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# Spatial distribution characteristics and influencing factors of traditional villages in Fujian Province, China

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As the historical and contemporary values of Chinese traditional villages continue to emerge and the circumstances of the times change, their preservation has a lasting and far-reaching significance in promoting the revitalisation and sustainable development of China's countryside. However, rapid urbanization began after China's reform and opening up, and continuous urban expansion led to the rapid decline or even disappearance of these villages. Previous studies on village protection tend to focus on morphological studies from the perspective of individual units, and rarely discuss the influencing factors of spatial distribution. Therefore, there are certain deficiencies in revealing the distribution rules, which makes it difficult to fully carry out the protection work. The article reconstructs the traditional village system of Fujian Province, whose traditional villages cover both national and provincial historical and cultural villages and national and provincial traditional villages. The spatial distribution characteristics and influencing factors of traditional villages in Fujian Province were studied using 1,606 traditional villages of various levels as research objects. The results of the study show that: (1) the spatial distribution of traditional villages in Fujian Province is cohesive, with significant uneven distribution, and there are three high-density agglomerations and two sub-density agglomerations; (2) The spatial distribution shows a pattern of "large scattering, small concentration, more in mountainous areas and less in coastal areas"; (3) Topography, river systems, transportation and socio-economic conditions combine to influence the spatial distribution of traditional villages in Fujian Province, but the degree of influence varies. Physical and geographical conditions play a leading role in the distribution of traditional villages, and road traffic conditions and socio-economic conditions have a secondary impact on the distribution of traditional villages. There is an obvious agglomeration of traditional villages in the mountainous river areas, while there is a certain degree of negative correlation between road traffic conditions and socio-economic conditions and the number of traditional villages. (4) With the support of good policies and economic conditions, the protection and continuation of traditional villages can be promoted to a certain extent, and it is also conducive to the spread of local multicultural culture. Finally, corresponding policy recommendations are made for the conservation and sustainable development of traditional villages in Fujian Province.

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## Introduction

The protection of traditional villages has become an important task for Chinese countryside revitalization since it is emphasized that "the importance of preserving traditional villages and rural features" at the 2020 Central Rural Work Conference. According to the definition given in a document jointly issued by four national ministries and commissions, including China's Ministry of Housing and Urban-Rural Development, traditional villages are villages that were formed earlier, have richer traditional resources, have certain historical, cultural, scientific, artistic, social and economic values and should be protected because they are rich in traditional culture and are the greatest legacy of China's agrarian civilization (Feng et al. 2017; Hu et al. 2014). The protection of traditional villages is related to the inheritance of history and culture (Katapidi 2021), the development of rural characteristics and the enhancement of rural appearance. At present, China has accumulated certain achievements in traditional village protection, and till 2020, 6,819 traditional villages have been included in the national list, forming the world's largest cluster for the protection of the heritage of agricultural civilization.

However, due to rapid industrialization and urbanization in past decades, traditional villages have been declining or even disappearing (Wang et al. 2021). Thus, how to protect the traditional villages during the process of urban-rural integration is still a research question. Especially when the population dynamic is taking place greatly, it needs to strengthen the research and protection of rural areas to keep their traditional spatial patterns and social-economical characters (Balsa-Barreiro et al. 2021). For solving this problem, planning approaches are usually employed, such as developing spatial protection policies to keep traditional spatial patterns (Ma et al. 2021), economical revitalize policies to attract labors (Ian and Yue 2022), etc. Although researchers and governors paid great efforts on developing protection policies for accelerating village development and in the meantime, keeping its traditional characters, some traditional villages are still facing problems and challenges such as showing a singularization development paths (Daskon 2010) and the fragmentation of historical resources (Zhang et al. 2020). Due to the reasons, to some extent, lack of spatial characteristics and its evolution process of traditional villages on spatial and social-economical aspects would be the key. In this context, it is important to study the spatial characteristics of traditional villages at a macroscopic regional scale and to analyze the developing history and influencing factors on their distribution and evolution (Ma and Tong 2022) of traditional villages. This is also the purpose of present work.

To a certain extent, a comprehensive multifactor analysis would provide a basis for recognizing the effective factors for the conservation and sustainable development of traditional villages in China and provide a basis for further in-depth case studies of traditional villages. Existing literatures in this field mainly covers macroscopic scales such as national (Kang et al. 2016) and provincial (Chen et al. 2023), mesoscopic scales such as city and county (Chen, Li (2016)) and watershed (Liu et al. 2019), and microscopic scales such as township (Zheng et al. 2021) and village (Guo, Zhou (2020)). Although there is a wealth of research on the spatial characteristics of tradition al villages, and many results have been achieved through GIS and geometric methods, there are still some research questions have not been solved. Researches on the spatial characteristics of traditional villages mostly elaborates on the overall layout, but lacks in-depth analysis of layout factors (Li et al. 2016). Meanwhile, there is a problem of regional imbalance in the research results related to traditional villages, especially the spatial distribution patterns and formation mechanisms of traditional villages at the provincial spatial scale are not much explored (Hu et al. 2021), and there is a lack of spatial research results in the economically developed coastal provinces. Once again, domestic research results on the ephemeral and co-occurrence of traditional villages are relatively scattered and lack systematic research (Li et al. 2018). In general, human settlement sites are located in locations with convenient transportation, which also lays the foundation for the development of settlement sites into towns later. However, the location of traditional villages in Fujian Province was originally formed due to the need of the Central Plains people to escape the war in the south, so most of them choose mountain areas, which are also because the traffic in mountain areas is relatively blocked and there are fewer foreign cultural invasions. Researches on traditional villages protection in Fujian Province mainly focused on the types of traditional dwellings, landscape characteristics (Li et al. 2010; Li and Lan, 2016) and the study of individual traditional villages (The Editorial Committee of the Series of Ancient Towns and Villages of Bamin, 2017; Li et al. 2010), and seldom explore the distribution characteristics and regular mechanisms of traditional villages at the regional level.

In addition, some existing literatures explored the spatial distribution of traditional villages in Fujian Province mostly affected by mountains, rivers and shipping (Hu et al. 2021), especially shipping by rivers is recognized as the key influencing factor and also one of the main characters of Fujian's traditional village distribution among China (Zhang and Yu, 2021; Que et al. 2023). Some scholars in the existing literature believe that a relatively large feature of Fujian Province compared with Zhejiang and Guangdong Province (Feng et al. 2017; Wu and Yu, 2021) is that the spatial order of Fujian Province is back to the mountains and facing the sea (Hu et al. 2021). The distributions and development of traditional villages have a great correlation in natural factors of water and shipping. But relevant researches seldom explain the strong and weak sequence of influencing factors quantitatively. Lacking of complete data support across natural and cultural of traditional villages and systematic research on influencing factors make them relatively weak in explain the distribution and characteristics of traditional villages in Fujian province, and thus, supporting government recognize the key factor for making protection policies. It is also supposed to be the contribution of present work.

Based on this, present work takes Fujian Province as the study area, systematically composes the base map of traditional villages in Fujian Province by integrating multiple elements across natural and cultural aspects. From the two dimensions of natural conditions and humanistic conditions, present research selects four indicators, including terrain and landscape factors system, river system, ancient and modern transportation system, and socio-economic system, in order to comprehensively analyze the influencing factors of the spatial distribution of traditional villages in Fujian Province, and systematically study the influence degree of these influencing factors on the spatial distribution of traditional villages. These series of calculation indicators and methods are objective and effective. On the basis of making full use of traditional village data at all levels in Fujian Province, present research rationally uses relevant calculation indicators. Present research is supposed to provide reference and certain guiding suggestions for the follow-up special protection planning of territorial space, and provide ideas for the study of traditional villages at the provincial scale, and provide reference for the rural development of other countries and regions in the world.

The remainder of present research is organized as follows: the overview of the study area, various data sources, research framework and research methodology are introduced in Section Data Sources and Research Methodology. In the section of Spatial distribution characteristics of traditional villages, the spatial distribution characteristics, pattern, density and trend of traditional

villages in Fujian Province are analyzed clearly. In the section of Analysis of Influencing Factors, it analyzes the impact of various influencing factors on the spatial distribution of traditional villages in Fujian Province and the strength of the impact from both natural and human aspects. Finally, in Section Conclusions and recommendations, the research results are discussed, and the targeted protection suggestions are put forward.

## Data sources and research methodology

### Study area overview and data sources

*Study area*. Fujian Province is located on the southeast coast of China, with an irregular trapezoid shape with two parallel sides and concave sides, and is governed by nine districts and cities, with a total area of about 124,000 $hm^2$ (Fig. 1). The unique mountain and sea natural geographical environment and Hakka social culture in Fujian Province have bred a large number of valuable ancient villages, including traditional villages at various levels, famous historical and cultural villages, and traditional villages with high conservation value that have not yet been included in the above list (Fig. 2) (Dai, 2000). At the same time, the total number of national traditional villages in Fujian Province ranks sixth in China, and its quantity and quality occupy a leading position in the country, with outstanding value for conservation research. The most famous traditional village in Fujian Province is the Hakka traditional village in the west of Fujian Province, which was formed when the Han people in the Central Plains fled the war and moved south five times. For safety reasons, the Hakka people choose to live in the valleys or mountains in the southwest of Fujian Province. The earliest Hakka settlement was in Shibi Village, Ninghua County, and then moved along the Tingjiang River valley in Fujian Province, and integrated with the local ethnic groups to form a unique cultural characteristics of the Hakka people. Typical houses of Hakka people generally present tulou and fort, which is also for the need of defense and the consideration of life privacy. This paper takes the various types of traditional villages and famous historical and cultural villages① in Fujian Province at all levels in the list as the object of study, including seven batches of national-level famous historical and cultural villages, a total of 57 villages, six batches of provincial-level famous historical and cultural villages, a total of 138 villages, five batches of national-level traditional villages, a total of 494 villages and four batches of provincial-level traditional villages, a total of 917 villages. A few villages exist in both the traditional villages and famous historical and cultural villages in the list due to their special value and significance However, due to the necessity of classification research, they are not screened out. According to the criteria for village classification and selection in China, both traditional villages and historical and cultural villages are villages with important historical value. In addition, this study also needs comprehensive village data as support, so as to draw relatively reliable conclusions. Therefore, the total number of traditional villages in Fujian Province studied in this paper reaches 1606 (Table 1).

