

Article

Distribution Characteristics and Influencing Factors of Traditional Villages in the Lingnan Region of China

Dongxu Zhang ¹, Xinyi Zhang ¹, Li Teng ², Wenjie Ma ¹, Lingge Tan ³ and Honghao Li ^{1,*}

¹ College of Architecture and Urban Planning, Guangzhou University, Guangzhou 510006, China; zhangdongxu@gzhu.edu.cn (D.Z.); 2112209013@e.gzhu.edu.cn (X.Z.); clairema0626@gmail.com (W.M.)

² School of Geography and Remote Sensing, Guangzhou University, Guangzhou 510006, China; tengli@gzhu.edu.cn

³ School of Design, The Hong Kong Polytechnic University, Hong Kong SAR, China; linggtan@polyu.edu.hk

* Correspondence: lihonghao@gzhu.edu.cn

Abstract: Traditional villages are important parts of architectural and material cultural heritage in China. This study focuses on 710 national-level traditional villages in the Lingnan Region, which are analyzed with ArcGIS 10.8 and spatial analysis methods on the basis of the proximity index, geographic concentration index, kernel density estimation, and Geodetector. The aim is to reveal the spatial distribution patterns of traditional villages in the Lingnan Region and explore the mechanisms through which natural and socioeconomic factors affect their distribution. The results show that the spatial distribution of traditional villages in Lingnan is heterogeneous, with a certain degree of cohesion, and forms one high-density cluster and four secondary high-density clusters. The distribution is influenced by natural factors, such as climate, terrain, and river systems, as well as socioeconomic factors, such as intangible cultural heritage, population, and gross domestic product. However, the direction and magnitude of these influences vary. Among all the factors, temperature and intangible cultural heritage have the strongest explanatory power for the spatial distribution of traditional Lingnan villages. The combined influence of each factor with the other factors is greater than that of each factor alone. This research provides a scientific basis for the protection and development of traditional Lingnan villages.



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Keywords: Lingnan traditional villages; spatial distribution characteristics; influencing factors; socioeconomic status; Geodetector

1. Introduction

China, a country that has traditionally relied on agriculture since ancient times, has a long history of traditional villages. The formation and development of these villages are closely tied to the rise of agriculture, which not only shaped the unique characteristics of the villages but also profoundly influenced multiple aspects of ancient Chinese society, economy, and culture [1]. The traditional villages mentioned in this article refer to “villages that were formed early, possess rich traditional resources, are relatively well preserved, and hold significant historical, cultural, scientific, artistic, social, and economic value [2,3]”. Lingnan is a general term for the region south of the Five Ridges in southern China, which is separated from inland areas by mountains. Currently, Lingnan specifically refers to Guangdong, Guangxi, Hainan, Hong Kong, and Macao. Before the Qin Dynasty, the Lingnan Region was home to brilliant civilizations during the Neolithic and Bronze Ages, making it one of the birthplaces of Chinese civilization. To date, 8171 traditional villages have been identified in China through six rounds of selection [4], among which 710 are

located in the Lingnan Region (this study does not include the Hong Kong and Macau regions), accounting for approximately 8.7% of the national total [5]. The geographical location and surrounding environment of traditional villages are important factors that influence their architectural style, cultural practices, and way of life. The similarities in climate, geography, living customs, and culture give Lingnan traditional villages certain common features. Analyzing their distribution patterns can help uncover the cultural roots behind the unique landscapes that were formed during the historical development of these villages and provide targeted measures for the long-term preservation of this traditional village heritage. Consequently, this research holds significant value for the study of ancient Chinese architectural history and Lingnan culture.

Unlike typical rural villages, China's traditional villages attract significant academic attention because of their high historical, cultural, aesthetic, and tourism value. Research on China's traditional villages has primarily focused on areas such as heritage protection [6], spatial genealogy [7,8], village landscapes [9,10], spatial morphology [11,12], village micro-climate [13], and evaluation system construction [14,15]. Moreover, village clusters have been explored, including studies of evolution patterns, spatial distribution characteristics, and factors influencing rural settlements. These studies are divided by scale: macro-scale, such as national-level research [16]; meso-scale, such as provincial [17] and river basin studies [18,19]; and micro-scale, such as township and village analyses [20]. Traditional villages have increasingly received global interest, prompting scholars from various disciplines to study the factors related to their preservation. UNESCO has been credited with considering rural landscapes as heritage from the 1980s onwards [21]. In relation to architectural culture, research based on social surveys of local residents and tourists indicates that the conservation and development of architectural heritage in traditional villages require societal consensus [22]. Japanese scholars have analyzed data from public surveys to study public perceptions of rural landscapes and their cultural values with the aim of integrating this information into rural management strategies [23]. Additionally, research on ecological restoration by Greek scholars [24] has greatly enriched the understanding of traditional village conservation. With the advent of computer technology, the use of geographic information systems (GIS) for spatial analysis has expanded to encompass a wide range of issues, such as the impact of urban expansion on agricultural land in Norway [25], landscape changes in rural southern Italy [26], and the use of multi-temporal GIS by Iraqi scholars for detailed analyses of historical and contemporary satellite images to examine rural settlement patterns [27].

With respect to the geographic distribution characteristics of traditional villages, commonly used analytical methods in previous studies included the nearest neighbor index [28], geographic concentration index [29], imbalance index [30], kernel density estimation [31], spatial autocorrelation analysis [31], and overlay analysis methods [30]. The results indicated that the overall distribution of traditional villages in China is highly heterogeneous, with a general pattern of more villages in southern China and fewer in northern China. These villages are primarily concentrated on the southeastern side of the Hu Huanyong Line in South China and East China [32]. Studies focusing on various regions have revealed that traditional villages in Southwest China are concentrated mainly in the southeastern and southwestern parts of the region. Six spatial clusters are located in eastern Guizhou and west-central Yunnan, whereas other areas exhibit large, dispersed distributions of traditional villages [31]. In Guizhou Province, ethnic minority villages display a significant spatial clustering phenomenon [33]. In the southeastern coastal region, the spatial layout of traditional villages has distinct distribution patterns, such as "three cores with multiple secondary clusters" in Jiangxi Province, "two cores and two secondary

clusters” in Guangdong Province, and “one core and two secondary clusters” in Fujian Province [34].

In previous studies of the factors influencing traditional village distribution patterns, approaches based on the Pearson correlation coefficient [16], logistic regression [35], multiscale geographically weighted regression [36], and Geodetector [37,38] methods have been employed. The results indicated that population and genealogy are the two most critical factors influencing village distribution, with their interaction having the most significant effect on the spatial pattern of traditional Chinese villages ($q = 0.82663$) [39]. The spatial distribution of rural settlements exhibits specific directional characteristics, such as transportation-oriented, central-place-oriented, arable land resource-oriented, and environmentally livable region-oriented patterns [40]. In conclusion, the distribution patterns of traditional villages and their influencing factors vary across different regions in China. Therefore, understanding the spatial distribution characteristics and factors influencing traditional villages requires in-depth, region-specific investigations that account for local conditions.

Academic research on traditional villages in the Lingnan Region has primarily focused on macro-level studies of overall village structures [41], meso-level studies of the survival conditions of villages within megacity areas in the Pearl River Delta [42], and micro-level case studies with in-depth exploration [43,44]. However, traditional Lingnan villages have not been considered holistically to investigate their distribution characteristics and the factors influencing these patterns. Thus, it is necessary to explore the spatial distribution characteristics and driving factors of traditional villages in Lingnan from a macro perspective. This approach yields a systematic understanding of the reasons behind the formation and development of traditional Lingnan villages and aids in formulating comprehensive strategies for village protection and development. In this study, the following two questions are addressed:

- (1) What are the patterns and characteristics of the spatial distribution of traditional villages in the Lingnan Region?
- (2) What are the main factors influencing the distribution of traditional villages in the Lingnan Region? What is the intensity of these influencing factors, and do they interact with one another?

This study focuses on national-level traditional villages in the Lingnan Region. First, their distribution characteristics are identified, and then the factors influencing their spatial distribution are comprehensively assessed from two perspectives: natural conditions and sociocultural conditions. The analysis incorporates multiple indicators, such as geographical and environmental factors, climate, river systems, and socioeconomic factors, to systematically assess the extent to which these factors influence the spatial distribution of traditional villages in Lingnan.

