

The spatial form of traditional villages in Fuzhou area of Jiangxi Province determined via GIS methods

Yapeng DUAN^{1,5}, Liangqing YAN¹, Ziling LAI³, Qianting CHEN², Youying SUN², Li ZHANG (✉)^{2,4,5}

¹ College of City Construction, Jiangxi Normal University, Nanchang 330022, China

² School of Geography and Environment, Jiangxi Normal University, Nanchang 330022, China

³ School of Architecture and Planning, Hunan University, Changsha 410082, China

⁴ Key Laboratory of Poyang Lake Wetland and Watershed Research,

Ministry of Education, Jiangxi Normal University, Nanchang 330022, China

⁵ Nanchang Base of International Centre on Space Technologies for Natural and Cultural Heritage under the Auspices of UNESCO, Nanchang 330022, China

© Higher Education Press 2022

Abstract Traditional villages are precious historical and cultural heritage. Here, we investigate Fuzhou area of Jiangxi Province, China, and consider 114 national-level and provincial-level traditional villages, applying fieldwork, historical document searches, GIS spatial analysis, spatial syntax analysis, and other methods to explore the spatial form characteristics of traditional villages in this area on a macroscopic and microscopic (individual) level, and the relationships between scales. It is found that on a macroscopic regional level, the spatial distribution of traditional villages is unevenly distributed at a low altitude and at a close proximity to water systems; while on a microscopic level, traditional villages are mainly small and medium-sized, with landscape environments mainly determined by eight different types of waterfront hills. Among the four types of village boundaries, there are more villages with finger-like characteristics, including finger-like villages with banded features and finger-like villages with cluster characteristics. The living environment patterns mostly determined by four different types of comb settlements due to the limitations of regional environments as well as the topographic and cultural factors. Our results are significant for the improved evolution, protection, and development of traditional villages such as those found in the Fuzhou area.

Keywords GIS technology, traditional villages, spatial form, Fuzhou area

1 Introduction

Traditional villages refer to those villages built in a long

Received May 28, 2021; accepted March 3, 2022

E-mail: zhanglinu@126.com

time, which have undergone a long historical evolution and are still mainly inhabited and engaged in agricultural production by farmers, and retain the traditional living forms and cultural forms. Traditional villages have long history, rich traditional resources, and important historical, cultural, scientific, artistic, social and economic values. Compared with other villages, the most distinctive features of traditional villages are the existing traditional architectural features are intact, the village site selection and pattern maintain traditional characteristics, and the intangible cultural heritage stays alive and well (Hu et al., 2014). Therefore, traditional villages in China provide important historical evidence for early humans who adapted and learned to live in harmony with nature in a period of time, representing the precious heritage left by Chinese ancestors to the future generations (Tong, 2014). The modern world has seen rapid economic development, industrialization, and urbanization, which has led to the gradual disappearance of regional and traditional ways of living. Thus, existing traditional villages face a serious existential threat. The protection of traditional villages and cultural heritage in China is a critical and ongoing effort. The protection of traditional village cultural resources has attracted wide attention from all sectors of society. Relevant governmental authorities of China began conducting survey and appraisal of “Chinese Traditional Villages” (defined as “traditional villages” hereafter) in 2012 and have already added 6819 traditional villages to their directory of traditional villages. The Jiangxi Provincial Department of Housing and Urban-Rural Development announced the first batch of 248 provincial-level traditional villages in August of 2017.

