# RESEARCH





# Temporal and spatial patterns of traditional village distribution evolution in Xiangxi, China: identifying multidimensional influential factors and conservation significance

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# Abstract

This study systematically investigates the spatio-temporal distribution, influential factors, and conservation significance of 413 traditional villages in Xiangxi, China. Employing methods such as ArcGIS spatial analysis, geographic statistical analysis, and historical literature review, this work meticulously delineates the intricate interplay of natural, societal, and cultural elements in shaping the evolution of village distributions. As pillars of China's rich traditional culture, these villages encapsulate profound historical, folkloric, and architectural values. Their spatial and temporal transformations are instrumental in unraveling Xiangxi's historical and cultural tapestry, thereby informing strategic conservation efforts. The research findings are as follows: (1) from a spatial perspective, traditional villages in Xiangxi, China, exhibit an overall clustering tendency, characterized by a distribution pattern of "more in the core, fewer on the periphery, with small clusters and significant dispersion." These villages are distributed in multiple bands along ancient postal routes, the Wuling Mountains, the Xuefeng Mountains, and river basins. (2) Traditional villages in Xiangxi primarily originated prior to the Yuan Dynasty, with a predominant north-south spatial orientation. Over successive dynasties, the distribution center gradually shifted northeastward, resulting in an expansion of the spatial distribution range and a decrease in directional bias. (3) The formation and distribution evolution of traditional villages are influenced by a combination of natural factors, socio-economic factors, and historical-cultural factors. Natural factors and cultural elements influence the selection and layout of traditional village sites, while socio-economic and historical-cultural factors impact their development and evolution. In conclusion, the distribution evolution of traditional villages in Xiangxi, China, underscores the intricate interplay of diverse factors, spanning the realms of nature, society, and culture. Recognizing this complexity is essential in comprehending the historical and cultural tapestry of Xiangxi and in formulating strategies for the preservation of these invaluable cultural and historical assets. The preservation of traditional villages transcends mere heritage conservation; it represents a pivotal step towards safeguarding the multifaceted heritage of Xiangxi.

Keywords Traditional villages, Spatial distribution, Historical evolution, Influencing factors, Heritage preservation, Xiangxi, China

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# Introduction

Over the past 5 years, there has been an increasing focus on traditional villages in China that hold historical and cultural significance [1]. These villages represent the living essence of China's cultural foundations and serve as a conduit between the Huaxia civilization's storied past and dynamic present. However, rapid urbanization poses a severe threat to their survival, with numerous villages diminishing or facing extinction [2]. Recognizing this, the era of ecological consciousness and rural revitalization strategies has spurred government actions to protect and rejuvenate these villages as cornerstones of rural culture [3, 4]. The concept of traditional villages gained official recognition with the first national list in late 2012, a move that underscored a policy shift toward their active preservation and legal status. By the close of 2019, a total of five lists had been compiled, officially identifying 6819 villages as national traditional villages [5, 6].

In the 1920s, initial research on traditional village settlements emerged in the Western field of geography, with focused investigation beginning after the 1940s [7]. Kohl, a German geologist, systematically studied these settlements, covering aspects like geography, morphology, rural landscapes, and the evolution of traditional villages [8]. In China, research on traditional villages only began in the 1990s, influenced by various historical, economic, and cultural factors. Notable contributions include Liu Peilin's "The Image of Traditional Villages in China," which encompassed comprehensive studies ranging from site selection intentions to property rights analysis in village development [9]. Recent research on traditional villages is diverse. Firstly, in terms of spatial distribution, the research focuses on an in-depth exploration of the spatial characteristics, differentiation, and influencing factors of the villages [10-14]. Secondly, in the field of protection and development, the research covers the challenges faced, dilemmas, and their solutions, including the construction of related evaluation systems [15–17]. Additionally, in the study of the human living environment, scholars have analyzed the evolutionary process of the environment and explored how to achieve the revitalization and transformation of the impacted village environment [18–20]. There are also studies that have comprehensively examined the villages from multiple perspectives such as culture, ecology, and climate, and introduced innovative theoretical methods, such as the DFRI base theory and gene landscape [21, 22]. However, current research predominantly focuses on analyzing traditional villages either from a spatial dimension or from the perspective of individual villages. There remains a significant dearth of studies which investigate the historical characteristics of traditional villages at a temporal scale, thus failing to comprehensively elucidate the spatiotemporal patterns of traditional village distribution and the underlying, multifaceted influencing factors [23, 24]. Previous research has tended to isolate the factors influencing traditional village layouts, with limited exploration of the interrelationships between these factors. Recognizing this gap, our study aims to address the following scientific issues: what are the historical characteristics and spatiotemporal patterns of traditional village distribution in Xiangxi, China? How do various multidimensional factors influence these patterns? By addressing these questions, this research seeks to offer a more comprehensive understanding of the evolution of traditional villages, integrating historical, spatial, and socio-cultural perspectives to uncover the intricate interplay of factors shaping their development.