2. Materials and Methods

2.1. Study Object

The Lingnan Region ($18^{\circ}10' - 26^{\circ}24' \text{ N}$, $104^{\circ}28' - 117^{\circ}19' \text{ E}$) covers a total area of approximately 452,800 square kilometers. The entire northern side is surrounded by five mountain ranges, whereas the southern side is adjacent to the South China Sea (as shown in Figure 1). Most of the region has a subtropical humid monsoon climate, with southern Hainan Island experiencing a tropical climate. The Lingnan Region receives abundant solar radiation and experiences extended periods of sunshine. The Pearl River, the largest river in the region, forms a centripetal water system that flows from north to south into the South China Sea. Lingnan has a typical semi-enclosed geographical environment, which has profoundly influenced its historical and geographical development. Over more than two

millennia of development, a significant number of traditional villages have been preserved in this region. This study focuses on 710 national-level traditional villages in Lingnan, the vast majority of which have a history that ranges from two to three centuries to as long as seven or eight centuries. Based on historical records, local gazetteers, and the remaining architectural structures of villages, the establishment of some traditional villages has been estimated. The villages that can be verified were founded in the Tang, Song, Yuan, Ming, and Qing dynasties (Tang 2.3%, Song 18.3%, Yuan 2.3%, Ming 53.1%, Qing 24%).

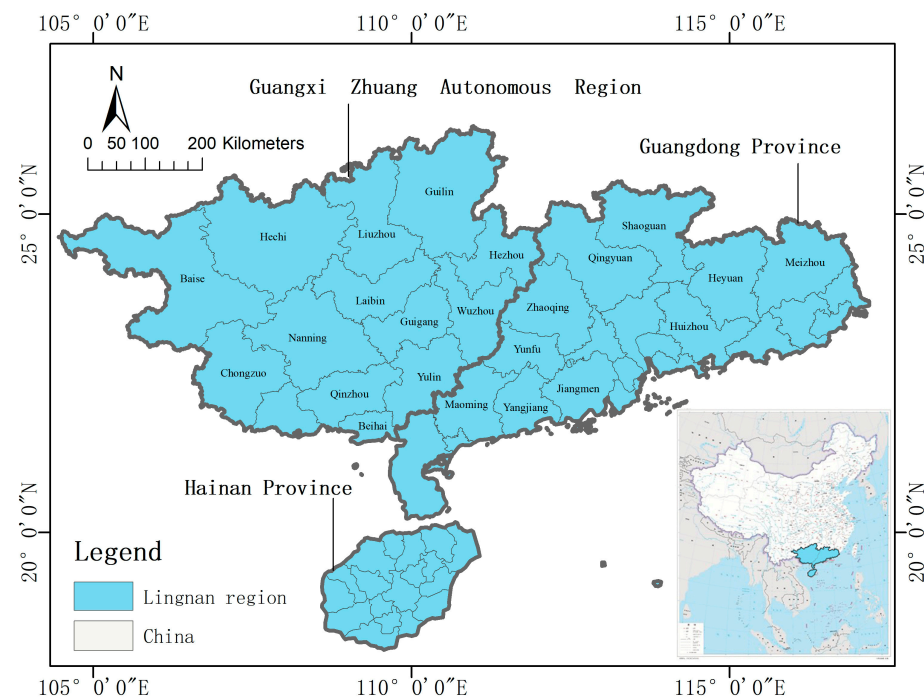


Figure 1. Location of the study area.

2.2. Data Collection

The data for traditional villages were obtained from the China Traditional Villages website [5], which provides a list of villages approved by the Ministry of Housing and Urban-Rural Development. To standardize the geographic coordinates of traditional villages in the Lingnan Region, the MapLocation tool was used for batch conversion of latitude and longitude data to ensure that all coordinates adopted the WGS-84 coordinate system. These standardized coordinates were then transformed into vector data in shapefile (shp) format via ArcGIS, resulting in a spatial distribution map of traditional villages in the Lingnan Region. The digital elevation model (DEM) data were sourced from the geospatial data cloud [45] via SRTMDEM elevation data with a 90-m resolution. These data were then imported into ArcGIS and clipped to obtain the topographic map of the Lingnan Region. ArcGIS 10.8 was subsequently used to generate slope direction and river information from the DEM data. Provincial and municipal administrative division data were obtained from the DataV.GeoAtlas data visualization platform. We converted the downloaded JSON format files into shp format and imported them into ArcGIS. The population and gross domestic product (GDP) data for each city were sourced from the 2023 statistical yearbooks of the three Lingnan provinces (Guangdong, Guangxi, and Hainan). The distribution information on intangible cultural heritage (e.g., Hakka folk songs, Chaozhou Yingge, Cantonese opera, dragon boat racing) was obtained from the China Intangible Cultural Heritage Data Museum [46]. Annual average temperature and annual precipitation data were sourced from the National Earth System Science Data Center [47]. All of the abovementioned data were imported into ArcGIS for visualization processing.

2.3. Research Tools and Methods

In this study, the distribution patterns of traditional villages in the Lingnan Region and their influencing factors were systematically analyzed. Various analytical techniques based on ArcGIS 10.8 [25,26], including the nearest neighbor index, kernel density estimation, and overlay analysis methods, were employed to investigate the spatial distribution characteristics of traditional villages in the region. Additionally, the Geodetector tool was applied to quantitatively analyze the factors influencing the spatial distribution of these villages. This approach was used to assess the intensity of each influencing factor, the interactions among factors, and the relationship between the distribution of traditional villages and various elements, such as environmental and socioeconomic factors.

2.3.1. Statistical Analysis Models

In this study, statistical analysis models such as the nearest neighbor index, imbalance index, and geographic concentration index models are used. By integrating these models and analyzing data for traditional villages, the spatial distribution patterns of traditional villages were obtained.

(a) Nearest Neighbor Index

The nearest neighbor index is a geographical indicator used to represent the degree of proximity between point features in geographic space. ArcGIS 10.8 software was used to measure the proximity of traditional villages in the Lingnan Region. The formula is as follows:

$$R = \frac{\bar{r}_1}{\bar{r}_E} \quad (1)$$

where $\bar{r}_1$ is the actual nearest neighbor distance, $\bar{r}_E$ is the theoretical nearest neighbor distance, and R is the nearest neighbor index. When $R = 1$, it indicates a random distribution of point features; when $R > 1$, the point features tend to be uniformly distributed; and when $R < 1$, the point features tend to be clustered.

(b) Imbalance Index

The imbalance index is used to measure the degree of clustering in the spatial distribution of samples, and it is expressed as follows:

$$S = \frac{\sum_{i=1}^n Y_i - 50(n+1)}{100n - 50(n+1)} \quad (2)$$

where n is the number of cities in the Lingnan Region; Y_i represents the cumulative percentage of traditional villages in each city, sorted in descending order of the proportion of the total number of traditional villages; and S is the imbalance index. S ranges between 0 and 1. If $S = 0$, it indicates a uniform spatial distribution of traditional villages; if $S = 1$, it indicates that all traditional villages are concentrated in one area.

(c) Geographic Concentration Index

The geographic concentration index describes the degree of concentration of the study objects within the research area and is expressed as follows:

$$G = 100 \times \sqrt{\sum_{i=1}^n \left(\frac{X_i}{T} \right)^2} \quad (3)$$

where n is the number of cities in the Lingnan Region; X_i represents the number of traditional villages in the i -th city in the Lingnan Region; T is the total number of traditional villages; and G is the geographic concentration index. The value of G ranges from 0 to 100, where a large G value indicates a concentrated spatial distribution of traditional villages and a small G value signifies a more dispersed distribution.

2.3.2. Kernel Density Estimation Method

The kernel density estimation (KDE) method is a nonparametric approach in which it is assumed that geographic events can occur at any spatial location, although the probability of occurrence varies by location. High kernel density values indicate high concentrations of point features, indicating a high likelihood of geographic events occurring in those areas; conversely, low density corresponds to a low probability. By calculating the density of point features around each output raster cell, the degrees of dispersion and concentration of point features are determined. In this study, the kernel density of traditional villages in the Lingnan Region was calculated to analyze the corresponding clustering trends and distribution characteristics.

2.3.3. Map Overlay Analysis

The map overlay analysis method is a commonly used spatial analysis technique in GIS that involves superimposing different geographical data layers to examine their spatial relationships. In this study, the spatial distribution map of traditional villages in the Lingnan Region was overlaid with data layers such as a DEM, population data, economic data, and river systems. Using related charts, the spatial distribution characteristics of traditional villages were analyzed in light of the effects of various factors, and the relationships with these factors were explored.