Modern research of Chinese traditional villages began

broadly in the 1980s, with significant findings coming from many fields of study. Investigations of the spatial form of traditional villages primarily focus on two areas (Fu and Huang, 2016): the spatial distribution patterns of traditional villages from a geographical perspective (Liu et al., 2014; Sun et al., 2017; Li et al., 2018a), and the spatial relationships with various elements within these traditional villages from an architectural perspective (Wang and Zhou, 2011). At the same time, with the development of spatial analysis computing theory and intelligent technology, a variety of spatial quantitative research ideas and methods produced in the fields of mathematics, computer science, and complex systematic science have gradually penetrated into village morphology research (Yang, 2020). Since the early 2000s, GIS has been applied to multiple levels of historical and cultural geography (Ebert, 2004; Lv and Guo, 2016). Combined with GIS spatial statistics methods, spatial patterns and their changes can be quantified (Entrikin, 2001; He et al., 2018). Space syntax can rationally and efficiently do quantitatively analyze on the settlement space from the spatial relationship point of view, so as to analyze and summarize the spatial structure of traditional villages. Fractal theory breaks the traditional method of qualitatively dividing the form of villages. It simplifies the complex and disordered village space into irregular geometric figures, and uses geometric eigenvalues to improve the accuracy of the description of village morphological characteristics (Li et al., 2020).

In summary, compared with traditional research methods, interdisciplinary quantitative analysis methods and mathematical models have expanded the ideas and fields of traditional village spatial morphology research (Deng et al., 2021). The depth and breadth of quantitative analysis methods of spatial morphology are also increasing. However, due to the lack of a large number of field verification samples and data, most traditional village studies are only limited to qualitative analysis, and do not study the characteristics of spatial form and law of villages from a quantitative perspective. Thus, we take Fuzhou area of Jiangxi Province, which contains many distinct cultural characteristics and prominent regional integrity as an example, apply the methods of GIS, space syntax and fractal geometry, and use a combination of qualitative and quantitative approaches to analyze the spatial distribution and spatial morphological characteristics of traditional villages in Fuzhou from a cultural geographic perspective, with the objective of providing improvements for the future protection, construction, and development of traditional villages.

2 Study area and data

2.1 Study area overview

Fuzhou City, located in eastern Jiangxi Province, China,

includes 11 counties and districts of Guangchang County, Nanfeng County, Lichuan County, Nancheng County, Zixi County, Jinxi County, Yihuang County, Chongren County, Le'an County, Lichuan District, and Dongxiang District (Fig. 1). The area has a subtropical monsoon climate with four distinct seasons (average temperature = 16.9°C/yr–18.2°C/yr), abundant rainfall (precipitation = 1600–1900 mm/yr) and sufficient sunlight (sunshine duration = 1582–1928.1 h/yr). The terrain of Fuzhou is high in south and low in north, surrounded by mountains in east, south and west, and gradually inclined to Poyang Lake Basin in north, forming a relatively closed environment. The landscape is complex, with mountains, hills, hillocks, and valley plains; hills are the dominant feature. The region has a dense network of river systems, with the Fuhe River and its tributaries being the major waterway.

Fuzhou area is within the Lichuan cultural region, a regional culture that is the product of the Jiangyou people from eastern Jiangxi Province. It appeared during the Qin and Han Dynasties, reached its peak during the Song Dynasty, and lasted up until the Ming and Qing Dynasties. The culture made brilliant achievements in education, literature, the arts, science, and other fields, and developed into a unique and prominent regional culture throughout the long course of its history. During the Ming and Qing Dynasties, the commodities economy of Fuzhou was dynamic. There are a large number of country fairs in Fuzhou, and in terms of their number and scale, they exceed the level of Yangtze River and Pearl River Delta during the same period (Li and Wang, 2002). Ancient post roads and rivers have built a bridge between merchants and the country fairs, providing the possibility for the prosperity of the market and long-term trade. So, a large accumulated wealth derived from highly developed trade networks, and a prosperous economy and commercial wealth which provided material guarantees for settlement construction. Overall, the unique physical geographic conditions and profound cultural deposits of the area gave rise to a unique settlement culture. There are numerous traditional villages in Fuzhou area that are densely distributed, creating distinct regional characteristics, which provide an ideal domain for the study of traditional villages in China.