The traditional villages in Xiangxi, China, boast a rich and ancient history, spanning from the Shangzhou period to the Ming and Qing dynasties, characterized by profound historical and cultural heritage [25]. The most common ethnic minorities in Xiangxi are the Tujia, Miao, and Dong ethnic groups, whose traditional dwellings manifest distinct ethnic styles and local cultural traits, visually reflecting the diversity of minority cultures and the multitude of traditional villages [26]. With 413 villages recognized at the national or provincial level, Xiangxi stands as a prominent guardian of traditional villages in China. However, the region has faced challenges in preserving these historical sites amidst broader socioeconomic transformation [27]. Therefore, this study employs quantitative geographical methods and GIS spatial analysis techniques to analyze the spatiotemporal patterns of traditional village distribution evolution in the Xiangxi region. It aims to explore their distribution characteristics and investigate the multidimensional factors influencing their distribution. The objective is to promote the preservation and evolution of traditional villages in Xiangxi while simultaneously tracing their origins from a historical and cultural perspective [28]. This research holds significant practical significance for the inheritance and conservation of the historical and cultural heritage in the Xiangxi region of China [29].

# **Materials and methods**

#### Study area

The term "Xiangxi" refers to the western region of Hunan Province, encompassing Zhangjiajie, Huaihua, Xiangxi Tujia and Miao Autonomous Prefecture, and Shaoyang (Fig. 1). Geographically positioned between longitudes 109° 10′ E to 112° 15′ E and latitudes 25° 44′ N to 29° 47′ N, it adjoins the Yunnan-Guizhou Plateau to the west and the Dongting Lake Plain to the east [30]. The region is traversed by the Wuling and Xuefeng Mountains, extending from the southwest to the northeast, which imparts



Fig. 1 Location of the study area

a predominantly mountainous landscape. The Yuan and Li Rivers course through from southwest to northeast, shaping a topography of 'two rivers cradled by two mountains.' Xiangxi's terrain is intricate, with elevated areas in the east, south, and northwest, and lower central terrain. Interspersed between the mountains are mid-low elevations and rolling hills, with a complex network of streams and rivers, creating a distinctive enclosed topography of nested basins and enveloped hills. Traditional villages nestled within this varied topography showcase adaptive and diverse layouts, reflecting a coexistence of human settlements with the natural environment [31]. Positioned in a low-latitude belt, Xiangxi experiences a humid subtropical monsoon climate with plentiful summer rainfall and warm, moist conditions, contrasting with the less precipitous, cold, and dry winters [32]. In terms of socio-economic aspects, the local economy of the villages primarily relies on agriculture, particularly crop cultivation and animal husbandry. Over time, some villages have begun to explore diversified economic models based on tourism and cultural industries to adapt to socio-economic changes and developments [33]. Xiangxi boasts a rich history and serves as a confluence of various ethnic cultures, as reflected in architectural styles, lifestyles, and traditional festivals. Its traditional villages, characterized by a rich cultural heritage, have become a popular area for tourism development. Thanks to its profound cultural depth and diverse ethnic features, the region has been designated as China's tourism priority area for two consecutive years, with the slogan "Charming Xiangxi," highlighting the enchanting allure of Xiangxi [34].

#### Data source and processing

This study focuses on 413 traditional villages in Hunan Xiangxi, listed by the Ministry of Housing and Urban-Rural Development, the Ministry of Culture, the State Administration of Cultural Heritage, and the Ministry of Finance across five batches. We collected detailed information on their locations, layouts, site conditions, and river systems through field surveys and drone-assisted aerial photography [35]. In ArcGIS 10.7, we performed map vectorization, establishing a spatial attribute database and generating a geographic distribution map of these villages (Fig. 2). The municipal boundary vector of Xiangxi was obtained from China's Basic Geographic Information Database [36] and elevation data from the Chinese Academy of Sciences' Resource and Environment Science Data Center (https://www.resdc.cn/). River data were sourced



Fig. 2 Spatial distribution of traditional villages in western Hunan, China

from the National Earth System Science Data Center (https://www.geodata.cn/) [37] while socioeconomic data for the region were derived from the "Hunan Statistical Yearbook 2021 [38]."