2.3.4. Geodetector

Geodetector is a quantitative method used to determine whether a geographic factor influences the spatial distribution of a given index or its weight. By using factor detection and interaction detection modules, the factors influencing the spatial differentiation of traditional villages can be identified. The corresponding formula is as follows:

$$q = 1 - \frac{\sum_{h=1}^L N_h \sigma_h^2}{N \sigma^2} \quad (4)$$

Y is composed of L strata ($h = 1, 2, \dots, L$), which are partitioned based on Y or an explanatory variable, X . The terms “stratification” and “partition” are equivalent and can be classified or zoned. The numerator in the equation is the summation of the within-strata variance, and the denominator is the pooled variance; N and σ^2 denote the number of units and the variance of Y in a study area, respectively [48]. The q value range is $[0, 1]$, with high values indicating stronger explanatory power for the independent variable than for the dependent variable.

3. Spatial Distribution Characteristics of Traditional Villages in the Lingnan Region

3.1. Spatial Distribution Pattern

The 710 traditional villages in the Lingnan Region were treated as point features, and the average nearest neighbor tool in ArcGIS 10.8 was used to calculate the actual nearest neighbor distance (9213 m), the theoretical nearest neighbor distance (12,699 m), and the nearest neighbor index ($R = 0.726$). Since $R < 1$, and with a Z score of -13.989 (Z scores reflect the statistical significance of spatial autocorrelation, with negative scores indicating clustering, positive scores indicating dispersion, and zero indicating no pattern), it can be concluded that the overall spatial distribution of traditional villages in the Lingnan Region demonstrates a clustered pattern.

Additionally, the number of traditional villages in each city within the Lingnan Region was calculated. Among the 54 cities in the region, the distribution of traditional villages is heterogeneous. Guilin City has the largest number of villages, totaling 171 (24.1% of the

total), followed by Meizhou City, with 78 villages. In contrast, nine cities contain only one traditional village, and five cities have none.

The geographic concentration index of traditional villages in the Lingnan Region was calculated as $G = 29.775$, and the index would be 13.608 if the villages were evenly distributed. This indicates that the distribution of traditional villages is relatively concentrated. At the municipal scale, villages are primarily located in a few cities, such as Guilin and Meizhou. The imbalance index was calculated as $S = 0.678$, which is greater than 0 and relatively close to 1, indicating an uneven spatial distribution of traditional villages. The Lorenz curve, drawn on the basis of the cumulative percentage of traditional villages, has a typical concave shape (as shown in Figure 2). Among the 54 cities in the Lingnan Region, the eight cities with the highest number of traditional villages (13% of all cities) account for 59% of the total number of villages. This finding further highlights the heterogeneous and highly clustered spatial distribution of traditional villages.

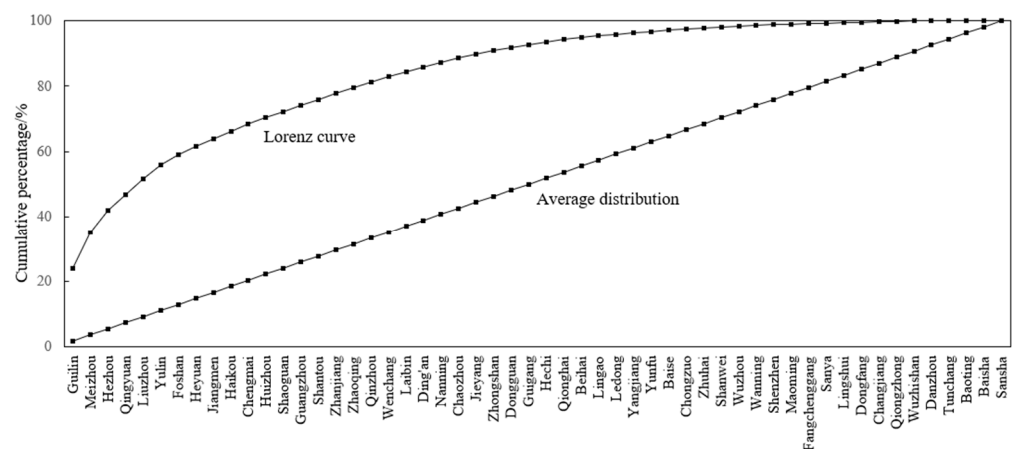


Figure 2. Lorenz curve of the spatial distribution of traditional villages.

3.2. Spatial Distribution Density

The kernel density tool in ArcGIS 10.8 was used to perform kernel density estimation for traditional villages in the Lingnan Region, and a kernel density map of their spatial distribution was generated. As shown in Figure 3, the overall spatial distribution of traditional villages is highly heterogeneous, with one high-density cluster in the northern Lingnan Region, centered on Guilin City, and four secondary high-density clusters located in the central, southeastern, eastern, and southern parts of the region. Traditional villages in other areas are characterized by low density and scattered distribution patterns.

The northern region has historically been the cultural center of the Lingnan area, primarily because ancient Chinese civilization originated in the Central Plains, located in the Yellow River and Yangtze River Basins. This region was long the political and economic center of China, while the Lingnan area is separated from the Central Plains by the expansive Five Ridges. During the Qin Dynasty (221–207 BCE), the construction of the Lingqu Canal, one of the oldest canals in the world, connected the Yangtze and Pearl River systems, opening a passage from the Central Plains to northern Lingnan. This development caused Guilin City, near the Lingqu Canal, to become the political and economic center of the Lingnan Region for an extended period [49]. With multiple ethnic groups settling there, this area became the region with the highest density of traditional villages in Lingnan. The other four clusters of traditional villages are also closely tied to the region's historical role. For example, the central and southern parts of Lingnan served as the starting points of the ancient Maritime Silk Road, attracting a large population and resulting in the formation of many villages. Similarly, traditional Hakka village clusters in eastern Lingnan formed as a result of five large-scale migrations of the Hakka people throughout history. Additionally,

some traditional villages in Lingnan are located in relatively remote ethnic minority areas, where they are less influenced by external factors, making them more likely to be preserved and retained.

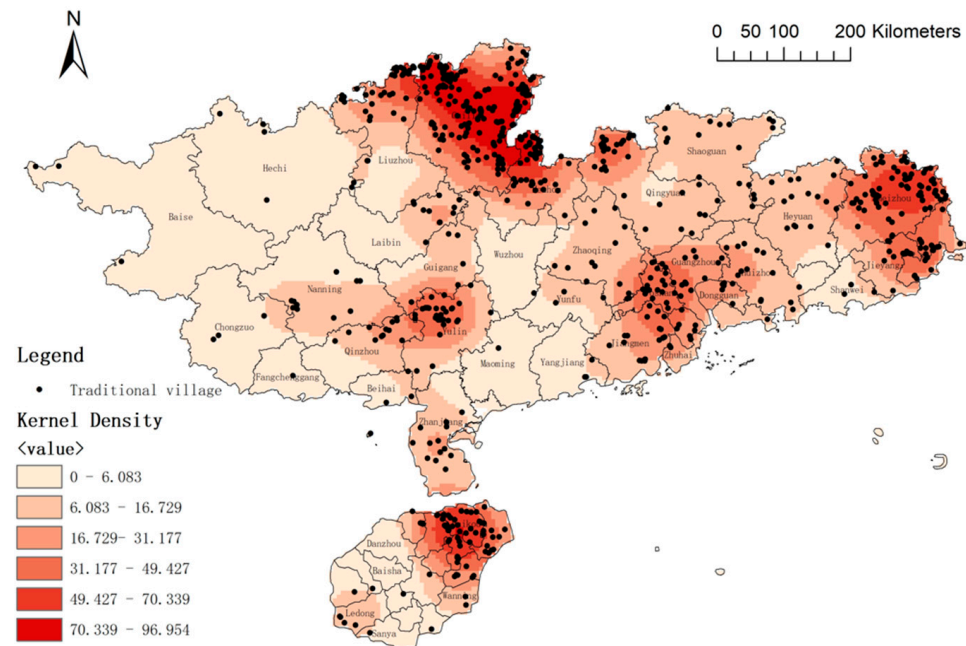


Figure 3. Distribution and kernel density of traditional villages in the Lingnan Region.

4. Factors Influencing Spatial Distribution

4.1. Environmental Factors

The Lingnan Region encompasses diverse and complex natural and geographical environments. In this study, the impact of environmental factors on the spatial distribution of traditional villages was analyzed.