*Data sources*. The data studied in this paper includes three major categories: (1) Map data is based on DEM data of Fujian Province, and spatial information such as elevation, slope, slope direction, water system and roads are extracted to establish a basic database of Fujian maps, and the data source is the open source website of geographic data. (2) The village data was obtained from the official websites of the Ministry of Housing and Urban-Rural Development of China and the Department of Housing and Urban-Rural Development of Fujian Province. The geographical coordinates of traditional villages were mainly obtained through online map queries, and the spatial distribution map of traditional villages in Fujian Province was drawn by overlay. (3) Socio-economic data related to cities and counties as well as data on ancient post roads were obtained through statistical yearbooks, local chronicles and historical atlases, among which statistical yearbooks were obtained through the official website of Fujian Provincial Bureau of Statistics by searching 《Fujian Statistical Yearbook – 2021》.

*Research framework*. Firstly, the traditional village data of Fujian Province at all levels and types and the map data of Fujian Province were used as data sources to construct a basic data-base of traditional villages in Fujian Province. Secondly, the spatial distribution characteristics were analysed in depth. Specifically, the statistical analysis model was used to determine the type of spatial distribution and analyse the overall distribution status of traditional villages; by using the spatial autocorrelation analysis tool, the regional relationship pattern of the spatial distribution of traditional villages was measured; on this basis, the kernel density estimation method was used to sort out the spatial distribution density of traditional villages and analyse the clustering area of traditional villages. On the basis of this, the spatial distribution density of traditional villages is sorted out using the kernel density estimation method, and the specific situation of traditional village clusters is analysed. The spatial distribution trend is determined by using the standard ellipse difference tool, and the expansion trend of traditional villages is analysed. Finally, by combining the spatial distribution characteristics with the correlation characteristics of the influencing factors, the distribution pattern of traditional villages in Fujian Province is revealed and summarised, and targeted planning and protection suggestions are made (Fig. 3).

### Research methodology

*Statistical analysis models*. The statistical analysis models such as the nearest point index, geographical concentration index and imbalance index were used for quantitative analysis to determine the types of spatial distribution of various types of traditional villages at different levels in Fujian Province (Table 2) (Zhang et al. 2020). The innovation of this statistical analysis model is that it can accurately determine the spatial distribution type of traditional villages in Fujian Province by using a variety of indicators and combining the data of all kinds of traditional villages in Fujian Province for comprehensive analysis.

*Spatial autocorrelation analysis*. Spatial autocorrelation analysis is an analytical method to examine the interactions and interdependencies between regions in space, including global autocorrelation and local autocorrelation. The former is commonly used to analyse the global Moran's I index as a measure of the degree of spatial autocorrelation, while the latter is commonly used to explore in detail the distribution state of spatial elements in local space with the local Moran's I index. In particular, the global Moran's I index represents the spatial characteristics of an attribute of a study object across the study area, and is used to measure the overall spatial correlation between regions, and is calculated as follows (Wu, 2014):

$$I = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(y_i - \bar{y}\right)\left(y_j - \bar{y}\right)}{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2} \quad (4)$$

where: $y_i$ and $y_j$ denote the attribute values of the ith spatial unit and the jth spatial unit respectively; $W_{ij}$ is the spatial weight value; S is the sum of $W_{ij}$; n is the total number of spatial units under study. the value of Moran's I index is between [−1, 1], its value greater than 0 is positive correlation, indicating the existence of


**Fig. 1 Location map of Fujian Province in China.** The figure shows the position of Fujian Province in China. It can be clearly seen that Fujian Province is in the southeast of China. The red line is the border of Fujian Province, whose capital is Fuzhou.

agglomerative distribution characteristics, less than 0 is negative correlation, indicating the existence of dispersive distribution characteristics, equal to 0 indicates no correlation, indicating a random distribution.

While the local Moran's I index indicates the specific spatial location and distribution of agglomerative centres, which can better reflect the homogeneity and heterogeneity of spatial elements, five relationships usually emerge: high-high clustering (HH), i.e. high-value centres and surrounded by high-value areas; high-low clustering (HL), i.e. high-value centres and surrounded by low-value areas; low-high clustering (LH), i.e. low-value centres and surrounded by high-value areas ; low-low clustering (LL), i.e. low value centres surrounded by low value areas; and no obvious clusters. In this paper, the global Moran's I index is used to measure the overall association characteristics of the spatial distribution of traditional villages in Fujian Province, and on this basis, the local Moran's I index is used to analyse the homogeneity and heterogeneity characteristics of each spatial unit of traditional villages in Fujian Province and its neighbouring units.

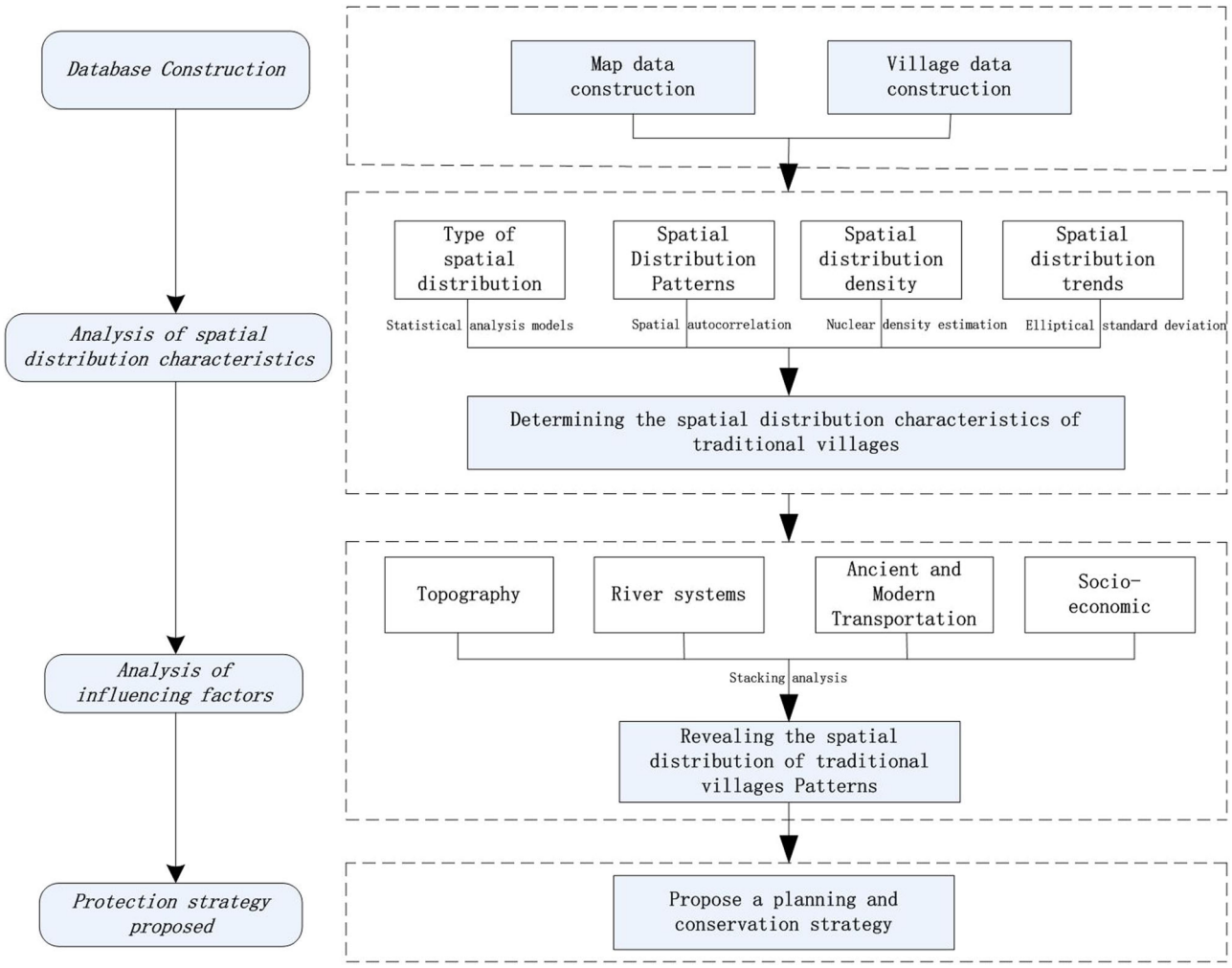


**Fig. 2 Spatial distribution of traditional villages in Fujian Province.** This figure shows the specific distribution of traditional villages at various levels in Fujian Province, China. The dark red dots represent national traditional villages, the light red dots represent provincial traditional villages, the dark green dots represent national historical and cultural villages, and the light green dots represent provincial historical and cultural villages.