# **Research methodology**

To categorize the spatial distribution of Xiangxi's traditional villages, we applied ArcGIS 10.7's spatial analysis tools, including the nearest neighbor index, geographic concentration index, imbalance index, and standard deviation ellipse, supplemented by a review of historical literature. We then analyzed the villages' spatial distribution characteristics using kernel density and both global and local spatial autocorrelation analyses. To explore the spatiotemporal evolution and identify the complex factors critical for preservation, we utilized linear distance, buffer, reclassification, and overlay analyses, as depicted in Fig. 3 [39].

# Nearest Neighbor Index

The Nearest Neighbor Index (NNI) serves as an essential tool for analyzing spatial patterns, indicating whether points are clustered, randomly dispersed, or uniformly distributed. It compares the observed mean distance to the nearest neighbor with the expected mean distance in a random distribution, quantifying the degree of spatial clustering. The specific formula for NNI is as follows [40]:

$$E = \frac{\overline{r_1}}{\overline{r_E}} = \sqrt[2]{D} \tag{1}$$

In this equation: E represents the Nearest Neighbor Index (NNI);  $r_1$  signifies the actual average nearest neighbor distance between features;  $r_E$  stands for the

theoretical average nearest neighbor distance between features; *D* denotes point density. When E = 1, it indicates a random spatial distribution of point features. When E > 1, point features tend towards a uniform distribution. Conversely, when E < 1, point features exhibit a clustered distribution pattern.

#### Geographic Concentration Index

The Geographic Concentration Index (*G*) is employed to measure the degree of concentration of traditional villages within a specific geographic area. The calculation formula for *G* is as follows [41, 42]:

$$G = 100 \cdot \sqrt{\sum_{i=1}^{n} \left(\frac{P_i}{Q}\right)^2} \tag{2}$$

In this equation: G represents the Geographic Concentration Index; n is the number of counties or districts in the Xiangxi region;  $P_i$  represents the number of traditional villages in the i th county or district; Q is the total number of traditional villages in Xiangxi. The Geographic Concentration Index (G) falls within the range of 0 to 100. A higher G value indicates a greater concentration of traditional



Fig. 3 Research flow chart

villages in a particular region, while a lower G value suggests a more evenly dispersed distribution of traditional villages.

#### The Imbalance Index

The degree of concentration or dispersion of traditional villages across different regions within a geographic area can be assessed using the Unevenness Index. The specific calculation formula for the Unevenness Index is as follows [43]:

$$S = \frac{\sum_{i=1}^{n} M_i - 50(n+1)}{100 \cdot n - 50(n+1)}$$
(3)

In this equation: n is the number of counties or districts in the Xiangxi region; S represents the Imbalance Index, with values ranging from 0 to 1; As S approaches 0, it indicates a more even distribution of traditional villages across different counties or districts, while a higher S value signifies a more uneven distribution;  $M_i$  stands for the cumulative percentage of the total number of traditional villages accounted for by the number of traditional villages in the ith county or district when counties or districts are sorted in descending order based on their proportion of traditional villages to the total.

# Standard Deviational Ellipse

The Standard Deviational Ellipse (SDE) is a spatial statistical tool that quantifies the spatial attributes of geographic entities, shedding light on their distribution's directionality, centroid, and spread [44]. This method's primary parameters are the ellipse's center, the orientation angle, and the lengths of the major and minor axes. The major axis delineates the primary direction of distribution, while the minor axis measures data spread. The flattening ratio, or the major to minor axis ratio, gauges the distribution's directionality. A higher ratio signifies a pronounced directional distribution, and a lower ratio, nearing a circle, indicates less directionality with broader dispersion. The specific calculation formula for the Standard Deviational Ellipse is as follows [44]:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^n \left(w_i \widetilde{x}_i \sin\theta - w_i \widetilde{y}_i \cos\theta\right)^2}{\sum_{i=1}^n w_i^2}}$$
(6)

In this equation:  $\theta$  is the rotation angle, and  $\sigma_x$  and  $\sigma_y$  are the standard deviations along the x-axis and y-axis, respectively. In this study, we employed the Standard Deviational Ellipse analysis method within the ArcGIS platform to investigate the evolution of the distribution centroid and dispersion trend in the spatial pattern of traditional villages in Xiangxi, China.

# **Research results**

# Spatial distribution characteristics Spatial distribution categories

The spatial distribution of traditional villages in the Xiangxi region of Hunan is primarily of a clustered type. This assertion is substantiated by an Nearest Neighbor Index (NNI) analysis using ArcGIS 10.7, which reveals a mean actual nearest neighbor distance ( $r_1$ ) of 6.459 km, contrasted with an expected distance ( $r_E$ ) of 7.555 km, yielding an NNI ratio (R) of 0.855. The negative Z-score of -5.638 and a P-value approaching zero signify a statistically significant clustered pattern among the 413 traditional villages studied.