4.1.1. Elevation and Longitude/Latitude

Elevation is one of the key natural factors influencing the selection of sites for traditional villages. Different elevation zones have distinct temperature and precipitation conditions, which shape production, development, and lifestyles. Using ArcGIS software, a DEM map was overlaid with the coordinates of traditional villages (see Figure 4). The results reveal that the elevation in the Lingnan Region ranges from -55 to 2124 m, with a topographical pattern of higher elevations in the northwest and lower elevations in the southeast. The analysis shows that the 710 traditional villages are distributed within an elevation range of -2 to 1247 m, with an average elevation of 203 m. Figure 4 illustrates a gradual decrease in the number of villages as elevation increases. The correlation coefficient (Pearson) between elevation and the number of villages in this elevation range (divided into 100 -m intervals) is -0.789 ($p < 0.01$), indicating that elevation is a significant factor influencing the distribution of traditional villages. High-elevation areas generally experience lower temperatures than low-elevation areas, which hinder crop growth and increase transportation costs. In contrast, low-elevation areas typically feature open, gently sloping terrain, associated with lower transportation and construction costs while supporting long-term agricultural stability. Consequently, traditional villages were more commonly established in low-elevation areas.

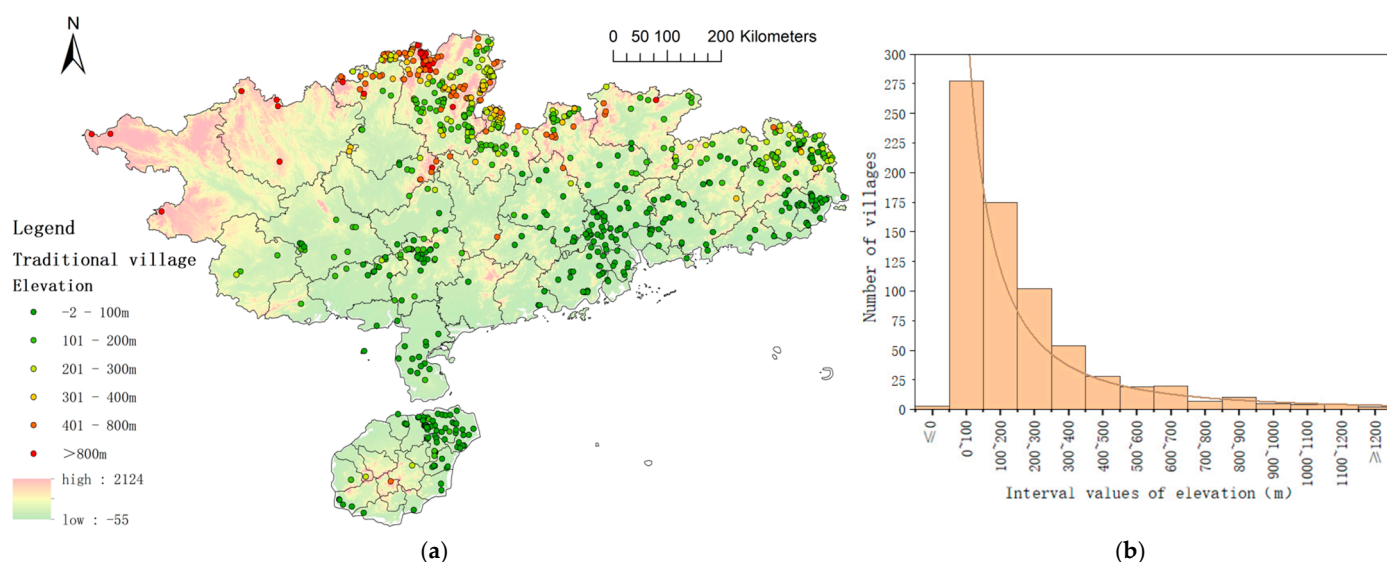


Figure 4. Elevation analysis: (a) DEM map and distribution of traditional villages in Lingnan and (b) elevation interval distribution.

Among the 710 villages studied in this paper, the latitudinal range is from 18.36° to 26.24° . To assess the relationship between the elevation and latitude of traditional villages, a regression analysis was conducted, as shown in Figure 5, with a curve fitting degree of 0.699. As latitude increases, the elevation of villages generally displays a corresponding upward and scattered trend. In the region around latitude 26° , the distribution of village elevations is the most diverse.

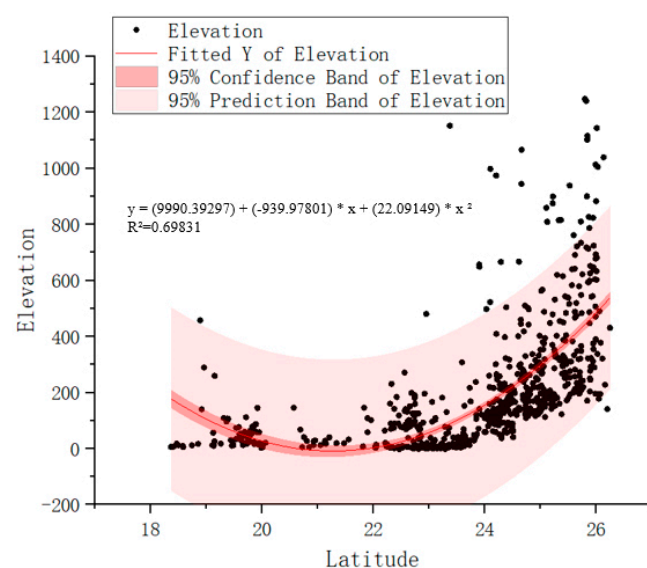


Figure 5. Spatial distribution of the elevation and latitude of traditional villages in the Lingnan Region.

4.1.2. Slope Direction and Slope

(1) The slope direction refers to the orientation of a local land surface in three-dimensional space [50] and is related to the duration and intensity of sunlight received by traditional villages, significantly impacting residents' production activities and daily routines. Choosing an appropriate slope direction can help villages avoid adverse local wind directions and optimize sunlight exposure by integrating architecture with the terrain. Thus, slope direction may be one of the factors influencing the spatial distribution of traditional villages. On the basis of the specific location of each village, the geometric center of the village's projection plane was used as the calculation point. The slope direction

was determined as the direction of the maximum rate of change in the z value among the grid cells surrounding a selected point. The extracted slope direction results from ArcGIS were categorized into eight types (as shown in Figure 6a). Owing to the diverse and complex mountainous terrain, the village slope directions in Lingnan are highly variable. With respect to the overall distribution of traditional villages based on slope direction, as shown in Figure 6b, villages were most commonly constructed on southwest-facing slopes, totaling 114, whereas villages on northeast-facing slopes were least common, with only 49. This could be because Lingnan's winters are dominated by north or northeast winds, making northeast-facing slopes windward in winter and deprived of adequate sunlight, which creates unfavorable conditions for a comfortable living environment. However, in terms of slope direction, unlike villages in the cold regions of northern China, where a southern orientation is preferred, in Lingnan, slope direction does not seem to be a primary factor in the selection of village sites. This could be because the region is characterized by high solar altitudes and intense sunlight across all seasons, with overall high temperatures. Consequently, the need to maximize sunlight exposure is less critical than in northern regions.