**Table 1 Statistics of Traditional Villages in Fujian Province at all levels.**

| | Category | Management | Quantity (unit) |
|---|---|---|---|
| Historic and Cultural Village | National level | Fujian Provincial Department of Housing and Urban-Rural Development | 57 |
| | Provincial level | | 138 |
| | Subtotal | | 195 |
| Traditional Village | National level | Fujian Provincial Department of Housing and Urban-Rural Development | 494 |
| | Provincial level | | 917 |
| | Subtotal | | 1411 |
| | Total | | 1606 |

*Nuclear density estimation method*. The kernel density estimation method is a non-parametric approach that assumes that geographic events can occur at any spatial location, but with different probabilities of occurrence at different locations. The denser the point element, the higher the kernel density value, the higher the probability of a geographical event occurring; conversely, the lower the probability. The degree of discrete concentration of point elements is reflected by calculating the density of point elements around each output raster, which is calculated as (Hu et al. 2016):

$$f(s) = \sum_{i=1}^{n} \frac{1}{h^2} k\left(\frac{s - c_i}{h}\right) \quad (5)$$

Where: f(s) represents the kernel density function; h is the bandwidth; n indicates the number of points whose linear distance from point s is less than or equal to h; the k function indicates the distance relationship between each element point s and the core $c_i$; the estimation of kernel density depends on the selection of the kernel function and bandwidth h. In this paper, by calculating the kernel density of various types of traditional villages at various levels in Fujian Province, the analysis reflects the gathering area and distribution characteristics of traditional villages in Fujian Province.

*Superposition analysis method*. Overlay analysis is an analytical method that superimposes two or more groups of elements from

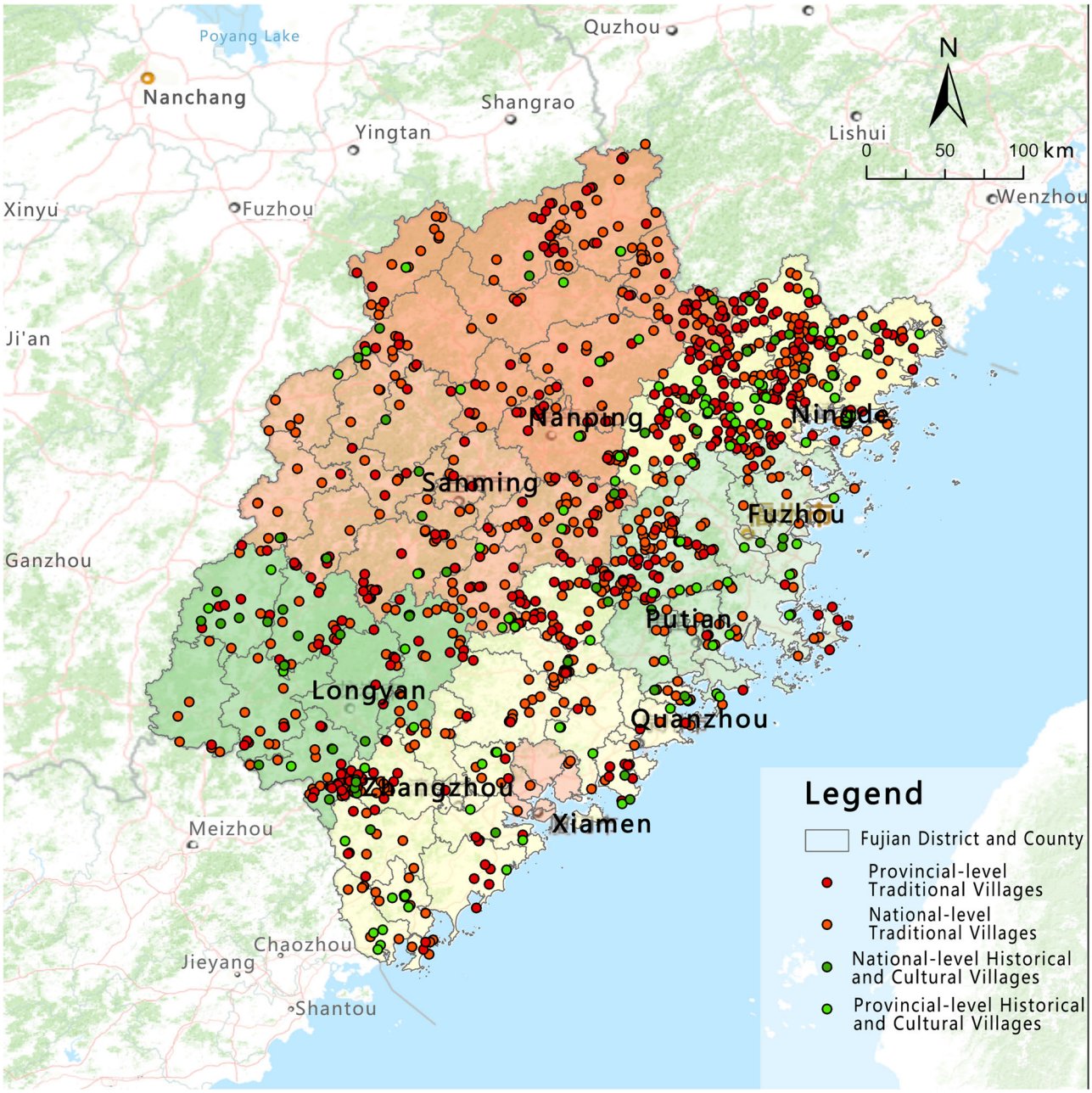


**Fig. 3 Spatial distribution characteristics of traditional villages in fujian province and analysis framework of influencing factors.** This figure shows the research framework from the construction of the database to the analysis of the specific spatial distribution characteristics of traditional villages to the analysis of the influencing factors to the proposal of conservation strategies.

the same area to produce new features (Long and Zhao, 2022). In this paper, the spatial distribution maps of various types of traditional villages at various levels in Fujian Province are overlaid with digital map elevation (DEM), river system and ancient post road data respectively to form a new multi-factor layer, and the spatial distribution of traditional villages under the influence of different factors and their correlation with each factor are analysed through relevant charts.

## Spatial distribution characteristics of traditional villages

*Type of spatial distribution*. Considering the traditional villages in Fujian Province as point shapes, the spatial distribution types of these points are studied, i.e. the spatial distribution types of traditional villages are studied. According to the nearest neighbour index (Clark and Evans, 1954) model in Table 2, it can be seen that cohesive, uniform and random distribution are the three types of spatial distribution of point elements, and the nearest neighbour distance and nearest neighbour index can be applied to measure the type of spatial distribution of point elements. According to Eq. (1), the theoretical nearest distance of traditional villages in Fujian Province is 13.33 km, the actual average nearest distance is 4.11 km, the nearest point index $R = 0.31$, $R < 1$, and $Z = -53$ calculated by Z test, (Z scores are used to test the statistical significance of spatial autocorrelation analysis, with a negative Z score representing agglomeration, a positive score representing dispersion, and a zero score being uncharacteristic), The significance level P value is 0.00, indicating that the probability of randomly generating agglomeration patterns is less than 1%.

**Table 2 A statistical analysis model of the spatial distribution of traditional villages in Fujian Province.**

| Serial number | Index | Model | Model interpretation | Geographical significance |
|---|---|---|---|---|
| Eq. (1) | Nearest neighbour index | $R = \frac{\bar{r}_1}{\bar{r}_E} = 2\sqrt{D} \times \bar{r}_1$ | $\bar{r}_1$ is the actual nearest-neighbour distance; $\bar{r}_E$ is the theoretical nearest-neighbour distance; D is the point density. | The spatial distribution of traditional villages is reflected. When R = 1, traditional villages are randomly distributed; when R > 1, traditional villages tend to be uniformly distributed; when R < 1, traditional villages tend to be clustered. |
| Eq. (2) | Geographical concentration index | $G = 100 \times \sqrt{\sum_{i=1}^{n} (\frac{X_i}{T})^2}$ | Xi is the number of subjects in the ith area; T is the total number of subjects; n is the total number of sub-districts. | The value of G ranges from 0 to 100, the higher the value, the more concentrated the distribution of traditional villages; on the contrary, the distribution of traditional villages tends to be scattered. |
| Eq. (3) | Imbalance Index | $S = \frac{\sum_{i=1}^{n} Y_i - 50(n+1)}{100n - 50(n+1)}$ | $Y_i$ is the cumulative percentage of a factor in each region ranked from the ith largest to the smallest of all regions; n is the number of regions. | Reflects the balanced distribution of villages within Fujian Province. When S = 1, the villages are all concentrated in one area; when S = 0, the villages are evenly distributed across the districts; if S takes a value between 0 and 1, the villages are unevenly distributed. |

Therefore, the spatial distribution of traditional villages in Fujian Province is in a significant cohesive distribution. Secondly, according to equation (2), the G-value of the municipal-level geographical concentration index of traditional villages in Fujian Province is 39.48, indicating that there is a strong tendency of concentration in the distribution of traditional villages in Fujian Province. Again, according to equation (3), the municipal imbalance index S of traditional villages in Fujian Province is 0.38, indicating that the spatial distribution of traditional villages in Fujian Province is uneven at the municipal level. Finally, using the Lorenz curve (Fig. 4), it was verified that the traditional villages in Fujian Province are mainly distributed in the five cities of Ningde, Nanping, Longyan, Sanming and Fuzhou, with the number of traditional villages accounting for 80% of the total number of traditional villages in the province, which is in line with the above analysis of the concentrated but uneven distribution of traditional villages in Fujian Province. In summary, the spatial distribution of traditional villages in Fujian Province is cohesive and uneven.

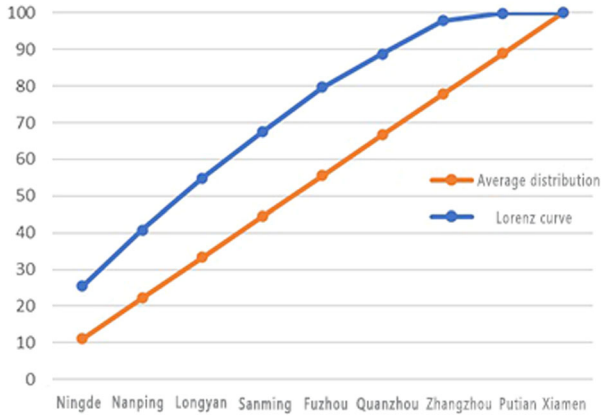


**Fig. 4 Lorentz curve of spatial distribution of traditional villages in Fujian Province.** The yellow oblique line in the figure represents the average cumulative distribution of traditional villages in prefecture-level cities of Fujian Province under ideal conditions, while the blue curve represents the actual cumulative distribution of traditional villages in prefecture-level cities of Fujian Province.