Further analytical rigor is applied through the coefficient of variation (CV) and the Geographic Concentration Index (GCI). The CV is calculated at 147.24%, significantly higher than the 64% benchmark, which suggests a deviation from a uniform spatial distribution. The GCI is determined to be 22.27, surpassing the theoretical index ( $G_0$ ) of 17.53, expected if the 413 villages were evenly dispersed. This GCI further corroborates the clustered nature of the village distribution within the region.

#### Spatial distribution equilibrium

The Unevenness Index can be utilized to reflect the degree of balance among traditional villages in different regions of Xiangxi. Given the various differences in natural, cultural, and social factors between counties

$$\tan \theta = \frac{\left(\sum_{i=1}^{n} w_i^2 \tilde{x}_i^2 - \sum_{i=1}^{n} w_i^2 \tilde{y}_i^2\right) + \sqrt{\left(\sum_{i=1}^{n} w_i^2 \tilde{x}_i^2 - \sum_{i=1}^{n} w_i^2 \tilde{y}_i^2\right)^2 + 4\sum_{i=1}^{n} w_i^2 \tilde{x}_i^2 \tilde{y}_i^2}}{2\sum_{i=1}^{n} w_i^2 \tilde{x}_i \tilde{y}_i^2}$$
(4)

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n} (w_i \tilde{x}_i \cos\theta - w_i \tilde{y}_i \sin\theta)^2}{\sum_{i=1}^{n} w_i^2}}$$
(5)

and municipal districts, the number of traditional villages varies among these administrative levels. Evaluating the balance of traditional village distribution in the Xiangxi region yields an Imbalance Index of S = 0.432 > 0,



Fig. 4 Lorenz curve of the spatial distribution of traditional villages in western Hunan, China

indicating an imbalanced distribution of traditional villages in Xiangxi. The Lorenz curve for urban traditional villages (Fig. 4) demonstrates that most of Xiangxi's traditional villages are situated in regions like Huayuan County, Tongdao Dong Autonomous County, Yongding District, Baojing County, Hongjiang City, Xupu County, Yuanling County, and Jishou City. The number of traditional villages in these areas approaches 50% of the entire Xiangxi region and nearly 30% of the entire province.

Visualizing the distribution of traditional villages in Hunan's Xiangxi region with ArcGIS 10.7 confirms the imbalanced spatial distribution (Fig. 5). Among these, the most concentrated cities are Xiangxi Tujia and Miao Autonomous Prefecture, and Huaihua City, while areas with sparser distribution are Zhangjiajie City and Huaihua City.

#### Spatial distribution density

This study employed the Kernel Density Analysis tool in ArcGIS 10.7 software to analyze the kernel of the 413 traditional villages in Hunan's Xiangxi region, resulting in the identification of the kernel density distribution pattern of traditional villages in Xiangxi (Fig. 6) [45, 46]. As depicted in Fig. 6, the spatial distribution of traditional villages in the Xiangxi region exhibits three high-density areas, namely the central and northwestern regions of Xiangxi Autonomous Prefecture; the southeastern part of Yongding District in Zhangjiajie City; and the confluence of the Yuan River Basin, where Huaihua City intersects with Shaoyang City. In the central and northwestern parts of Xiangxi Autonomous Prefecture, intricate waterways meander through the area, flanked by floodplains on both sides. As one gets closer to the river, the number of traditional villages increases proportionally, with the quantity correlating positively with the distance from the river. The general spatial distribution characteristics entail "more in the core, fewer on the periphery, smaller clusters, and larger dispersions."

### Temporal and spatial evolution characteristics

Our study traces the evolution of traditional villages in Xiangxi through three historical stages: before the Yuan Dynasty, during the Ming, and throughout the Qing Dynasty. Out of 405 villages with historical records, 28 originated before the Yuan, 103 during the Ming, and 274 in the Qing or later.