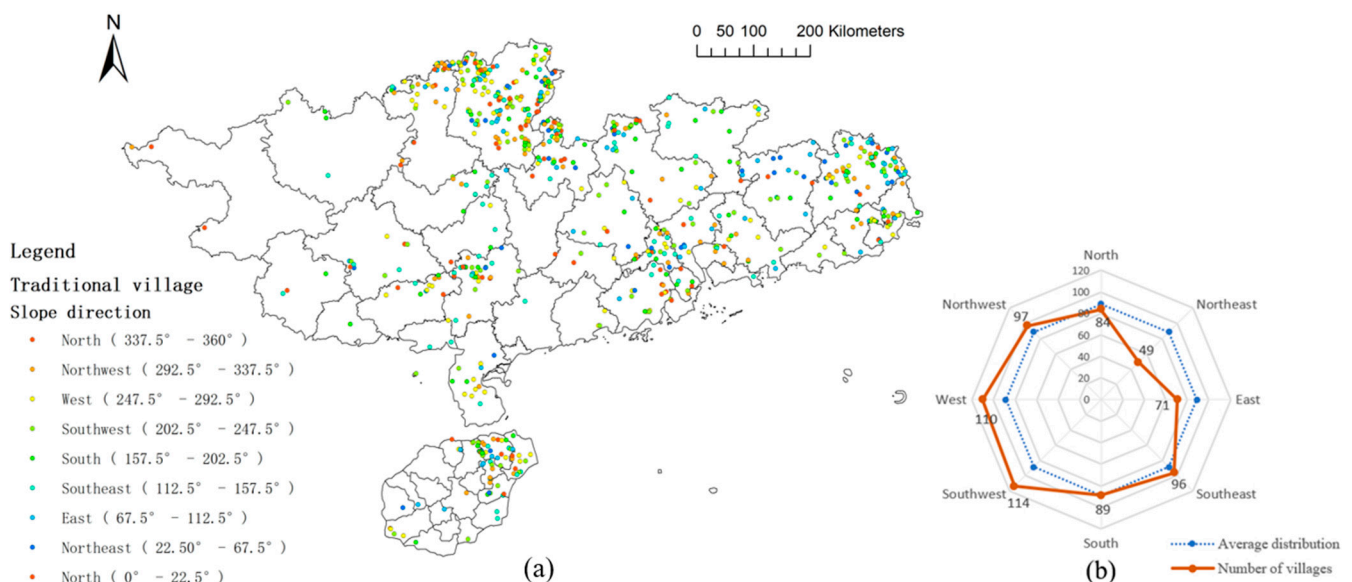


Figure 6. Slope direction of traditional villages in the Lingnan Region: (a) slope direction map of traditional villages in the Lingnan Region and (b) slope direction distribution map.

(2) Slope values indicate the degree of terrain undulation where a village is located. Slope directly affects the scale, intensity, and form of various production activities, as well as the difficulty of village construction. Using the geometric center of a village's projection plane from satellite imagery as the calculation point, the angle between the tangent plane at this point and the horizontal plane reflects the slope of the terrain and is considered the village slope. In this study, the slope data derived from a DEM (as shown in Figure 7) were overlaid with the distribution of traditional villages. Overall, the terrain in Lingnan is highly variable. Notably, 335 villages, or 47.2% of all villages, are located in flat terrain areas (slopes below 2°). Moreover, 158 (22.2%) villages have gently sloping terrain (2–6°), 128 (18.0%) villages have moderately sloping terrain (6–15°), 69 (9.7%) villages have slightly steep terrain (15–25°), and only 20 (2.8%) villages have steep terrain with a slope above 25°. The correlation coefficient (Pearson) between slope and the number of villages in each slope category is -0.600 ($p < 0.01$). These findings align with those of previous studies, which demonstrated that most traditional villages are situated in areas with low elevations and gentle slopes [16].

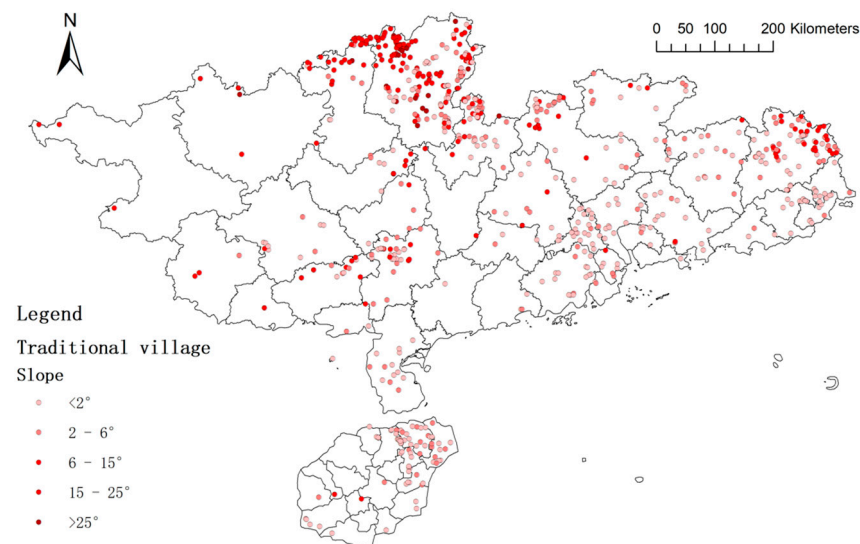


Figure 7. Slopes of traditional villages in the Lingnan Region.

In terms of topographical characteristics, traditional villages in the northeastern, southeastern, and southern regions (Hainan Island) of the Lingnan area are mostly distributed across various plains and hilly areas. These regions are characterized by low-lying and relatively flat terrain, which is ideal for agricultural production and village establishment. In contrast, the western part of Lingnan is an extension of China's western plateau (as shown in Figure 4), featuring numerous mountainous areas that are less conducive to agricultural activities, resulting in a sparse distribution of traditional villages in this region. In eastern Lingnan, many traditional villages are situated in low-altitude valleys (with steep slopes). This may be because these villages were predominantly established by the Hakka people, who historically migrated from central China to escape wars. At that time, the plains were already occupied by the native inhabitants, leaving the newly arrived Hakka no choice but to build their villages in mountainous areas.

4.1.3. River System

Rivers are critical factors for human production and daily life. Traditional villages near rivers benefit from favorable agricultural conditions and living environments. Rivers can also serve as essential transportation routes and create flat terrain for constructing houses and cultivating farmland, thereby increasing opportunities for the development and sustainability of traditional villages. Consequently, ancient people tended to establish villages along riverbanks or in areas with dense river networks. In this study, DEM data were used to generate a river network, which was overlaid with the locations of traditional villages in Lingnan to analyze the spatial relationship between the distribution of villages and the river system (as shown in Figure 8). A buffer zone statistical analysis revealed that in the Lingnan Region, 238 traditional villages (33.5% of the total) are located within 1 km of a river; 230 villages (32.3%) are within 1–3 km; 130 villages (18.3%) are within 3–5 km; and 112 villages (15.7%) are more than 5 km away from rivers. The correlation coefficient (Pearson) between river distance and the number of villages within each distance range is -0.843 ($p < 0.01$). Overall, the number of traditional Lingnan villages is inversely proportional to their distance from rivers. This finding corroborates previous studies, affirming that proximity to rivers is one of the primary environmental factors influencing the selection of sites for traditional villages [17,51].

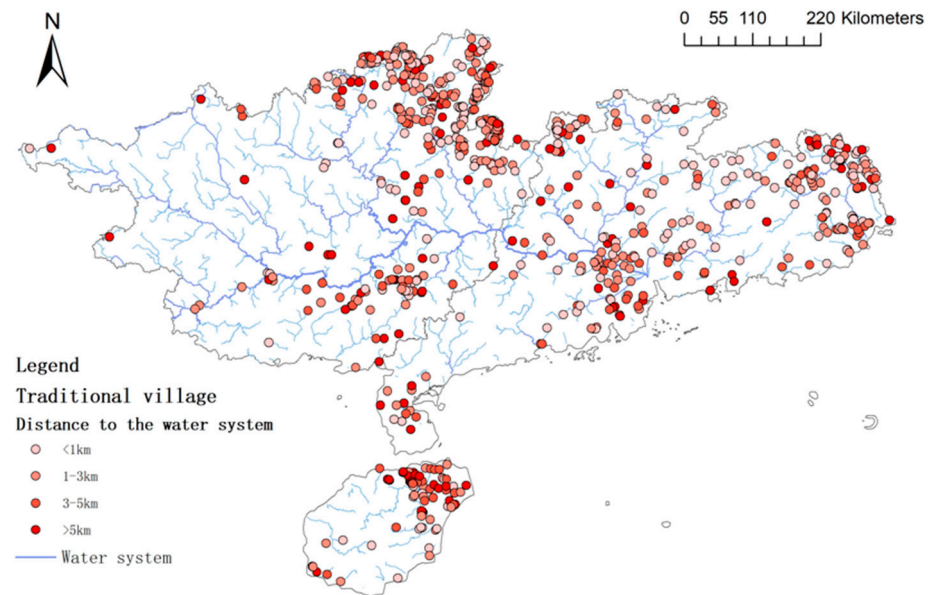


Figure 8. Water systems and distribution of traditional villages in the Lingnan Region.

4.1.4. Temperature and Precipitation

In the selection of village sites, climatic factors must be considered to ensure compatibility with local climate conditions. As shown in Figure 9a, the annual average temperature in the Lingnan Region exhibits a distinct north–south gradient, ranging from 10.53 to 26.89 °C, with villages distributed across all temperature gradients. Notably, 7 villages have an annual average temperature below 15 °C (1% of the total), while 233 are in the 15–20 °C range (32.8%), 446 are in the 20–25 °C range (62.8%), and 24 are in areas above 25 °C (3.4%). Figure 10 shows the distribution of village numbers across different temperature intervals, with most villages concentrated around an average annual temperature of 22–23 °C.