*Spatial distribution pattern*. On the basis of identifying traditional villages in Fujian Province as cohesive and uneven spatial types, spatial autocorrelation analysis was used to measure the spatial distribution pattern of traditional villages in Fujian Province and to examine the interdependence and interactions between regions in space. Firstly, based on the number of traditional villages distributed in each administrative unit of Fujian Province, the global Moran's I index was used to analyse the overall characteristics of regional differences in the spatial distribution of villages in Fujian Province, and it was calculated that the global Moran's I index of the spatial distribution of traditional villages in Fujian Province was 0.53, and $Z = 7.22$, $p = 0.00$, and the test satisfied $|Z| > 1.96$ and $p < 0.05$, The null hypothesis can be rejected. The spatial distribution of traditional villages in Fujian Province has a significant positive spatial correlation, i.e. the units with more traditional villages have more traditional villages in their surrounding units, and vice versa.

Secondly, on the basis of clarifying the relationship that the spatial distribution of traditional villages in Fujian Province is positively correlated, the local Moran's I index was applied to further reveal the local characteristics and distribution status of spatial units homogeneous or heterogeneous with their neighbouring units, and the local spatial autocorrelation LISA map of traditional villages in Fujian Province was obtained. As can be seen from Fig. 5, the high-high clustering areas (HH) are mainly distributed in the central part of Ningde City and the contiguous area formed in the western part of Fuzhou City (including Shouning County, Zhouning County, Fuan City, Jianou City, Pingnan County, Jiaocheng District, Gutian County, Yanping District, Youxi County, Minqing County and Dehua County) and Xinluo District in Longyan City, and the number of traditional villages distributed in these units and their neighbouring units is high. The low-high clustering area (LH) is mainly located in Tuorong County in Ningde and Shanghang County in Longyan, and the number of traditional villages distributed in these units is relatively small, but the number of villages in their surrounding units is high. The low-low clustering area (LL) is mainly distributed in six districts in the central city of Fuzhou (i.e. Jinan, Gulou, Mawei, Taijiang, Cangshan and Changle districts), Nan'an and Jinjiang in Quanzhou and Changtai County in Zhangzhou, and the number of traditional villages distributed in these units and their surrounding units is low. In summary, the overall spatial distribution pattern of traditional villages in Fujian Province is obviously positively correlated, with the majority of high and high clusters being in the Fanning contiguous area, but a few spatial units have negative correlations, such as Tuorong County in Ningde and Shanghang County in Longyan, which are

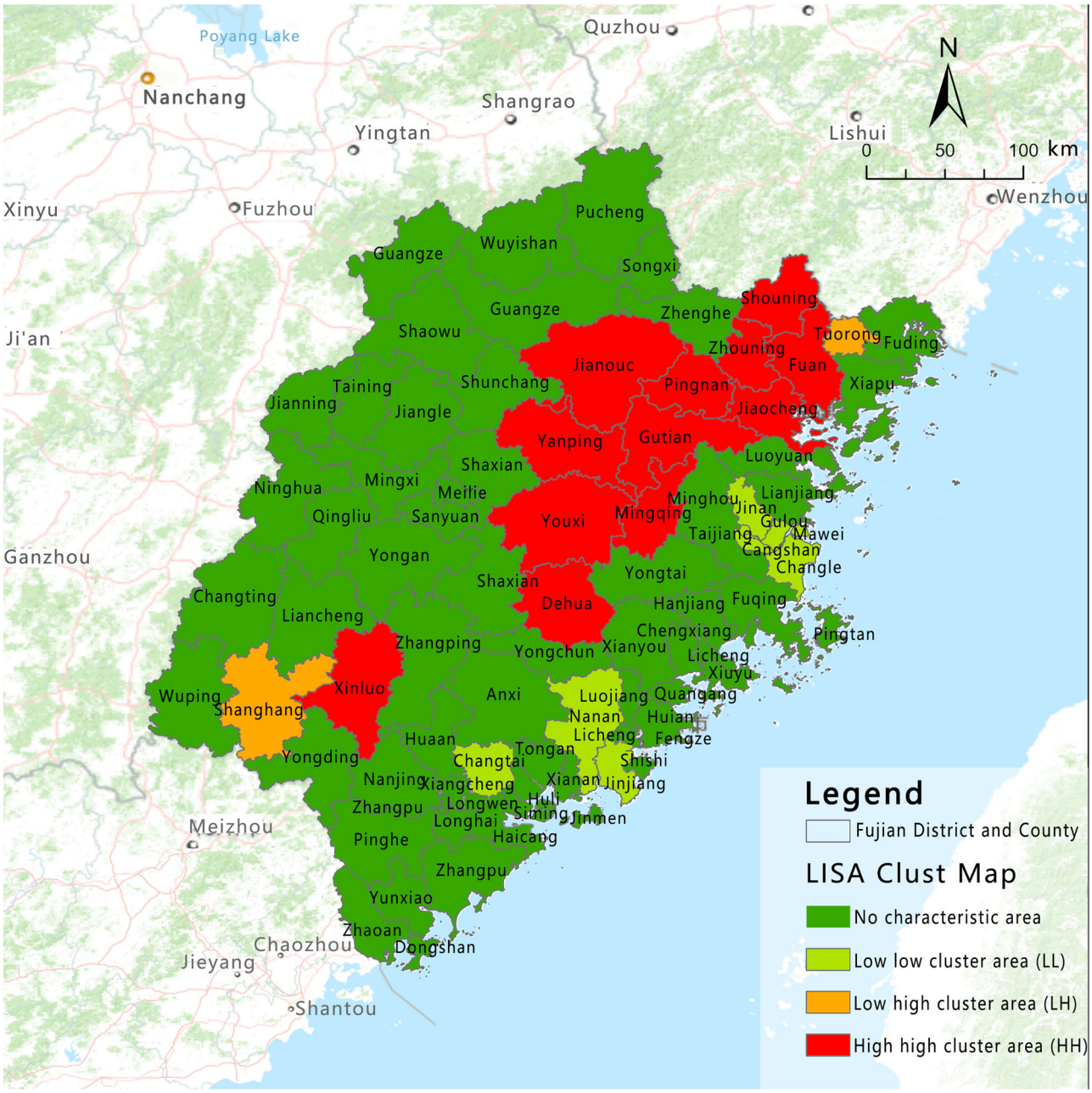


**Fig. 5 LISA map of local spatial autocorrelation of traditional villages in Fujian Province.** In the figure, the dark green area represents the featureless area, the light green area represents the low-low clustering area, the egg yellow area represents the low-high clustering area, and the red area represents the high-high clustering area.

low and high clusters, probably because the number of traditional villages declared in their own units is low, while the number of traditional villages in the surrounding units is high. Therefore, in the next step of conservation policy formulation, priority can be given to the excavation and declaration of traditional villages in Shanghang and Tuorong counties and the conservation and use of high and high clusters, while concentrated and continuous development and joint conservation can be adopted for high and high clusters.

*Spatial distribution density*. In order to accurately analyse the spatial distribution density of traditional villages in Fujian Province, firstly, the spatial distribution quantity and density of traditional villages in the province were counted, and it can be seen from Table 3 that, in terms of distribution quantity, the top 5 spatial distribution quantities of traditional villages in the province are Ningde City, Nanping City, Longyan City, Sanming City and Fuzhou City, but in terms of distribution density, Longyan City and Sanming City fall out of the top 5 positions, because The reason for this is that their municipalities are too large, resulting in smaller distribution densities and a relatively low position in the distribution density ranking. Therefore, the following discussion is conducted to accurately analyse the spatial distribution density of traditional villages in Fujian Province.

Secondly, in order to visually represent the aggregation characteristics of traditional villages in Fujian Province, the Kernel Density estimation method was introduced, and the Kernel Density tool was used to carry out kernel density analysis. After repeated experiments, 10 km was chosen as the search radius to generate a kernel density distribution map of traditional

**Table 3 Statistics on the Distribution of Traditional Villages in Fujian Province by Municipality.**

| City domain name | Number of Traditional Villages | City domain area (million km2) | Average density (Units per 10,000 km2) | Density Ranking |
|---|---|---|---|---|
| Ningde | 409 | 1.35 | 302.96 | 1 |
| Nanping | 247 | 2.63 | 93.92 | 6 |
| Longyan | 226 | 1.91 | 118.32 | 4 |
| Sanming | 201 | 2.29 | 87.77 | 7 |
| Fuzhou | 196 | 1.22 | 160.65 | 2 |
| Quanzhou | 147 | 1.13 | 130.09 | 3 |
| Zhangzhou | 146 | 1.29 | 113.18 | 5 |
| Putian | 32 | 0.41 | 78.05 | 8 |
| Xiamen | 2 | 0.17 | 11.76 | 9 |

villages in Fujian Province at all levels. From Fig. 6, it can be seen that traditional villages at all levels in Fujian Province exhibit a spatial distribution pattern of "large dispersion and small concentration" and the concentration tends to increase, i.e. on the whole, traditional villages at all levels are distributed in all regions of the province, but there is an obvious clustering effect in local areas. Specifically, there is one major catchment area and two sub-catchment areas for the spatial distribution of national and provincial historical and cultural villages. One major catchment area is in the southwest of Ningde City (Gutian County, Pingnan County, Fuan County, Zhouning County and Jiaocheng District); two sub-catchment areas are in the northwest of Longyan City (Changting County) and at the junction of western Zhangzhou and southeastern Longyan (Yongding District, Nanjing County and Pinghe County). There are three main clusters and one sub-cluster in the spatial distribution of national and provincial traditional villages. The three main clusters are: west-central Ningde (Fuan City, Jiaocheng District, Zhouning County), south-western Fuzhou (Yongtai County), and the intersection of western Zhangzhou and southeastern Longyan (Yongding District, Nanjing County, Pinghe County); the one sub-cluster is: the intersection of north-western Zhangzhou and southeastern Sanming City (Dehua County, Yongchun County, Dada County). There-fore, it can be concluded that the core agglomerations in central Ningde show a tendency to complement and strengthen, while the other secondary agglomerations also have a slightly complementary character. In summary, the overall spatial distribution of traditional villages in Fujian Province is characterised by one core agglomeration, two major agglomerations and two subagglomerations, with a clear core-edge distribution pattern. Nanjing County, Pinghe County); 2 sub-catchment areas: northwestern Zhangzhou and southeastern Sanming City intersection (Dehua County, Yongchun County, Dada County), northern Sanming City (Liancheng County).