The spatial distribution analysis, using the standard deviation ellipse (SDE), shows clear patterns (Fig. 7). The pre-Yuan villages were closely clustered, as indicated by a smaller SDE and a higher axis ratio. The Ming period experienced a spatial expansion of villages, with a larger SDE and a lower axis ratio, suggesting a broader, less focused spread. This dispersal continued into the Qing, with a slight contraction in the SDE and a minor increase in the axis ratio. The centroid of the villages shifted northeastward over time, moving from Hongjiang City to Maoyang Miao Autonomous County from pre-Yuan to Ming, and further northeast in the Qing. The major axis of the SDE consistently aligned with the north–south orientation of the region's topography, influenced by the Wuling and Xuefeng Mountains and the Yuanjiang and

Page 8 of 19



Fig. 5 Spatial distribution of the density of traditional villages in western Hunan, China

Lishui River Basins. This terrain, with its varied landscape, fostered agricultural development and village establishment [47, 48].

Figure 8 illustrates the changing density of traditional villages in Xiangxi across various eras. Pre-Yuan, villages were sparse, mainly in western Xiangxi and southern Huaihua, with notable clusters in Tongdao Dong Autonomous County. During the Ming, there was an increase, especially in the Wuling Mountains and near the Yuan River Basin, with Huayuan County



Fig. 6 Kernel density of traditional village distribution in western Hunan, China

becoming a prominent cluster center. Post-Qing, the peak in village numbers was reached, spreading in a north-south orientation, often adjacent to mountains and rivers, and showing a dispersed yet core-periphery pattern. Since the Qin and Han dynasties, Xiangxi has been under the nominal control of central authorities, yet its peripheral position made governance difficult. Before the Spring and Autumn period, the area was a mosaic of ethnic minorities, largely unknown to the central plains



Fig. 7 The overall evolution of spatial patterns in traditional villages in Xiangxi, China

[49]. The Chu State's incorporation of Xiangxi during this period marked the beginning of its integration into the administrative domain, with the Yuan and Lishui River basins becoming pivotal for migration and military strategy. Settlements flourished along these waterways, laying the groundwork for the region's early village development [50]. In the early years of the Yuan Dynasty, chieftain rebellions were incessant. Over the span of twenty-two years, from 1370 to 1392, rebellions erupted almost annually. The central government adopted a bifurcated policy of reward and punishment towards the chieftains. Those who rebelled were suppressed by military force, while those who surrendered were rewarded. Following the establishment of the chieftain system during the Ming Dynasty, the chieftains governed autonomously, and rebellions against the central rulers continued to occur, posing a threat to the Central Plains region. This compelled the central government to establish military outposts, particularly in the Lishui River basin, to consolidate control and alleviate ethnic tensions [51]. These military garrisons encouraged the emergence of unique village styles within self-sufficient economic zones,



Fig. 8 Spatial distribution density of traditional villages in Xiangxi region at different time periods

shaped by the challenges of the landscape and transportation. The Qing Dynasty faced the legacy of these systems, with the chieftain system particularly stifling social advancement, leading to significant Miao uprisings. The Qing's response to these uprisings underscored the necessity for a reinforced central influence in Xiangxi [52]. The military's strategic pivot to the Miao-dominated Lashan plateau influenced the east-northeastward shift of the village centroids. The Qing's military investments not only solidified control but also spurred Han migration, prompting the growth and centralization of traditional villages [53]. The military system's evolution and the consequent social reorganization profoundly impacted village distribution and structure, shaping Xiangxi's historical village landscape.

# Factors influencing spatial distribution *Natural factors*

(1) Topography and Landforms: The study integrated spatial data of traditional villages with topographical maps using ArcGIS 10.7, revealing the elevation-based distribution of these settlements in Xiangxi, Hunan (Fig. 9). The analysis categorized the villages into three elevation zones (Table 1), showing that 129 villages are located above 500 m, while the majority, 284 villages (68.7% of the total), are situated below 500 m, indicating a concentration in lower elevation areas.

While the lowlands and basins of the plains are relatively flat and abundant in agricultural land resources, the environment becomes increasingly challenging at higher elevations. Consequently, the number of traditional villages decreases with ascending altitudes. The levels of sunlight and precipitation in high-altitude mountainous areas often fail to meet the basic requirements for villagers' livelihoods. Thus, in a social structure predominantly reliant on agriculture and animal husbandry, hilly terrain and gently sloping lowland plains are more suitable for human habitation and settlement, as compared to high-altitude mountainous areas.

(2) River Water Systems: Water is a fundamental element for all life forms and inorganic processes, and it is indispensable to human existence and agriculture. Rivers, in particular, play a crucial role in shaping the settlement patterns of villages [54]. The Xiangxi region's riverine network, primarily comprising the Yuan River, Xishui, and Wushui, forms an elaborate fluvial system. Utilizing ArcGIS 10.7, we mapped the distribution of these rivers (Fig. 9), revealing the Yuan River's origin in Guizhou Province, its 1033-km journey, and its expansive 89,000 square kilometer basin. Analysis of the spatial relationship between traditional villages and river systems, using current hydrological data, allowed us to quantify the proximity of villages to these water bodies.