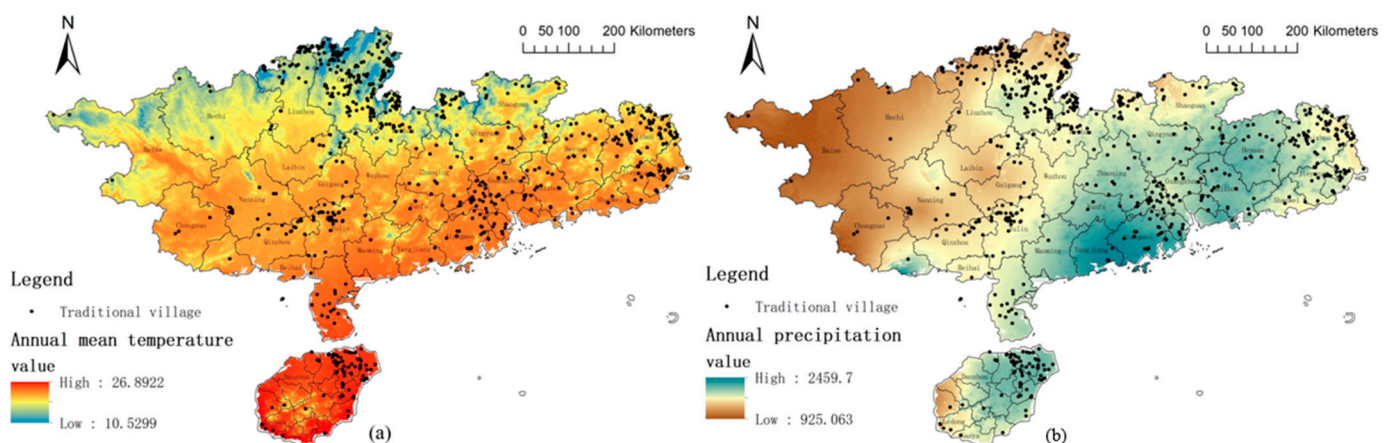


Figure 9. Climate and distribution of traditional villages in Lingnan Region: (a) annual average temperature distribution and (b) annual precipitation distribution.

The annual total precipitation in Lingnan ranges from 925.06 to 2459.7 mm. Figure 9b shows that areas with high precipitation are mainly located in the southern and eastern regions. Notably, 18 villages are located in areas with less than 1250 mm of annual precipitation (2.5%), 205 are located in areas with 1250–1500 mm (28.9%), 371 are located in areas with 1500–1750 mm (52.3%), and 116 are located in areas exceeding 1750 mm (16.3%). Figure 10 shows the distribution of village numbers across precipitation intervals, with most villages concentrated in areas with annual precipitation totaling approximately 1500–1800 mm. Traditional villages are relatively rare in areas with either too little or

excessively high precipitation, tending instead to be distributed in regions with moderate precipitation. This pattern is likely due to the challenges posed by insufficient precipitation, which can lead to water shortages and hinder agricultural production, and excessive precipitation, which increases the risk of natural disasters such as floods, making such areas less suitable for human settlement. Notably, the precipitation data used in this paper are from the year 2022. From the perspective of nearly a hundred years of history, the southeast coastal area has high precipitation, and the precipitation in Guangdong is slightly higher than that in Guangxi [52].

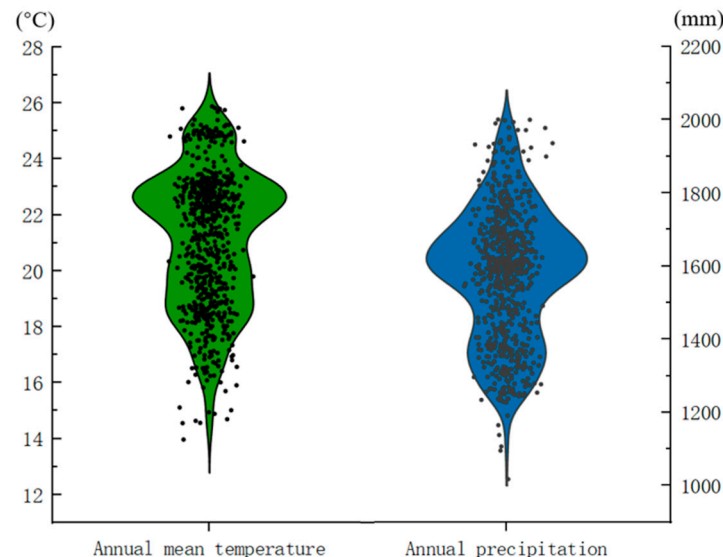


Figure 10. Distribution of the number of villages with respect to temperature and precipitation.

4.2. Social Factors

To explore the correlation between the distribution of traditional villages and socio-economic development, indicators such as population size and GDP for various cities in the Lingnan Region were selected, and a correlation analysis (Spearman's rho) with the number of traditional villages was conducted. The results showed a significant positive correlation between population size and the number of traditional villages in the 54 cities of the Lingnan Region, with a correlation coefficient of $r = 0.569$ ($p < 0.001$), indicating that cities with large populations tend to have more traditional villages than those with small populations. Similarly, GDP displayed a significant positive correlation with the number of traditional villages, with a correlation coefficient of $r = 0.480$ ($p < 0.001$). This suggests that areas with higher levels of economic development today were likely regions of economic prosperity historically. The relationships between economic and population factors and traditional villages are shown in Figure 11.

To explore the connection between the distribution of traditional villages and historical and cultural factors, the number of intangible cultural heritage features in each city in the Lingnan Region was determined. The relationship between intangible cultural heritage and the distribution of traditional villages is shown in Figure 12. A correlation analysis (Spearman's rho) was conducted on these two variables. The results also revealed a significant positive correlation between the number of intangible cultural heritage features and the number of traditional villages in the Lingnan Region, with a correlation coefficient of $r = 0.388$ ($p < 0.01$). This finding indicates that cities with a high number of intangible cultural heritage features tend to have more traditional villages within their boundaries than other cities. This implies that intangible cultural heritage, as a repository of cultural memory and practices, has a potential role in fostering community identity and resilience, which is crucial for the sustainable development of traditional villages.

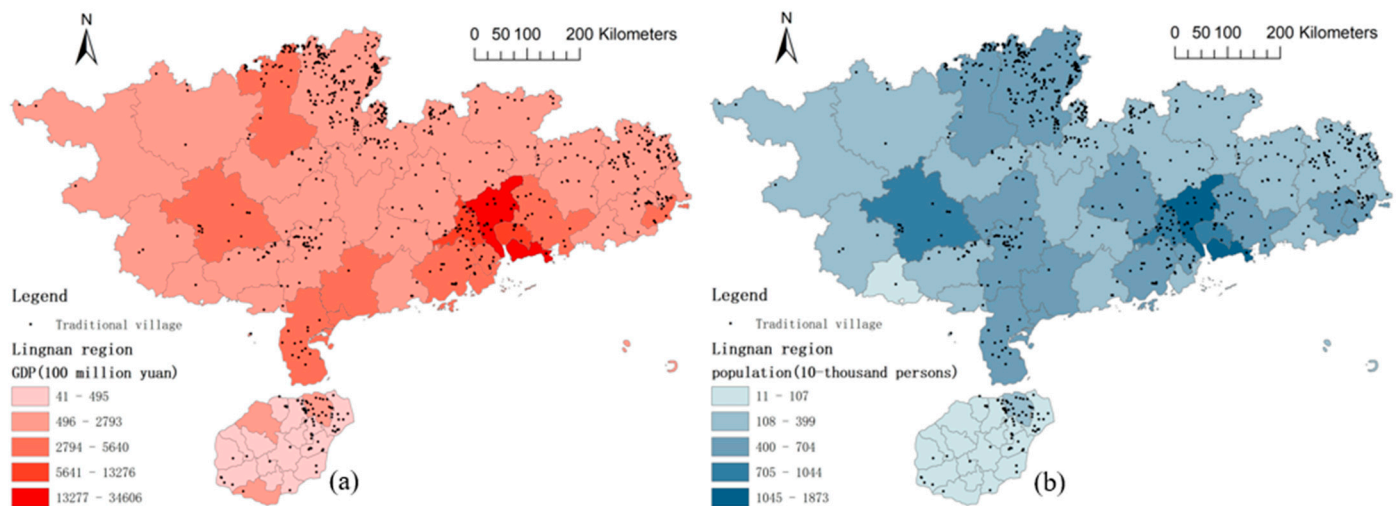


Figure 11. Population and economic analyses: (a) GDP and distribution of traditional villages in Lingnan Region and (b) population and distribution of traditional villages in Lingnan Region.

