive to human settlement. Concerning precipitation, traditional villages are mainly located in regions with annual rainfall ranging between 500 and 1000 millimetres, constituting 59.09% of the total. The interval of precipitation is highly favourable for agriculture.

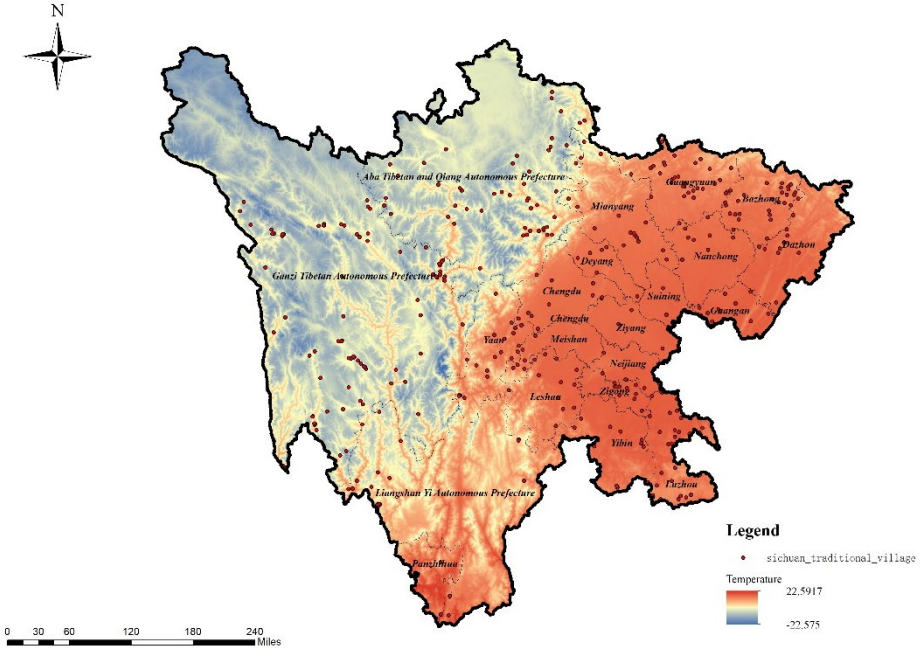

Figure 11. Temperature distribution of traditional villages in Sichuan

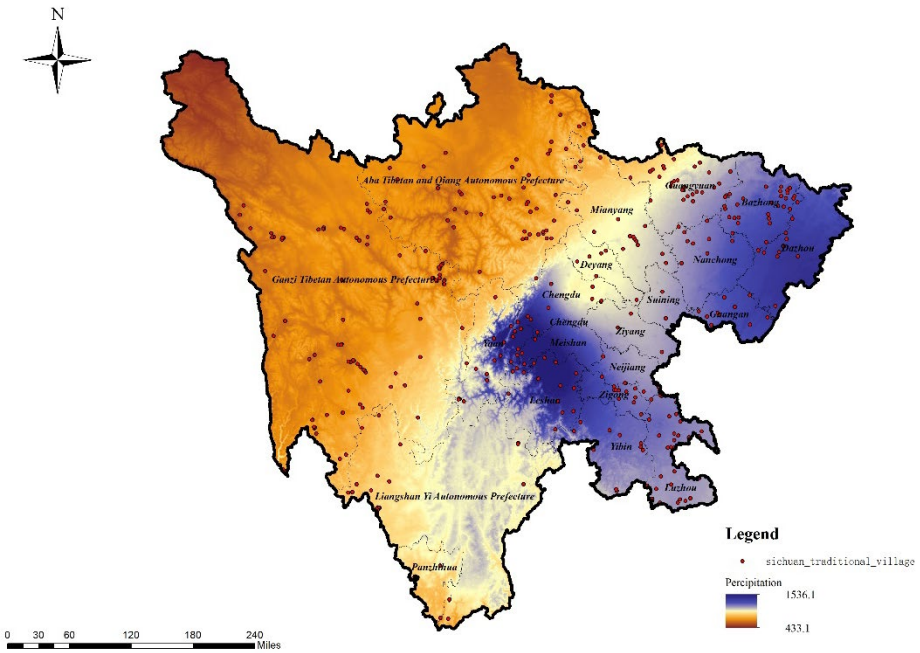

Figure 12. Precipitation distribution of traditional villages in Sichuan

3.2.5 Vegetation factors

The way to determine the condition and coverage of plant growth is with the Normalized Difference plant Index (NDVI). The larger the index, the denser the vegetation, and vice versa, indicating sparse vegetation. The vegetation index ranges from 0.29 to 0.93 in Sichuan. According to the natural breakpoint method, the vegetation index is divided from large to small into five sections: dense (>0.827), relatively dense (0.756-0.827), moderate (0.679-0.756), relatively sparse (0.560-0.679), and sparse (<0.560). It is evident that the quantity of traditional villages in the relatively dense section is the highest, with 127 villages, accounting for 32.07%, while the amounts of villages in the sparse section is the lowest, with only 22 villages, accounting for 5.56%. Overall, most traditional villages in Sichuan have good vegetation coverage, abundant green vegetation, and high ecological resources.