Proximity analysis (Table 2) revealed a significant clustering of traditional villages within 250 m of rivers, with 54.24% of villages situated in such close range, highlighting the rivers' pivotal role in village locations. Conversely, only 56 villages are located beyond 2000 m from rivers, reflecting the challenges of water scarcity on settlement patterns and agricultural development.

# Social factors

(1) Development of Transportation Infrastructure: Utilizing the buffer analysis functionality in ArcGIS 10.7 software, based on vector data including provincial roads, national highways, expressways, and railways in Hunan Province as of 2021, we divided and assigned buffer distance weights to different levels of roads. This



Fig. 9 Geographical spatial distribution and hydrological features of traditional villages in Xiangxi, China at different elevations

allowed us to calculate the transportation accessibility of each traditional village and classify them (Table 3). The analysis indicates a bell-curve trend in the distribution of traditional villages against transportation accessibility: an initial increase in village numbers with improved access, followed by a decline. Historically, many traditional villages were pivotal as relay stations and hubs for military and trade routes, often becoming economically and culturally vibrant. These villages typically aligned along ancient postal routes, leading to linear patterns

| Table 1 | Statistics of | geographic | types in west | ern Hunan |
|---------|---------------|------------|---------------|-----------|
|---------|---------------|------------|---------------|-----------|

| Landform features  | Number of traditional villages/pc | Percentage (%) |
|--|-----------------------------------|----------------|
|  | 29                                | 7.02           |
| Elevation 200–500 m, flat terrain, the wide range          | 255                               | 61.74          |
| Elevation > 500 m, mountainous terrain, gentle undulations | 129                               | 31.23          |

 Table 2
 River distance statistics in western Hunan

| Distance from river/m | Number of<br>settlements/pc | Proportion/% |
|-----------------------|-----------------------------|--------------|
| ≤250                  | 224                         | 54.24        |
| 250–1000              | 54                          | 13.08        |
| 1000-1500             | 45                          | 10.90        |
| 1500-2000             | 34                          | 8.23         |
| ≥2000                 | 56                          | 13.56        |

of development. Presently, there is a notable overlap between modern transport routes and historical paths from the Qin through Qing dynasties (Fig. 10), suggesting a slight increase in village numbers with better accessibility. However, the majority of villages (62.96%) have low accessibility scores (below 0.5), indicating their distance from major transport arteries. Villages in areas with sparse road networks and limited transport options remain less exposed to external influences, preserving their unique cultural identities and forming ethnic minority enclaves. Paradoxically, the lack of convenient transportation has aided in conserving these traditional villages. The distribution map shows that counties like Longshan, Huayuan, and Fenghuang have limited transport access, with Huayuan, despite its challenging terrain, boasting a high number of well-preserved villages. In contrast, regions with advanced transport infrastructures, such as Hecheng District and Shaodong and Cili Counties, feature fewer traditional villages.

(2) Economic Development Level: Topography and transportation significantly influence economic development. In comparison to Northern Hunan, Southern Hunan, and Eastern Hunan, Xiangxi's development lags behind, with a slower urbanization process. This has led to the preservation of numerous traditional villages [55]. By searching and organizing statistical data from the Hunan Provincial Bureau of Statistics website (http://tjj.hunan.gov.cn/) for the year 2021, a comparison of economic indicators for various counties and cities in Xiangxi was conducted (Fig. 11) [56]. From Fig. 11, it can be inferred that traditional villages are less prevalent in economically developed areas, while a higher distribution is observed in cities with lower development levels. Among these, the GDP rankings of Hecheng District in Huaihua City and Longhui County in Shaoyang City are second and third, respectively. Shaodong County holds the top GDP ranking, primarily due to the initiation of private sector economic reforms in the mid-1990s. The rapid growth of commerce and industry is linked to this development, along with its proximity to Shaoyang City, where it is administratively managed.