*Spatial distribution trend*. Using the standard deviation ellipse analysis tool to analyse the trend and direction of the traditional village point data set and the geometric centre location in Fujian Province, the expansion trend of traditional villages in Fujian Province can be grasped from a spatial and temporal perspective. As can be seen from Fig. 7, the ellipses of historical and cultural villages, traditional villages and integrated traditional villages all show a northeast-southwest development trend, and the ellipses of each category of traditional villages basically overlap; each ellipse direction is consistent with the direction of the

provincial boundary. In terms of the centre of gravity of distribution, the centre of gravity of traditional villages in each

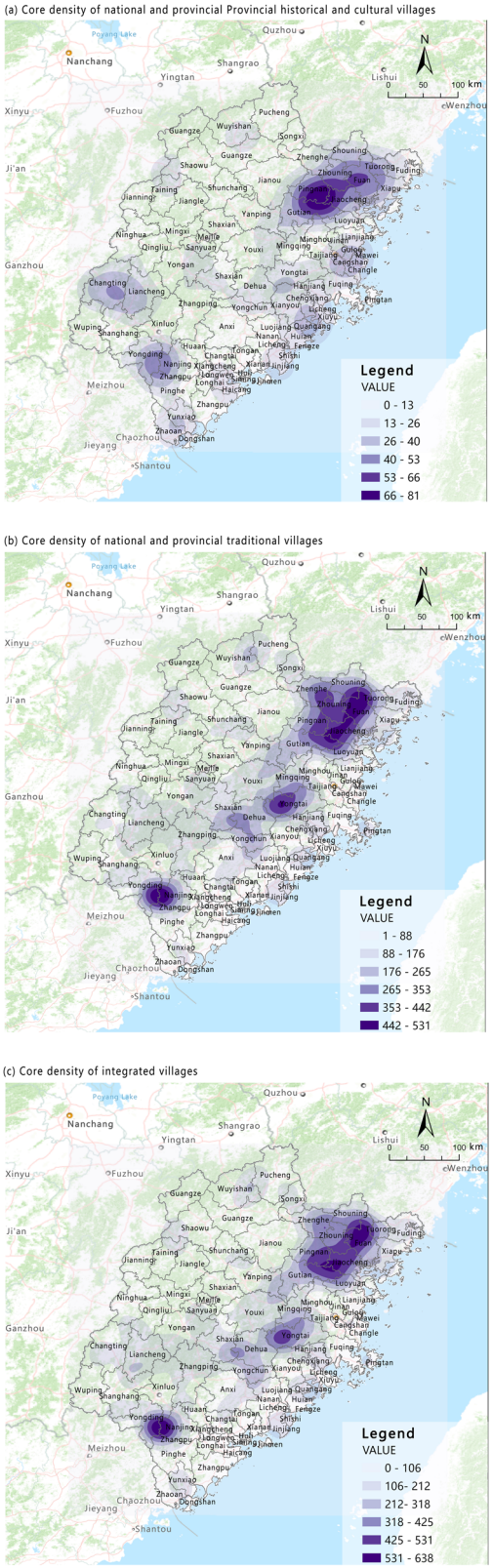


**Fig. 6 Map of the nuclear density distribution of traditional villages in Fujian Province.** (**a**) shows the distribution of nuclear density of historical and cultural villages at the national and provincial levels; (**b**) shows the distribution of nuclear density of traditional villages at the national and provincial levels; (**c**) shows the distribution of comprehensive nuclear density of villages, including historical and cultural villages and traditional villages.


**Fig. 7 Ellipse analysis of standard deviation of traditional villages in Fujian Province.** The picture shows the distribution of mean centers and standard deviations of all kinds of traditional villages at all levels in Fujian Province, reflecting the distribution centers and trends of all kinds of traditional villages at all levels.

category is located in Youxi County, northeast of Sanming City. In general, the distribution trend of traditional villages in Fujian Province is mainly from the northeast to the southwest, and Youxi County is the geometric centre of the distribution of traditional villages in Fujian Province.

In summary, traditional villages in Fujian Province are cohesive and uneven spatial types, with significant overall positive spatial correlations and only a few spatial units with negative correlations, with one core, two main and two sub-colonies and an obvious core-edge distribution, and with a northeast to southwest spatial expansion trend.

## Analysis of influencing factors

*Terrain and landscape factors*. Physical geography is one of the most important factors influencing the distribution of villages, especially the topographical factors. In this paper, we obtained DEM data of Fujian Province from the open source geographic data cloud website, processed the images with relevant software, obtained the elevations and then coupled and overlaid them with the traditional villages in Fujian Province (Fig. 8). The results show that the traditional villages in Fujian Province are mainly distributed in the northeast, central and southwest of the province along the mountainous areas, which is consistent with the northeast to southwest expansion trend analysed above. The northeast-southwest mountain range running through the province is the main axis of village clustering, with most of the traditional villages clustered along the Daiyun Mountains in the central part of the province and the Lufeng Mountains in the northeast (Hu et al. 2021), as well as along the Tortoiseshell Mountains and the Boping Ridge in the southwest. According to

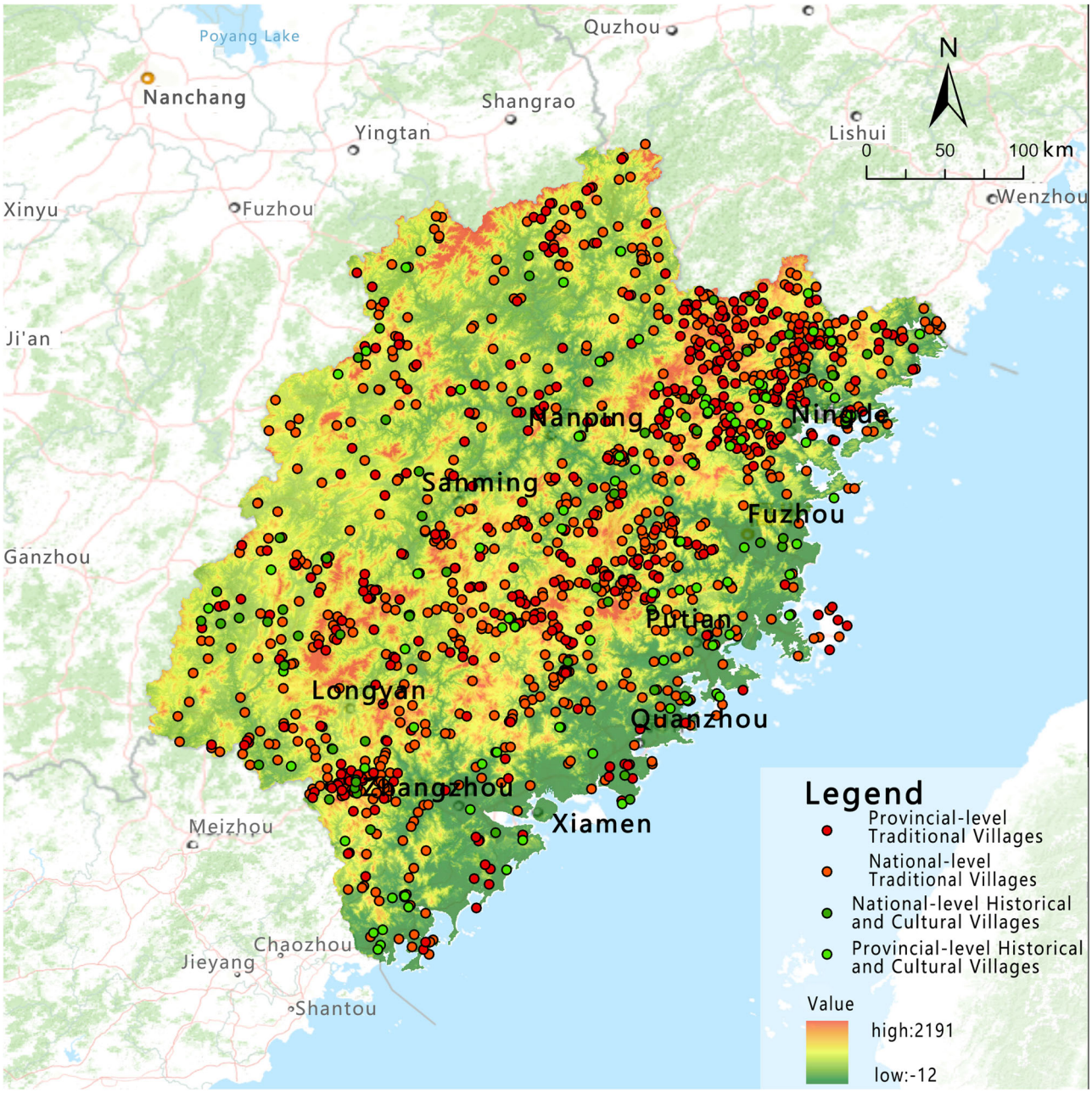


**Fig. 8 Association map of traditional villages and elevation in Fujian Province.** The points in the figure represent the distribution of traditional villages. The greener the lower the altitude, and the yellow the higher the altitude.