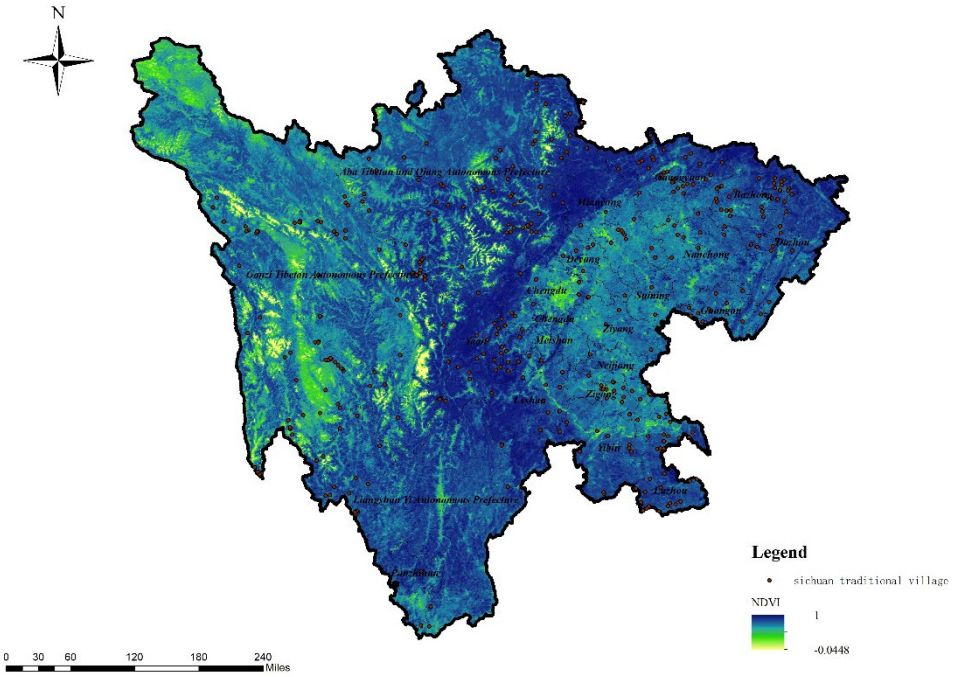

Figure 13. NDVI distribution of traditional villages in Sichuan

3.2.6 Population factor

Traditional villages are formed by long-term aggregation of villagers, containing the essence of agricultural civilization, rich historical and cultural information, and natural ecological landscapes. Villagers showcase the authentic life of traditional villages to tourists, becoming a unique scenery of traditional village tourism [19]. Therefore, retaining villagers is key to protecting and developing traditional villages. Utilizing the natural breakpoint method, the population density grid is categorized into five levels: high-density area (>64.89), relatively high-density area (40.27~64.89), medium-density area (18.73~40.26), relatively low-density area (5.95~18.72), and low-density area (<5.95). The population density values of each traditional village are extracted to obtain. It is observable that the count of traditional villages rises as population density declines. Primarily, traditional villages are dispersed across regions characterized by low population density. This is due to the fact that in areas with sparse population, human activities have less impact on traditional villages and natural resources, thus allowing traditional villages to be preserved.