### Historical and cultural factors

The Xiangxi region's traditional villages bear the imprint of its multicultural and multi-ethnic heritage, shaped by a confluence of historical and cultural dynamics (Fig. 12). Initially, indigenous peoples and ethnic minorities, such as the Miao, settled in the area, selecting locations based on resource availability and terrain. The expansion of the Chu state and subsequent Central Plains dynasties displaced these groups, prompting migrations to the seclusion of the Wuling Mountains. This period saw heightened interactions and conflicts among ethnicities, culminating in a history of resistance and settlement in the region. The Sui and Tang dynasties to the early Song period introduced the frontier control system, integrating the ethnic minority communities under central governance to some degree, influencing their social structures and cultural practices. The Song dynasty's era marked a significant migration from the north, particularly from

 Table 3
 Accessibility of transportation in traditional villages in Xiangxi, China

| Transport Accessibility Score | 0 <r≤0.2< th=""><th>0.1 &lt; R ≤ 0.3</th><th><math>0.3 &lt; R \le 0.5</math></th><th><math>0.5 &lt; R \le 0.8</math></th><th>0.8<r≤1< th=""></r≤1<></th></r≤0.2<> | 0.1 < R ≤ 0.3           | $0.3 < R \le 0.5$ | $0.5 < R \le 0.8$ | 0.8 <r≤1< th=""></r≤1<> |  |  |
|-------------------------------|---|-------------------------|-------------------|-------------------|-------------------------|--|--|
| Classification levels         | Extremely Inaccessible  | Moderately Inaccessible | Inaccessible      | Accessible        | Extremely Accessible    |  |  |
| Number of villages (Count)    | 70  | 120                     | 70                | 36                | 117                     |  |  |
| Percentage (%)                | 16.95   | 29.06                   | 16.95             | 8.72              | 28.33                   |  |  |



Fig. 10 Distribution map of transportation accessibility in traditional villages of Xiangxi, China

Jiangxi, catalyzing Hunan's economic growth and the proliferation of traditional villages—a movement encapsulated in the phrase "Jiangxi Filling Hunan [57, 58]." During the Yuan to early Qing dynasties, the tusi system granted local leaders administrative autonomy, shaping the governance and growth of traditional villages [59]. This period brought social stability, reflected in the increasing number of settlements. The later Qing dynasty's baojia system further restructured local communities [60], embedding military and civil defense responsibilities within the social fabric, impacting the lifestyle and social organization of traditional villages [61].



Fig. 11 Statistical chart of GDP for various cities and counties in Xiangxi, China in 2021



Fig. 12 Chart of significant historical milestones and multiple intra-provincial migration nodes in Xiangxi, China

In essence, the spatial distribution of Xiangxi's traditional villages is the result of multifaceted historical influences: ethnic diversity, central incursions, migratory patterns, geographic considerations, and political and military strategies have all played roles in creating the region's unique village tapestry.

The formation of traditional villages in Hunan's Xiangxi region can be categorized into four situations [62, 63]. The most common is through immigration, which led to the establishment of villages such as Liaoyuan, Zhai Surname, and Zhushan, where the immigrant population is predominant. The second category is generational residence, exemplified by villages like Longxi, Dayantou, and Sifangxi, which grew organically from the local populace expanding over time. Military strategic considerations form the third category. Villages such as Lao Siyan emerged around military installations like watchtowers during the Ming and Qing Dynasties. Similarly, during the War of Resistance Against Japan, Yangquepo became notable for its strategic use as a command center and its proximity to a medical facility within the Wang Family Ancestral Hall, earning renown as a resistance village. The fourth category is shaped by transportation and commerce. Villages like Changpo thrived as trading hubs due to their strategic locations, facilitating the exchange of commodities such as tung oil and wood in ancient western Hunan. Yankoushan, situated in Jinhe Town, prospered during the water transportation era, with its sailors and wooden ships navigating the Yuan River, connecting Dongting Lake to Hankou, and downstream to the Changde port, catalyzing the local economy through trade in fisheries and agriculture.

#### Discussion

This study has unearthed critical insights into the conservation and sustainable evolution of traditional villages in Xiangxi, China, serving as a cornerstone for future scholarly inquiry and policy-making. The intricate web of factors influencing the distribution of traditional villages in Xiangxi-ranging from geographical and hydrological to socio-economic and historical-cultural-demonstrates the complexity of traditional village development. To address the multifaceted nature of these determinants, future research must adopt a multi-disciplinary approach, integrating quantitative methods with qualitative analyses, such as comparative historical analysis, to understand the nuanced impacts of these factors. This could provide a more holistic understanding of village distribution patterns and the interplay between local history and socio-economic trajectories.

The broad-scale investigation of spatiotemporal patterns in this study sets the stage for more detailed research. Micro-level examinations are crucial to decode the intricate relationship between village settlement patterns, architectural heritage, and economic trajectories. Employing case study methodologies to examine individual villages will reveal the interdependence of architectural conservation and economic vitality. Addressing the dichotomy between economic advancement and historical preservation is another critical area for future research. The quest for economic growth should be harmoniously aligned with cultural conservation efforts, such as community-based tourism models that support both the local economy and heritage preservation. Traditional villages, like those in Xiangxi, could serve as exemplary sites for sustainable development models that combine ecological care with economic innovation.