Fig. 9, there are 258 traditional villages in Fujian Province with elevations below 100 m, accounting for 16.6% of the total, and 43 villages above 1000 m, accounting for only 2.7% of the total, the vast majority of which are in these mountainous areas within the range of mountainous hilly elevations.

From the above analysis, it can be seen that most of the traditional villages in Fujian Province are distributed along the central mountains from northeast to southwest and other mountainous areas. Its distribution law can be roughly as follows: at high altitude, there are more villages; At lower elevations, there are fewer villages. The natural topography of these mountainous and hilly areas is a protective barrier, which is conducive to the long and complete preservation of traditional villages. On the contrary, in the flatter coastal areas of eastern and southern Fujian Province, the distribution of traditional villages is relatively small, probably due to the fact that the original traditional villages on the plain terrain are more affected by social and economic development and external environmental influences, leading to the interruption and extinction of the villages.

*River system factors*. River systems are both the main source of water for residents' production and living, as well as undertaking certain transport functions, and play an important guiding and driving role in the siting and clustering of traditional villages. Fujian Province mainly has five rivers and one stream, specifically the six river systems of Minjiang, Jiulongjiang, Jinjiang, Tingjiang, Saijiang and Mulanxi. In this paper, the lo-cation overlay and buffer analysis of the river network and traditional villages in Fujian Province (Fig. 10) are used to reflect the spatial relationship between the spatial distribution of traditional villages and river system factors. From Fig. 8 and buffer statistics, it can be seen that: 509 traditional villages in Fujian Province are located

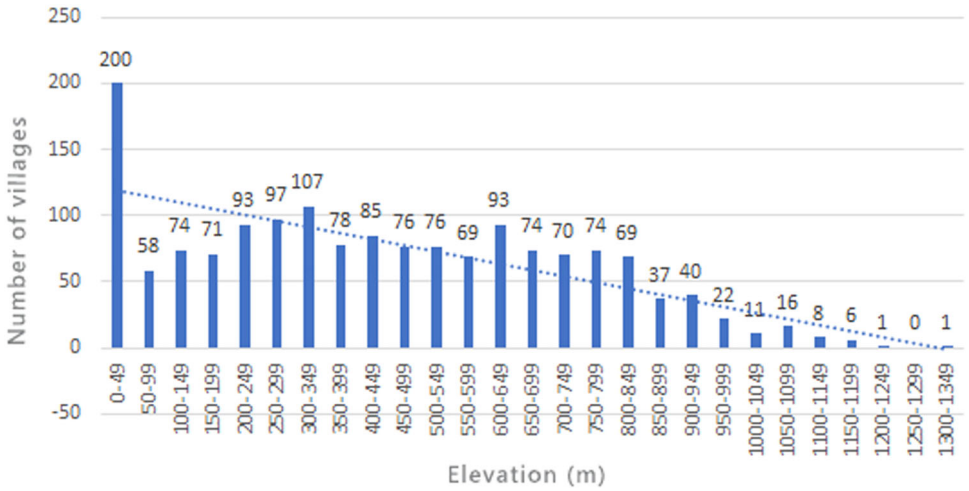


**Fig. 9 Statistical map of the elevation of traditional villages in Fujian Province.** In the picture, the horizontal coordinate represents the altitude segment and the vertical coordinate represents the quantity, which overall reflects the distribution of traditional villages in various altitude segments in Fujian Province.

within 500 m of major water systems, accounting for 31.7% of all villages; 812 traditional villages are located within 1 km, accounting for 50.6% of all villages. Most of the traditional villages are located in mountainous areas near rivers, and only a few of them are far away from big rivers and streams. The reason for this is that the inhabitants of villages located in mountainous areas with high altitudes mostly use the springs in the mountains, and the other is that the inhabitants of villages located near the sea mostly dig wells to get water or process seawater, so they can still solve problems such as using water for eating while being far away from big rivers and streams.

In general, the river system in Fujian Province is strongly correlated with the distribution of traditional villages, and the proximity to rivers is one of the leading environmental factors in the location of traditional villages. Traditional villages that are located along rivers have better agricultural production conditions and are able to obtain a better production and living environment, which also improves the chances of the development and continuation of traditional villages.

*Ancient and modern transportation factors*. The transportation factor is an important indicator of regional development and has an important influence in the formation and conservation and development of traditional villages. Firstly, analysing the correlation between ancient post roads and traditional villages is conducive to grasping the distribution characteristics of traditional villages from the perspective of their formation and development. In this paper, by consulting historical maps and local chronicles of Fujian Province, the ancient post roads in Fujian Province were compiled and mapped, and the buffer analysis was conducted using 1 km, 5 km and 10 km distance ranges to obtain the correlation degree map between ancient post roads and traditional villages in Fujian Province (Fig. 11) (Fujian Provincial Local History Editorial Committee, 2004). The results show that there are 33 traditional villages located within 1 km of ancient post roads in Fujian Province, accounting for 2.05% of all traditional villages in Fujian Province; 162 traditional villages within 5 km, accounting for 10.09% of all traditional villages in Fujian Province; and 330 traditional villages within 10 km, accounting for 20.55% of all traditional villages in Fujian Province. It can be seen that, on the one hand, the ancient post roads are somewhat related to the traditional villages under the existing system, but not as much as the influence of river systems and topography on the location and layout of villages; on the other hand, the overall shape of the ancient post roads is in the shape of an unsealed "8", laying a certain foundation for the formation of the modern transportation system in Fujian Province, which is the historical skeleton of the modern transportation system in Fujian Province.

Secondly, the data related to the number of road miles of each region in Fujian Province in 2020 were obtained from 《Fujian Provincial Statistical Yearbook-2021》 (Fujian Provincial Bureau of Statistics, 2021), on which the data were collated and the road density of each region was calculated to obtain Table 4, which was analysed in conjunction with Table 2 above. The results show that the road densities of Ningde, Longyan, Sanming and Nanping are small, ranking in the bottom four, while the distribution of the number of traditional villages in these four regions ranks in the top four; the distribution of the number of traditional villages is smaller in areas such as Quanzhou, Putian and Xiamen, which rank high in road density. It can be seen that there is a negative correlation between the traffic conditions and the number of traditional villages, as areas with poor traffic access have less convenient contact with the outside world. Under normal circumstances, human settlement sites were located in locations with more convenient transportation, which laid the foundation for the later development of cities and towns. However, the formation of traditional villages in Fujian Province was originally due to the need of the Central Plains people to escape the war in the south, and more people chose to live in mountainous areas. It was also due to the relatively closed transportation and less foreign cultural invasion that traditional villages were preserved and protected.

*Socio-economic factors*. Traditional villages are one of the important carriers of human civilization, and their protection and development cannot be separated from the promotion of social economy. With the continuous promotion of urbanization, the pursuit of economic benefits and urban expansion will inevitably lead to contradictions and conflicts with the protection of traditional villages. In order to analyse the relationship between the distribution of traditional villages and socio-economic development in Fujian Province, this paper selects four indicators reflecting the level of regional socio-economic development, including per capita disposable income of farmers, household deposits, urbanisation level and regional gross output value, and