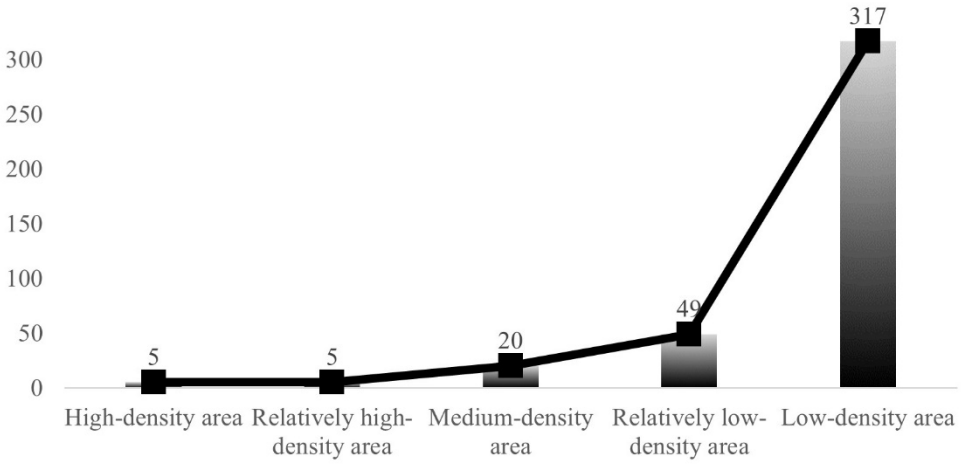

Figure 14. Quantity statistics of different population zones

3.2.7 Urbanization factor

The process of urbanization accelerates the decline of villages. The ArcGIS 10.8 analysis module's proximity analysis tool was utilized. A finding was made indicating that the mean separation between villages and urban centres extended to 89.36 kilometres. Traditional villages are typically situated at a distance exceeding 100 kilometres from urban centres, with 135 of them falling into this category, while there are 42 villages located at distances of 0-20 km from cities. This indicates that traditional villages are far from cities, with limited influence from urban market economies, allowing the long-standing traditional culture of villages to be preserved and continued. Additionally, using ArcGIS 10.8 to calculate the distance from villages to urban boundaries, it was determined that the mean distance from rural settlements to urban perimeters is shorter compared to the distance to urban centres, suggesting that conventional rural communities tend to be clustered in outlying regions distant from urban centres.

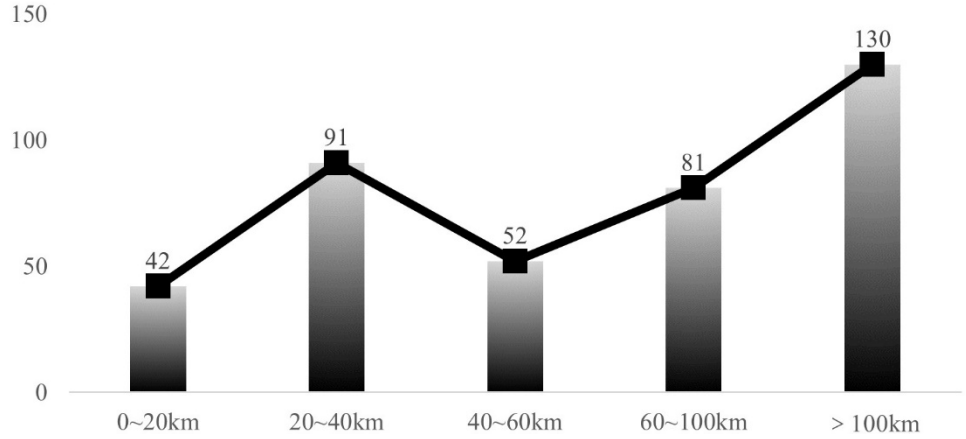

Figure 15. Quantity statistics of different distance from city

3.2.8 Traffic factor

Proximity analysis was conducted in ArcGIS 10.8. The distance from the national major roads was segmented into 4 zones. The count of traditional villages within varying distance was compiled. Studies demonstrate that a total of 195 conventional settlements are situated within a 5-kilometer radius of main thoroughfares, representing 49.24% of the total. Findings indicate that a reduction in the proximity to main roads corresponds to a rise in the number of settlements, highlighting the beneficial impact of public transportation on the conservation of traditional villages. It is important to highlight that within a buffer zone less than 5 kilometres away, traditional villages are located, 98 villages are found within a 1 km radius of major roads. This reveals that public transportation not only avoids disturbing traditional villages but also provides accessibility and convenience.