Xiangxi's traditional villages offer a unique ecological and cultural heritage, providing fertile ground for sustainable development strategies that actively sustain these communities. Villages with abundant water resources could develop aquaculture economies that respect and rejuvenate their natural ecosystems, while the mountainous regions present opportunities for the emerging forest healthcare industry, merging environmental conservation with health tourism. The cultural richness of these villages, influenced by Miao and Yao ethnicities, provides a vibrant foundation for creative industries. Research into leveraging these cultural assets for cultural and educational industries is vital, ensuring their essence remains intact. This study emphasizes the significance of cultural continuity, extending beyond physical preservation to the vibrancy of living traditions. Investments in education and healthcare are crucial for the cultural and economic revival of these communities.

In light of rapid urbanization, this study's insights into the intrinsic value and aesthetic qualities of traditional villages are practically significant for their conservation and sustainable development. The integration of ethnic cultures with natural landscapes and urbanization processes is a fertile ground for research, guiding tourism development, scenic planning, and regional branding strategies. This is particularly important as traditional village areas face urban encroachment, making the protection of regional identities and traditional cultures essential. In conclusion, this study not only sheds light on the current state of traditional villages in Xiangxi but also charts a course for future research and initiatives. It is a clarion call for a concerted effort to preserve the living heritage of these villages while steering them towards a sustainable and prosperous future.

#### Conclusions

This study rigorously investigates the spatiotemporal patterns of 413 traditional villages in Hunan's Xiangxi region, utilizing a methodological framework that combines quantitative geographic analysis, historical literature review, and advanced GIS techniques. Our analysis reveals a complex mosaic of village dispersion, uncovering the intricate patterns and driving factors behind their historical development. The study showed the following:

- (1) Spatial Distribution and Density Patterns: Traditional villages in Hunan's Xiangxi region exhibit an overall clustered pattern, characterized by "more in the core, less on the periphery, and small clusters with significant dispersion." This pattern reflects the influence of geographical suitability and historical settlement practices, particularly evident in the high-density corridors of Huayuan, Longshan, and Tongdao Dong Autonomous Counties. These corridors connect to key regions within the Xiangxi Autonomous Prefecture and adjacent districts, highlighting a historical and geographical determinism in village locations.
- (2) Temporal Evolution and Historical Dynamics: The development of these villages dates back to the pre-Yuan period, evolving through the Ming and Qing dynasties with a northeastward shift in their distribution centers. This movement mirrors sociopolitical changes and environmental responses, with the spatial transition from compact clusters to dispersed settlements narrating a history marked by dynastic evolution, conflict, and migration.
- (3) Multifactorial Influences on Village Distribution: The spatial distribution of Xiangxi's traditional villages is influenced by a complex interplay of topography and hydrology, with settlements typically located near mountains and water sources. Historical pathways and river valleys, especially along the Yuan and You Rivers, have historically facilitated settlement growth. Modern challenges such as transportation development, urbanization, economic pressures, and demographic changes now threaten the integrity of these historical villages.
- (4) Historical and Cultural Legacy: The layout of Xiangxi's villages encapsulates the region's extensive historical and cultural heritage. A diverse ethnic composition, the influence of Central Plains dynasties, migratory movements, and dynastic rule have all shaped the spatial and architectural characteristics of these settlements. Settlement patterns also reflect the strategic and economic significance of the region throughout history, including military and trade developments during the Ming and Qing dynasties.

In summary, Xiangxi's traditional villages serve as dynamic archives, capturing the delicate balance between human activity and environmental limits. They embody a rich cultural heritage, showcasing the region's adaptive responses and historical narratives. These villages merit scholarly interest and proactive preservation to ensure their enduring legacy. This research delineates the physical and cultural contours

# of these settlements, providing a strategic blueprint for their sustained preservation and responsible evolution.

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#### Author contributions

Conceptualization, methodology, software, investigation, writing—original draft, writing—review and editing, JZ (first author). Funding acquisition, supervision, review, project administration, XH. Conceptualization, methodology, investigation, writing—original draft, software, validation, WX. Software, investigation, writing—original draft, JS Software, investigation, YX. Funding acquisition, resources, supervision, review, project administration, BY (corresponding author). All authors have read and agreed to the published version of the manuscript.

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#### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

#### Declarations

#### Ethics approval and consent to participate

Not applicable.

#### **Consent for publication**

All participants included in this study have provided their consent for the publication of the research findings.

#### **Competing interests**

The authors declare that they have no competing interests.

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