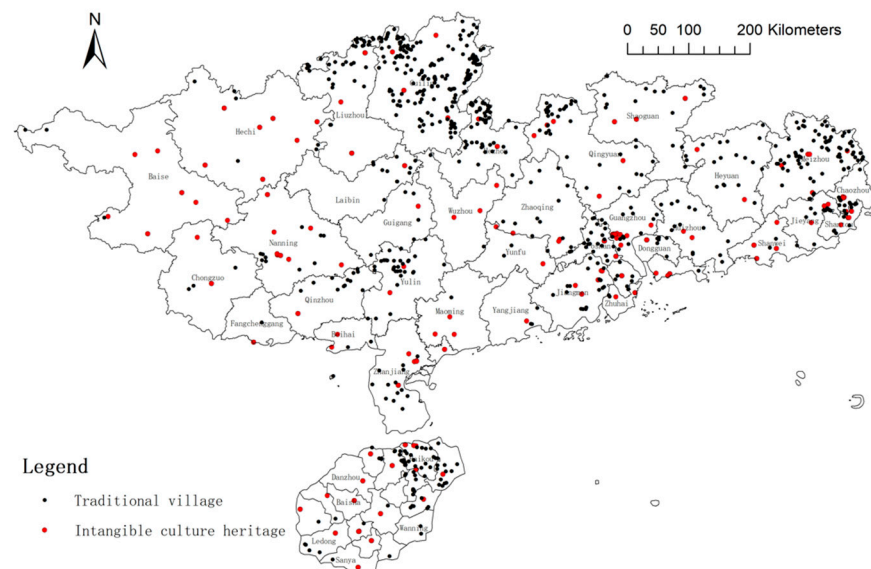


Figure 12. Distribution map of traditional villages and intangible cultural heritage in Lingnan.

4.3. Comprehensive Impact Factor Analysis

The spatial distribution of traditional villages is influenced by various factors, such as topography, climate, regional economic conditions, and population. To quantitatively assess the intensity of each influencing factor, nine key factors were selected for analysis on the basis of previous research findings and data availability. These factors included both natural and socioeconomic elements, such as elevation, slope, slope direction, distance from rivers, population, GDP, intangible cultural heritage, temperature, and precipitation. Using Geodetector, the magnitude of the influence of each factor on the spatial distribution of traditional villages was calculated. In accordance with previous research [53], slope (X8) was reclassified into five levels on the basis of the technical specifications of the third national land survey; population and GDP (X2, X3) were classified into eight levels using the geometric interval method; and the remaining six independent variables (X1, X4–X7, X9) were classified into eight levels using the natural breaks method.

4.3.1. Single-Factor Detection

The spatial factors related to the distribution of traditional villages in the Lingnan Region were analyzed using the Geodetector factor detection method (Formula (4)). The kernel density value of traditional villages (Y) was selected as the dependent variable, and nine commonly used geographical influencing factors were selected as independent variables [38,53]. The results of the factor detection are shown in Table 1. The q values of the factors are ranked as follows: annual average temperature (X6) > intangible cultural heritage density (X4) > annual precipitation (X5) > river density (X1) > elevation (X9) > population (X2) > GDP (X3) > slope (X8) > slope direction (X7). The p value for slope direction (X7) is 0.277, whereas the p values for the other eight influencing factors are all less than 0.01, indicating that they have a significant effect on the spatial distribution of traditional villages. Overall, annual average temperature (X6), a natural factor, and intangible cultural heritage density (X4), a social factor, display the strongest explanatory power regarding the spatial distribution of traditional villages.

Table 1. Single-factor detection results.

Dependent Variable	Independent Variables	Unit	q Value	p Value
Y—kernel density of traditional villages	X ₁ —river density	km/km ²	0.0156	0.000
	X ₂ —population	Person/km ²	0.0143	0.000
	X ₃ —GDP	CNY 10,000/km ²	0.0088	0.000
	X ₄ —intangible cultural heritage density	/	0.0988	0.000
	X ₅ —annual precipitation	mm	0.0851	0.000
	X ₆ —annual average temperature	°C	0.1446	0.000
	X ₇ —slope direction	°	0.0021	0.277
	X ₈ —slope	°	0.0039	0.004
	X ₉ —elevation	m	0.0151	0.000

4.3.2. Interactions Among Factors

On the basis of single-factor detection, multifactor interaction detection was performed, and a heatmap was created in Origin to reflect the interaction strength of the factors affecting the kernel density distribution of traditional villages (as shown in Figure 13). The results in the figure indicate that the q values of influencing factors increase to varying degrees when interactions with other factors are considered. The effects of two-factor interactions are stronger than the single-factor effects, and the interaction type is mainly nonlinear enhancement. Among these, the interaction between annual precipitation (X5) and intangible cultural heritage density (X4) ($q = 0.323$) has the strongest impact on the spatial distribution of traditional villages, followed by the interaction between annual average temperature (X6) and annual precipitation (X5) ($q = 0.319$). This suggests that the spatial distribution of traditional villages is influenced by the interaction between socioeconomic or cultural and environmental factors. The interaction effects between the factors are stronger than the explanatory power of any single factor. In conclusion, during the formation of traditional villages, factors were not considered independently, and their interactions influenced the spatial distribution of the villages.

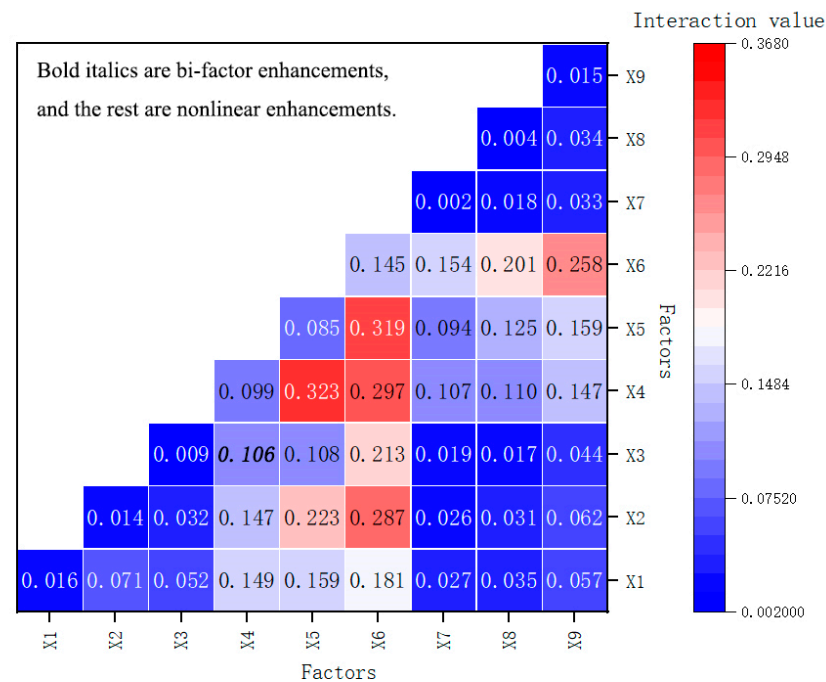


Figure 13. Interaction detection results.

5. Discussion

With respect to the role of socioeconomic and natural environmental factors in the distribution of traditional villages, the corresponding research in Hebei has revealed that these factors both influence the spatial distribution of villages, with socioeconomic factors playing a stronger role [17]. Similarly, a study on the distribution of traditional villages in Henan Province indicated that historical and cultural intensity is the primary factor driving spatial differentiation in that region [53]. However, some studies hold opposing views. For example, the spatial distribution of traditional villages in the Yellow River Basin is influenced by both natural and socioeconomic factors, with natural factors having a greater impact [19]. Similarly, a study on the distribution of traditional villages in Fujian Province indicated that natural geographical conditions play a dominant role, while road traffic conditions and socioeconomic factors have a secondary influence [30]. A study analyzing the spatial distribution of traditional villages across China identified climate-related variables as the most influential factors, with physical geographical factors ranking second in terms of significance [54]. Our research findings are more similar to those of the latter three studies because both environmental and socioeconomic factors have significant impacts on the distribution of traditional villages in the Lingnan Region. Among the environmental factors, temperature has the highest q value, indicating a prominent influence on the distribution of traditional villages. Socioeconomic factors also play a crucial role. Intangible cultural heritage is particularly influential and has the second-highest q value among all factors, following temperature.