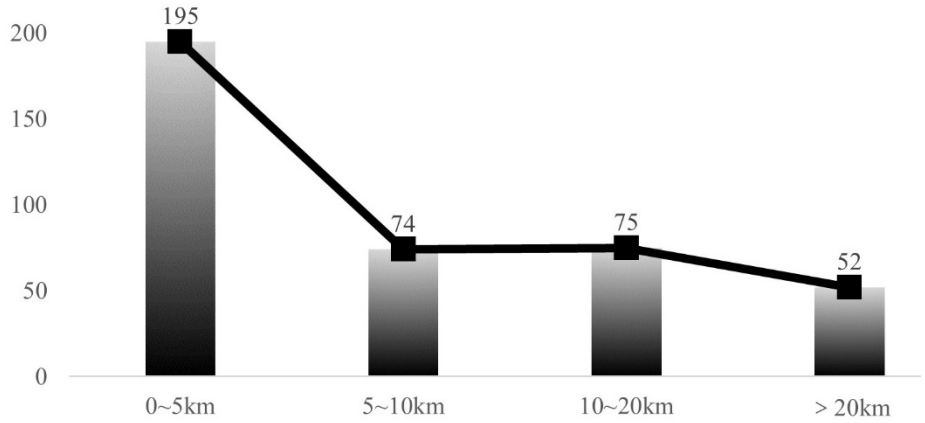

Figure 16. Quantity statistics of different distance from major road

3.2.9 Gross domestic product (GDP) factor

Sichuan's industrial development has shifted gradually from reliance on agriculture in the past to other industries currently. This transformation has seen a gradual enhancement in transportation infrastructure. Nevertheless, these advancements are predominantly focused on urban hubs, leaving Sichuan's villages grappling with issues such as underutilized resources and restricted economic capabilities [21]. The factors have resulted in widespread and deeply rooted poverty. Based on the annual per capita GDP, the majority of regions fall below 50,000 yuan. Villages are predominantly clustered in areas with per capita GDP ranging from 0 to 10,000-yuan, accounting for 53.28%. This could have a negative impact on the protection of these villages and may even hinder their protection and development.