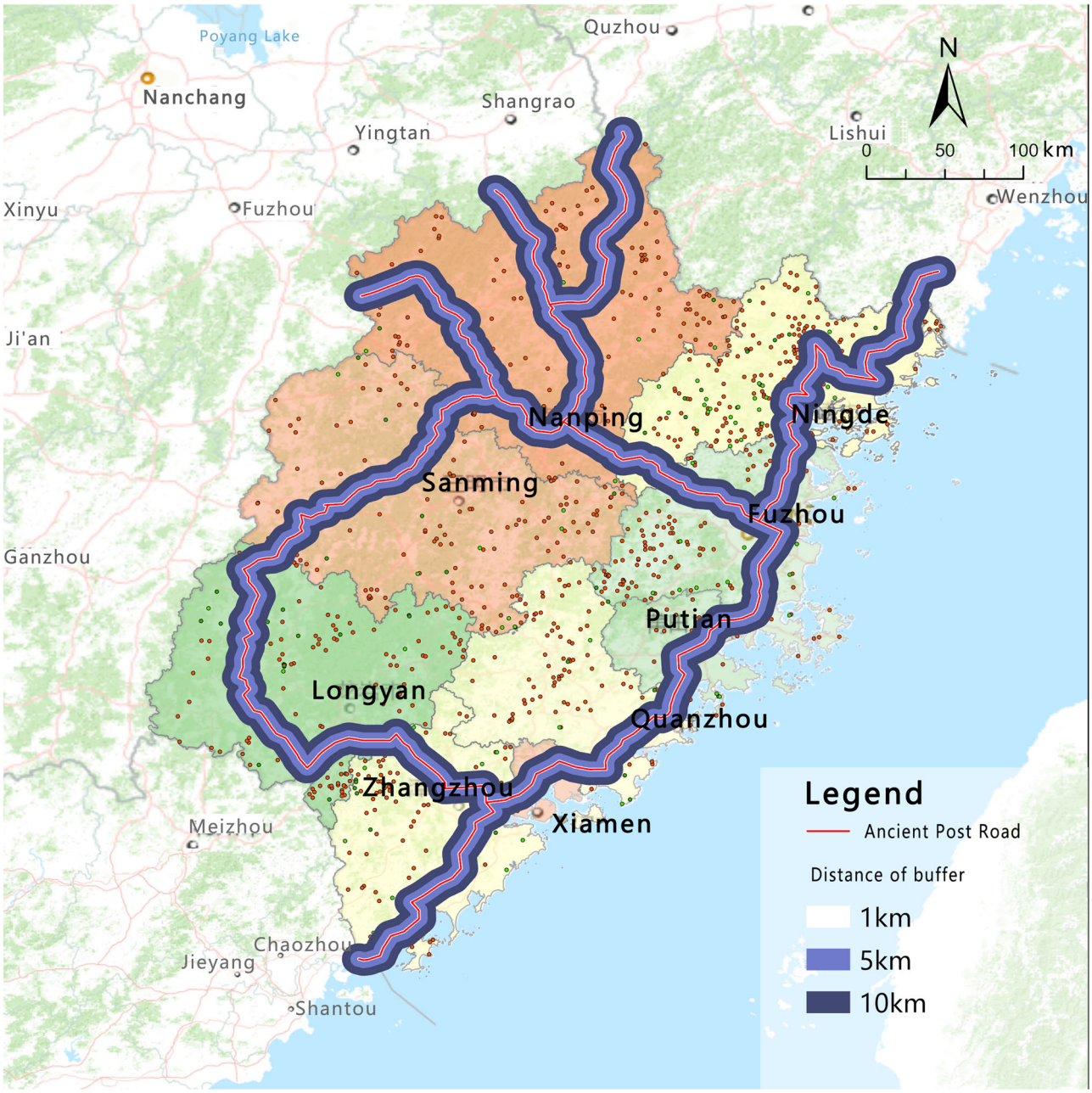


**Fig. 10 Association map of traditional villages and river systems in Fujian Province.** The blue lines in the figure represent the buffer areas of Fujian river system, which are buffered 500 meters, 1 km, 2 km, 3 km and 5 km according to different degrees of blue. Combined with the distribution of traditional villages, the overall correlation between traditional villages and river system is reflected.

collates them according to the relevant statistics of Fujian Province by region in 2020 published by Fujian Provincial Bureau of Statistics in 《Fujian Province Statistical Yearbook-2021》 (Table 5) (Fujian Provincial Bureau of Statistics, 2021). The results show that there is a close negative correlation between the distribution of traditional villages and the level of regional socio-economic development in Fujian Province, with the areas with more traditional villages (i.e. Ningde, Longyan, Sanming and Nanping) being in the bottom four in terms of disposable income and household deposits of farmers, and the level of urbanization and gross regional product also being at a lower level, lagging behind the provincial average; the areas with less traditional villages (i.e. Xiamen and Quanzhou) are at the top of the list with disposable income of farmers, household deposits, urbanisation rate and regional GDP all higher than the provincial average (Fig. 12); Fuzhou has a relatively large number of traditional villages, but its socio-economic strength is very strong. The reasons for this phenomenon can be speculated to be strongly linked to the importance it attaches to the declaration and protection of traditional villages as the capital city of the province, with both policy and economic advantages. This is also a reflection of the positive impact of China's urban hierarchy (Han et al. 2018).

From the above analysis, it can be concluded that there is a certain degree of negative correlation between the distribution of traditional villages and the level of socio-economic development, with areas with a higher number of traditional villages having a relatively lower level of socio-economic development and vice versa. In addition, with the support of both good policies and economy, the conservation and development of traditional villages can be promoted.

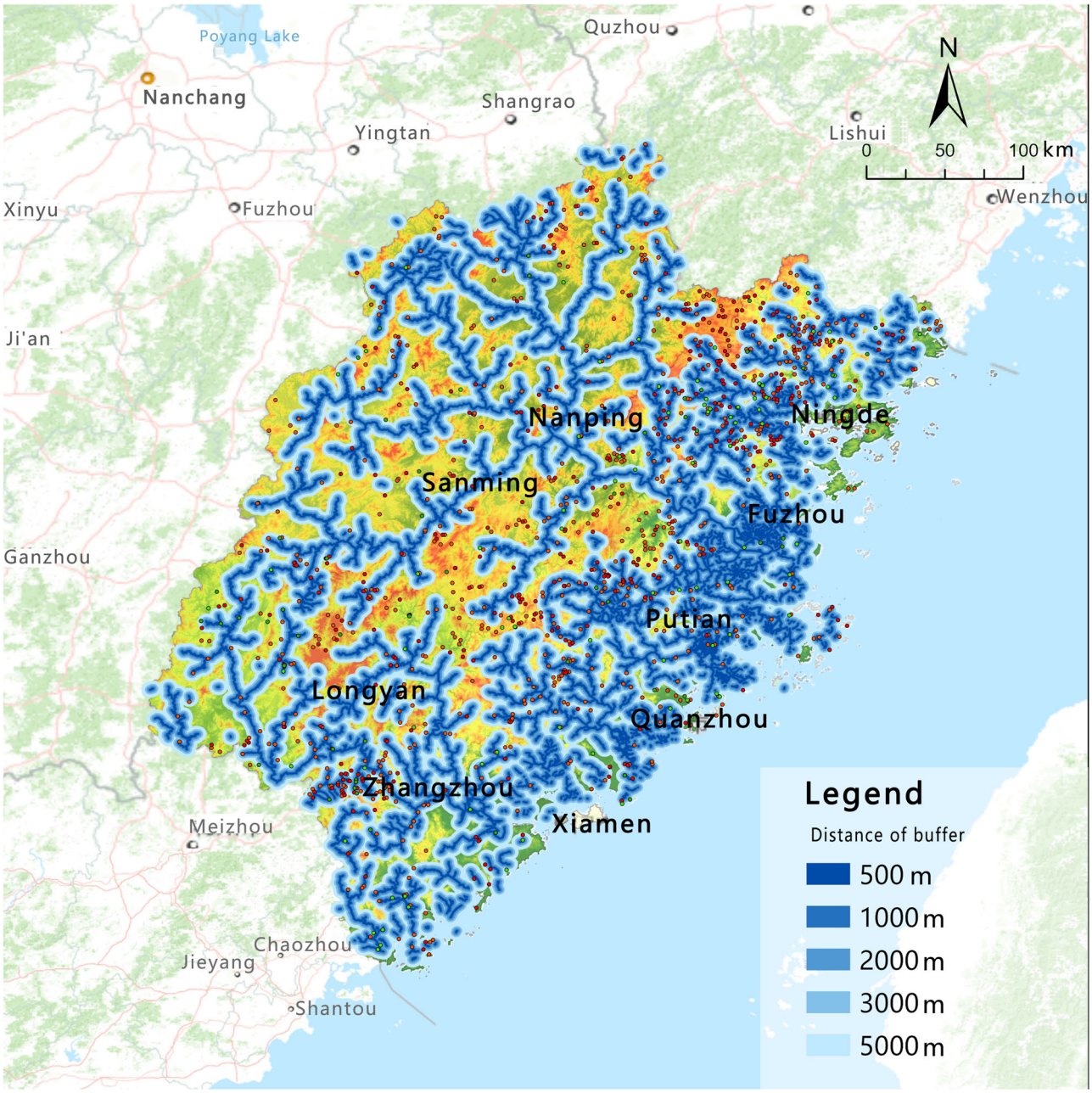


**Fig. 11 Association diagram of traditional villages and ancient post roads in Fujian Province.** The red lines in the figure represent the ancient post roads in Fujian Province, the white area represents the 1 km buffer zone, the light purple area represents the 5 km buffer zone, and the dark purple area represents the 10 km buffer zone, which overall reflects the distribution correlation between the ancient post roads and traditional villages in Fujian Province.

## Conclusions and recommendations

This paper selects 1606 traditional villages in Fujian Province as the research object, and conducts a comprehensive analysis of the spatial distribution characteristics of various types of traditional villages at all levels and their influencing environmental factors, and draws the following main conclusions: (1) The spatial distribution of traditional villages in Fujian Province is cohesive, with significant uneven distribution characteristics, and has formed three core agglomerations (west-central Ningde, southwestern Fuzhou, and the intersection of western Zhangzhou and southeastern Longyan), two sub-level agglomerations (the intersection of northwest Zhangzhou and southeast Sanming City, and northern Sanming City). (2) The overall spatial distribution of traditional villages in Fujian Province has a significant positive spatial correlation, but there are obvious regional differences, with the overall characteristics of "large dispersion, small concentration, more in mountainous areas and less in plains", and they are mostly concentrated in the central mountain range along the northeast to southwest. (3) Topography, river systems, transportation and socio-economics combine to influence the spatial distribution of traditional villages in Fujian Province, but there are differences in the degree of influence. Natural geographical conditions play a leading role in the distribution of traditional villages, and there are obvious concentrations in mountainous and river areas. Most of the traditional villages in Fujian Province are concentrated in the inland basin valley of northwest Fujian with an elevation above 500 m and the hills and low mountain areas on the outer edge of the Minzhong mountain belt with an altitude of 500–1000 m. Most of them are distributed along river systems in the upstream and tributaries of major river systems.