In terms of the impact of economic factors on traditional village distribution, a previous study revealed that in the western part of Hunan Province, economically underdeveloped regions tend to preserve many traditional villages. The primary reason for this is that underdeveloped economies lead to slower transportation and infrastructure development, creating favorable conditions for the preservation of traditional villages [29]. Another study revealed a significant negative correlation between the distribution of traditional villages and regional socioeconomic development levels in Fujian Province. Regions with a high concentration of traditional villages generally have lower-than-average levels of disposable farmer income, household savings, urbanization, and regional GDP [30]. The findings of

this study do not align with these earlier findings, likely because in the Lingnan Region—an economically developed area of China—the governments of cities with good economic conditions prioritize policies to maintain traditional villages, positively contributing to their preservation. This finding also corroborates the findings of another previous study, which suggested that in areas where the overall level of economic development has improved, the spillover effect of economic development has promoted the protection of traditional villages [51]. Overall, in areas with high levels of urbanization, the focus of traditional village protection should be on preventing excessive commercialization and destructive construction activities. In contrast, in remote and isolated regions, although the unique cultural landscapes of villages are relatively well preserved, local residents often face poor living conditions. In such cases, the protection of traditional villages should involve the promotion of economic development within villages.

The economic development of Lingnan villages shows a trend of diversification. There is a shift from traditional rice farming to diversified livelihoods. Traditional agriculture remains an important economic pillar; however, modern agriculture, ecological agriculture, and rural tourism are developing rapidly. With the rise of tourism, the land use of many traditional villages has transformed from traditional agricultural practices to multifunctional, tourism-oriented villages that combine living and production [55]. It is noteworthy that the functional transformation of villages driven by a diversified economy may reshape their spatial distribution patterns. The core concentrated areas face ecological overload and cultural homogenization due to the resource siphoning effect, while the peripheral non-intensive areas encounter a protection dilemma due to unbalanced development. Therefore, it is necessary to achieve a dynamic balance between protection and development through systematic strategies such as industrial upgrading, infrastructure optimization, and ecological constraints.

Based on a comprehensive analysis of the spatial distribution characteristics and influencing factors of traditional villages, the following scientific suggestions for sustainable development are proposed.

(1) Strengthen regional coordinated development to promote a balanced distribution of traditional villages across different regions. The results of this paper show that the distribution of traditional villages in the Lingnan Region is relatively concentrated, with one high-density cluster and four secondary high-density clusters. Traditional villages are more likely to be discovered and protected in areas with convenient transportation and relatively developed economies, while in remote areas with inconvenient transportation, the ability to discover and protect traditional villages is weaker. To address this issue, the government should play a major role in promoting balanced and coordinated development and should implement differentiated protection according to different density distributions.

(2) Adopt targeted protection measures for traditional villages according to contemporary developments and the uniqueness of their cultures. Different ethnic groups have formed in the Lingnan Region throughout the process of historical development. During the long-term process of adapting to the environment, they have formed their own settlement areas. Therefore, it is necessary to implement measures that reflect the unique cultures of different regions. For example, in the Hakka cultural area, such as in Meizhou, given the large mountain village slopes and significant population outflow, compensation policies should be developed to give special subsidies to the left-behind inheritors of intangible cultural heritage (such as Hakka folk songs and Hakka enclosure construction techniques). In addition, most villages with traditional ethnic characteristics are located in areas with inconvenient transportation and relatively low development. Because of the strong correlation between intangible cultural heritage factors and the distribution of villages, it is necessary to create a living transmission corridor for intangible cultural heritage, integrate

intangible cultural heritage performances into the village landscape, and foster a positive interaction between the protection of traditional villages and industrial revitalization.

(3) Utilize natural scenery and traditional village resources to develop eco-tourism. Guilin, as the city with the highest density of traditional village distribution in the Lingnan Region, provides unique conditions for the protection and development of traditional villages, with its unique karst landforms and rich cultural heritage. The international literature indicates that heritage protection, rural development, and traditional preservation emphasize the harmonious coexistence of culture and environment. The development of high-quality eco-tourism promotes the development of the regional economy and improves the living standards of villagers. At the same time, during the development process, the destruction of natural and cultural heritage due to excessive commercialization should be avoided to ensure the long-term preservation of the natural and cultural value of traditional villages.

Given the author's scope of knowledge and the availability of resources, the primary limitation of this study was that the majority of information regarding villages and residential buildings was sourced from the relevant literature, books, online resources, and historical data. This reliance may have resulted in computational inaccuracies. Additionally, the precipitation data and other data used in this paper are from the year 2022. The relationship between historical changes in precipitation and the emergence and location of villages will be analyzed in future research. Future studies can also compare data on village populations and economic development to determine the possibility of consolidation for more efficient use of territory. Due to limitations in data collection, the analysis of the non-material cultural aspects of the villages in this study is relatively insufficient, as we were unable to examine the impact of intangible cultural heritage on traditional villages through direct interviews or surveys with local residents. In future research, it is necessary to study the influence of human activities, as well as historical and cultural evolution, on traditional villages through methods such as interviews and to assess the spatial distribution patterns of different types and attributes of traditional villages. Additionally, future research should emphasize the application of digital preservation and management methods, such as the use of virtual reality (VR) and augmented reality (AR) technologies, to protect and archive traditional villages. By digitally recording and disseminating traditional customs, festivals, and oral traditions, these technologies aid in the documentation and preservation of the tangible and intangible cultural heritage of traditional villages and provide an interactive platform for education and cultural dissemination.

6. Conclusions

In this study, 710 traditional villages in the Lingnan Region were selected as research subjects to comprehensively analyze the spatial distribution characteristics and factors influencing nationally recognized traditional villages. The main conclusions are as follows:

(1) The distribution of traditional villages in the Lingnan Region is relatively concentrated, and these villages are primarily located in a few cities, such as Guilin and Meizhou. The spatial distribution exhibits significant clustering, with marked differences in the number of villages across regions and an uneven spatial distribution characterized by one high-density cluster and four secondary high-density clusters.

(2) Elevation, slope, and distance to river systems are critical natural factors that were considered in the selection of sites for traditional villages. These factors are all significantly negatively correlated with the number of villages, with correlation coefficients ranging from -0.600 to -0.843 ($p < 0.01$). As elevation increases, the number of traditional villages gradually decreases. In terms of slope, 69.4% of traditional villages are located on slopes of less than 6° . In terms of the river system, 84.2% of traditional villages are

within 5 km of a river. Additionally, many villages are concentrated in areas with average annual temperatures ranging from 22 to 23 °C and annual precipitation ranging from 1500 to 1800 mm.

(3) Socioeconomic conditions influence the distribution of traditional villages. In the Lingnan Region, areas with high overall levels of economic development tend to have more traditional villages than other areas. Population size, economic level (GDP), and the number of intangible cultural heritage features are significantly positively correlated with the number of traditional villages. This shows the significance of socioeconomic factors in the preservation of traditional villages.

(4) The distribution of traditional villages in the Lingnan Region is influenced by both natural and social factors. Among these factors, temperature and intangible cultural heritage have the strongest explanatory power regarding the spatial distribution of traditional villages. Moreover, the combined influence of each factor with the other factors is greater than the influence of each factor alone.

In summary, with the support of favorable economic conditions and policies, the preservation and continuation of traditional villages can be effectively promoted, which will foster the dissemination of local cultural diversity. The government should increase financial investment in the protection of traditional villages, especially in economically underdeveloped regions, to reduce disparities in regional development. By revitalizing and utilizing intangible cultural heritage, the attractiveness and economic value of traditional villages can be enhanced to achieve a positive interaction between cultural preservation and economic development. At the same time, through policy guidance, unified planning, and increased investment in infrastructure, the cultural vitality of traditional villages can be maximized while achieving organic integration with regional economic development. This study reveals the spatial distribution patterns of traditional villages and explores their specific influencing mechanisms. These research results can contribute positively to the formulation of more effective protection policies and strategies, enrich macro-level research on traditional villages in the Lingnan Region, and provide new perspectives and methods for the conservation and sustainable utilization of villages in other regions of the world.

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