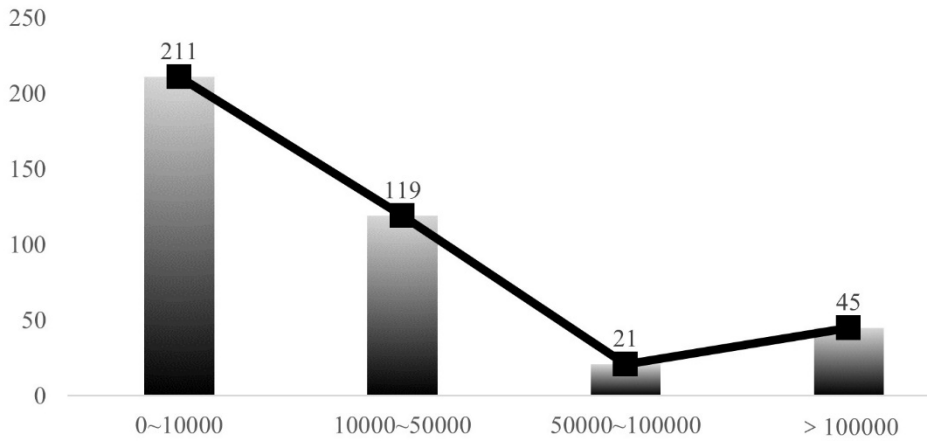

Figure 17. Quantity statistics of different GDP zones

3.3 Quantitative analysis of influencing factors

3.3.1 Single Factor Analysis

The study utilized ArcGIS 10.8 for the extraction of data concerning 10 significant variables. They include elevation (X1), slope (X2), distance to rivers (X3), temperature (X4), precipitation (X5), transportation distance (X6), population density (X7), per capita GDP (X8), distance to cities (X9), and NDVI (X10). Through the result of Geo-Detector 2015, temperature (X4), elevation (X1), precipitation (X5), and distance to cities (X9) are the main influencing factors, with corresponding q-values of 0.147, 0.134, 0.133, and 0.113, indicating high significance and reliable experimental results. Additionally, per capita GDP (X8) and transportation distance (X6) have a certain influence on the spatial distribution, although their driving forces are relatively smaller.

Table 3. Single factor analysis of the influencing factors

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
q	0.134	0.023	0.020	0.147	0.133	0.071	0.004	0.085	0.113	0.014
p	0.000	0.082	0.222	0.000	0.000	0.000	0.624	0.000	0.000	0.383

3.3.2 Interaction Factor Analysis

The interaction factor analysis of Deo-Detector 2015 assesses how interactions between two influencing factors alter the dependent variable's explanatory power. Five different types of interactions were found based on the correlation between the acquired q-values:

$q(A \cap B) < \min[q(A), q(B)]$, signifies a reduction in the non-linearity of the two factors when they interact. $\min[q(A), q(B)] < q(A \cap B) < \max[q(A), q(B)]$, implies that each factor interacts with the others separately. $q(A \cap B) > \max[q(A), q(B)]$, indicates a strengthening in the interaction between the two factors. $q(A \cap B) = q(A) + q(B)$, denotes that the two factors display independence. $q(A \cap B) > q(A) + q(B)$, implies a non-linear interaction between the two factors.

Table 4. Interaction factor analysis of the influencing factors

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	0.134									
X2	0.173	0.023								
X3	0.221	0.095	0.020							
X4	0.216	0.180	0.233	0.147						
X5	0.293	0.195	0.202	0.371	0.133					
X6	0.237	0.114	0.106	0.250	0.196	0.071				
X7	0.200	0.053	0.064	0.207	0.195	0.106	0.004			
X8	0.196	0.136	0.141	0.231	0.225	0.150	0.133	0.085		
X9	0.304	0.169	0.161	0.302	0.275	0.194	0.152	0.213	0.113	
X10	0.209	0.055	0.091	0.235	0.157	0.104	0.049	0.132	0.146	0.014

Research indicates that the driving forces of bivariate interactions are stronger than single-factor effects, with nonlinear enhancement being the predominant interaction type [11]. Compared to single-factor effects, the q-values of each influencing factor increase to varying degrees when they interact with other factors. Key interacting factors that significantly affect the dependent variable Y in spatial space include temperature (X4) intersecting with precipitation

(X5), temperature (X4) intersecting with distance to cities (X9), and elevation (X1) intersecting with distance to cities (X9). Among these, elevation (X1), temperature (X4), and precipitation (X5) exhibit relatively strong effects on other factors, with their enhancement being particularly evident during interaction.

4. DISCUSSION

4.1 Factors Influencing the Distribution of Traditional Villages

The rapid economic and social progress observed in China has induced a significant influx of rural labourers into urban areas, consequently diminishing the vibrancy of traditional villages. Sichuan, recognized for its multitude of rural regions, generally contends with comparatively underdeveloped economic circumstances and has been notably impacted by the consequences of urban economic advancement. The evolution of industrialization has precipitated a transformation in the fundamental nature of traditional villages, leading to modifications in their production methods, gradual erosion of traditional customs, and reduction in their residential areas, thereby relocating traditional villages further away from urban centres.

However, the positive impacts of economic progress are also noteworthy. Through the organic integration of economic, cultural, and ecological assets, the conservation efforts of traditional villages can be effectively enhanced. In endeavour to safeguard and enhance traditional villages, China places considerable importance on the matter, encouraging these villages to capitalize on their ecological surroundings, historical heritage, and advantages in agricultural industrialization. Moreover, the proximity to cities plays a significant role in the trading of agricultural goods and the development of rural tourism. Villages in close proximity to cities enjoy the benefits of easier agricultural transactions and greater strategic advantages for rural tourism.