**Table 4 Statistics on road mileage and road density by region in Fujian Province in 2020.**

| City domain name | City domain area (km2) | Road mileage (km) | Road density (km/ 100 km2) | Ranking |
|---|---|---|---|---|
| Quanzhou | 11300 | 18147 | 160.59 | 1 |
| Putian | 4100 | 6427 | 156.75 | 2 |
| Xiamen | 1700 | 2223 | 130.76 | 3 |
| Fuzhou | 12200 | 12225 | 100.20 | 4 |
| Zhangzhou | 12900 | 12900 | 100.00 | 5 |
| Ningde | 13500 | 12275 | 90.93 | 6 |
| Longyan | 19100 | 14702 | 76.97 | 7 |
| Sanming | 22900 | 15406 | 67.28 | 8 |
| Nanping | 26300 | 15986 | 60.78 | 9 |

**Table 5 Statistical Table of Economic Development Indicators by Region in Fujian Province in 2020.**

| Indicators | Disposable income per farmer (yuan) | Household deposits (billion) | Level of urbanization (%) | Gross regional product (billion) |
|---|---|---|---|---|
| Provincial average | 21328 | 2667.34 | 65.8 | 4883.53 |
| Quanzhou | 23459 | 4793.80 | 67.9 | 10158.66 |
| Fuzhou | 22669 | 6951.54 | 71.8 | 10020.02 |
| Xiamen | 26612 | 3684.39 | 89.2 | 6384.02 |
| Zhangzhou | 21103 | 2010.74 | 60.7 | 4545.61 |
| Longyan | 20150 | 1241.33 | 60.6 | 2870.90 |
| Longyan | 19533 | 1200.14 | 61.9 | 2702.19 |
| Putian | 20823 | 1551.27 | 61.7 | 2643.97 |
| Ningde | 19050 | 1164.77 | 59.5 | 2619.00 |
| Nanping | 18557 | 1408.09 | 58.5 | 2007.40 |

Road traffic conditions and socio-economic conditions have a secondary impact on the distribution of traditional villages. There is a certain degree of negative correlation between road traffic conditions, social and economic conditions and the number of traditional villages, that is to say, there are fewer traditional villages distributed in areas with higher traffic accessibility and better social and economic conditions, and vice versa. (4) The existing literature holds that the location selection of traditional villages in Fujian Province attaches importance to landscape pattern and relies on water navigation (Hu et al. 2021), which is consistent with the results of this study. The present study defines the strength of the influencing factors of each traditional village, and finds that with the support of good policies and economic conditions, the protection and continuation of traditional villages can be promoted to a certain extent, and it is also conducive to the spread of local multicultural culture. In other words, the level of economic development in theory will not become an obstacle to the survival of traditional villages. With the rapid economic development and the support of good policies, traditional villages still have the possibility of survival, and also have better protection and development.

In view of the grim trend that traditional villages in Fujian Province are numerous, diverse in type, culturally diverse and in urgent need of protection, the following suggestions are made for the protection and utilisation of traditional villages in Fujian Province, taking into account the distribution characteristics and patterns of traditional villages in Fujian Province: (1) Firstly, the study of the overall spatial influence and cultural zoning of traditional villages in Fujian Province should be emphasized. Focus on strengthening the overall contiguous protection of traditional villages in the three core gathering areas of central and western Ningde, southwestern Fuzhou, and the intersection of western Zhangzhou and southeastern Longyan. It is necessary to accelerate the establishment of a spatial protection pattern and cultural heritage protection network for traditional villages in Fujian Province, classify them in a hierarchical manner, and clarify priority protection villages, key protection villages and general protection villages (Wu and Yu, 2021). (2) Secondly, formulate protection policies suitable for the development of traditional villages in Fujian Province to promote the development and inheritance of the characteristics of traditional villages. In view of the constructive damage caused by the existing "one side for every village", it is necessary to implement policies in different areas and villages. When studying and implementing conservation projects in different areas and types of traditional villages, attention should be paid to the excavation and innovation of local culture. Traditional villages in developed areas can be marketed and developed for tour-ism to a certain extent (Gao and Wu, 2017); for traditional villages in backward and poor areas, protection policies and financial input should be appropriately
(Fang et al. 2022) tilted to help farmers improve their resilience (Sun et al. 2023). (3) Thirdly, the identification and protection of traditional villages that have not yet been included in the above list should be strengthened. Some "unlisted" traditional villages with certain historical and cultural value should also be studied and protected, and those that meet the conditions should be included in the overall planning and protection scope in a timely manner. At the same time, it is necessary to strengthen the excavation, identification, protection and utilization of secondary traditional village gathering areas. (4) Finally, we should pay attention to the protection of the ecological background of traditional villages. In view of the current single tourism development of traditional villages in Fujian Province, while pursuing economic benefits, we should also pay attention to social and ecological benefits, and protect the overall ecological environment of villages. In the context of current territorial spatial planning, it is necessary not only to strengthen the construction of new countryside and the development and utilization of tourism to help the development of agricultural and rural economy, but also to fully consider that development projects meet the policy requirements of protecting and developing traditional villages in China (Xu et al. 2023). Under the premise of green and low-carbon development, we should comprehensively and harmoniously protect the traditional village clusters affected by different physical geography and human and social factors. Focus on overall consideration of the organic connection between individual traditional villages and provinces, districts and village groups, and explore the establishment of control and protection mechanisms at all levels by using new technologies (Yang et al. 2021) and new methods (Li et al. 2023).

This paper studies the spatial distribution characteristics of various types of traditional villages at all levels in Fujian Province from the macro level, and conducts a spatial analysis of their influencing factors based on mathematical statistics model and geographic information system. Under the constant changes of various environmental factors today, the positive and negative correlations between the distribution of traditional villages and different factors such as topography, river system, traffic elements and social economy are identified. The invariance of the distribution law of traditional villages is discussed in order to provide basic support for the protection and utilization of traditional villages and the planning of village agglomeration area in the future.

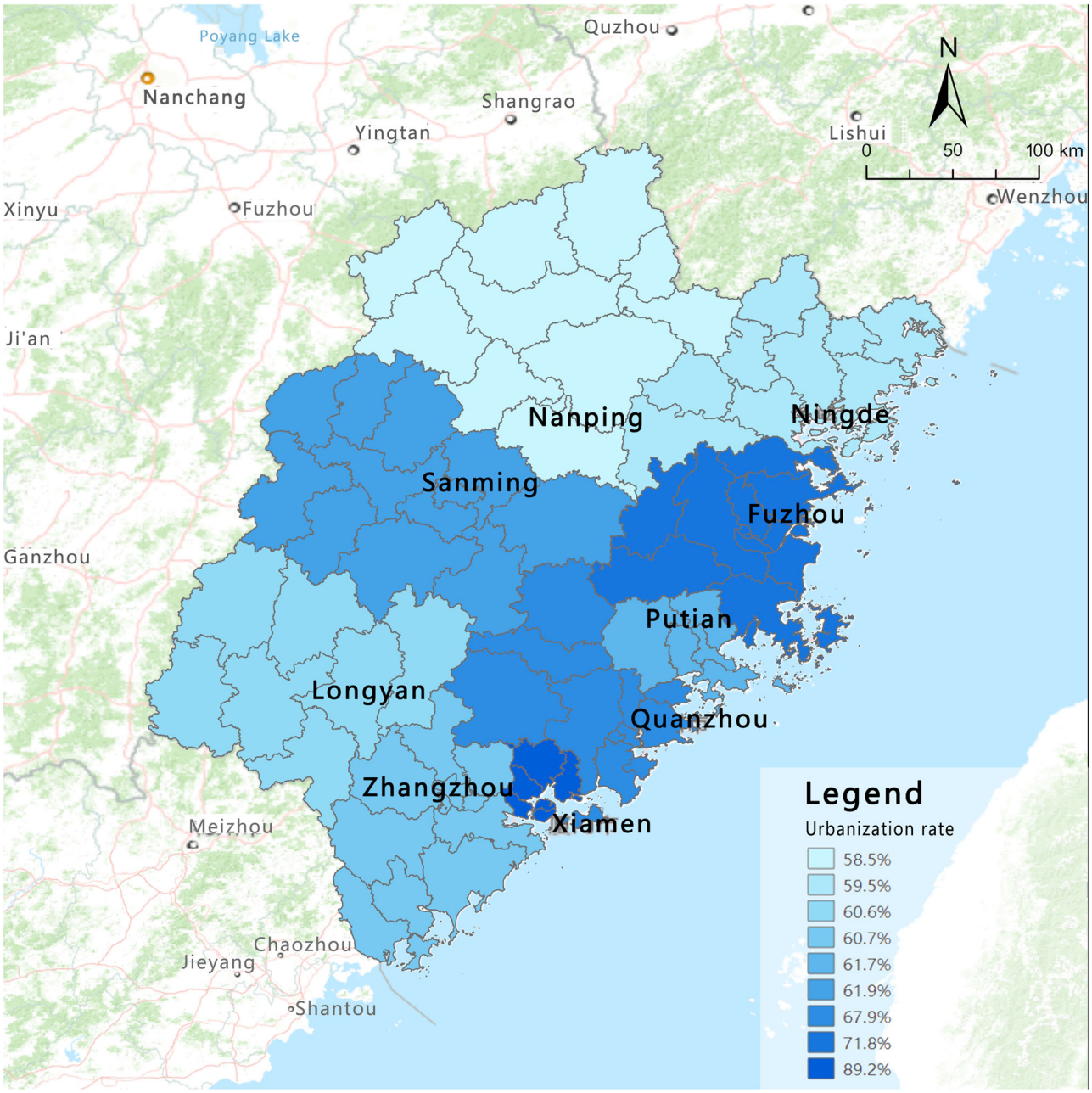


**Fig. 12 Urbanization rate of Fujian Province in 2020.** The color change from light blue to dark blue in the figure represents the change of urbanization in different regions, and overall reflects the distribution of urbanization rate in all regions of Fujian Province in 2020.

## Data availability

The website of the traditional village directory sources in Fujian Province: http://www.chuantongcunluo.com/. The website of spatial data sources in Fujian Province: https://www.gscloud.cn/. The website of social and economic data sources in Fujian Province: https://tjj.fujian.gov.cn/. In addition, see the Supplementary Dataset S1 for the list and coordinate data of traditional villages in Fujian Province.

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## Author contributions

Conceptualization: YM and QZ; methodology: YM, QZ, LH; writing—original draft preparation: YM and QZ; writing—review and editing: YM and LH; funding acquisition: YM and LH.

## Competing interests

The authors declare no competing interests.

## Additional information

**Supplementary information** The online version contains supplementary material available at https://doi.org/10.1057/s41599-023-02407-1.

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