4.2 The Protection and Development Strategy of Traditional Villages

Based on the aforementioned research, the emphasis in protection and development strategies for traditional villages in Sichuan should be placed on industrial development and ecological conservation, considering natural environmental factors. The natural environment surrounding traditional villages should be cherished as the driving force, ensuring their authenticity and providing continuous momentum for development [22]. Adequate financial assistance can be provided through promoting modern agriculture and tourism, fostering the development of traditional villages without urbanization [23]. However, common characteristics within the same contiguous area should be emphasized, and classified discussions should be conducted. To promote protection and development of these villages, the following development ideas are proposed:

Firstly, supporting village-initiated ecological agriculture and sustainable agricultural projects is essential. This involves exploring sustainable ecological farming models that promote sustainable and ecologically friendly agriculture projects tailored to the unique ecological characteristics of the region. Local farmers can have better economic prospects if organic agriculture, traditional crop types, and agricultural tourism are promoted. It's crucial to stimulate farmers' initiative to advance this model [24]. Simultaneously, planning the concentrated development of the tourism industry while preserving the ecological environment is vital. Utilizing the diverse topographical landscapes and historical culture can drive the development of ecotourism, emphasizing unique natural and Humanistic landscapes in the region. The planning of the government will be crucial to this strategy and protecting the natural environment from destruction.

5. CONCLUSION

To address the requirements of conservation and development in traditional villages, this research carried out spatial analysis utilizing ArcGIS 10.8 and statistical techniques to examine the distribution patterns of traditional villages in Sichuan. Additionally, it delved into the impacts of socio-economic and environmental factors on the spatial distribution of traditional villages, offering valuable insights to aid in their preservation and progress. The primary findings of the study are outlined as follows:

a) Traditional villages in Sichuan demonstrate an unbalanced, clustered distribution pattern. These villages are primarily concentrated in Bazhong and Guangyuan cities in northeast Sichuan. Additionally, areas of secondary clustering include Li County of Aba Prefecture, Danba County of Ganzi Prefecture in northwest Sichuan, the junctions of Zigong, Neijiang, and Luzhou in southern Sichuan, and the junctions of Ya'an, Meishan, and Leshan in the Chengdu Plain.

b) The spatial arrangement of traditional settlements in Sichuan is closely intertwined with a variety of natural environmental and socio-economic influences. Most of villages are located at altitudes ranging from 1000 to 3500 meters, with a predominance of sunny slopes. They are commonly situated within 5 kilometres of rivers. Climate is conducive to agricultural development. Most villages are situated within the geographical area characterized by an average annual temperature of 15-20°C and annual precipitation ranging from 500 to 1000 millimetres. Traditional villages tend to cluster in regions characterized by low population density, with per capita GDP ranging from 0 to 10,000 yuan annually, and most villages are located over 100 kilometres away from cities and within a 5-kilometer radius of major roads.

c) Temperature, altitude, precipitation, and distance to cities significantly influence the spatial distribution of traditional villages in Sichuan, with the explanatory power of each factor being as follows: temperature > altitude > precipitation > distance to cities > per capita GDP > transportation distance. The interaction between temperature, precipitation, and most other factors shows a notable enhancement effect.

d) The following protection and development strategies are proposed: supporting spontaneously organized eco-friendly and sustainable agricultural projects by farmers, as well as planning the development of concentrated and contiguous tourism industries while protecting the ecological environment.

This research employed a macro-level method to examine potential influencing factors and distribution patterns. Additionally, it is regarded as foundational research in studying the spatial layout and ecological conservation at the micro-level in the region. The aim of this study is furnishing theoretical underpinnings and strategic insights for addressing the pressing issues of rural poverty and rural revitalization, while offering insights for similar areas facing analogous issues.

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AUTHOR CONTRIBUTIONS

Zhou Zi Hua.: Conceptualization, Methodology, Writing- Original draft preparation
Omar Jamaludin. Doh Shu Ing.: Supervision

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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