2.2 Data sources

Fuzhou area had 96 designated national-level traditional Chinese villages as of December 2018, according to the Ministry of Housing and Urban-Rural Development of the People's Republic of China and 83 designated provincial-level traditional villages according to the Department of Housing and Urban-Rural Development of Jiangxi Province. Our study will analyze these two designated groups of villages, excluding duplicate data, with a total of 114 are considered. The location coordinates of traditional villages are queried using

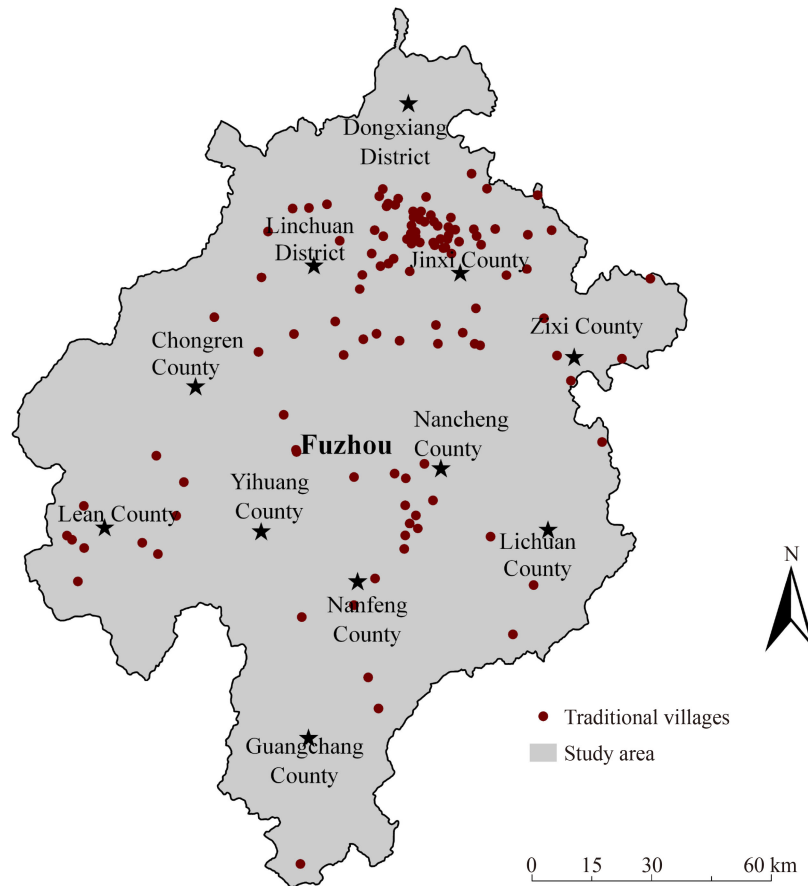


Fig. 1 Map of the Fuzhou area and traditional villages distribution.

Google Earth Pro; Digital Elevation Model (DEM) comes from the ASTER DEM digital elevation data set with a resolution of 30 m and the ALOS DEM digital elevation data set with a resolution of 12.5 m in the Geospatial Data Cloud. The water system data comes from the basic data set of 1:250000 in Jiangxi Province. Ancient post road comes from the Chinese Historical Atlas edited by Tan (1982).

3 Macroscopic regional level: spatial distribution characteristics of traditional villages

3.1 Overall spatial distribution of traditional villages

Heat map is good at showing where point features are concentrated. The kernel density method was used to calculate the heat map density. The work of kernel density is to calculate the density of point features around each output raster cell. So, we used the kernel density method (bandwidth = default value) to form a heat map of traditional villages in Fuzhou area (Fig. 2.). The layout of the spatial distribution of traditional villages is in clusters, with a single high-density cluster seen, and having an

uneven overall distribution. The high-density cluster is located in north region of Fuzhou, in Jinxi County. Jinxi County contains the most villages (52) of the 11 counties and districts considered here, accounting for 45.6% of the total. This area is located on flat land with an average elevation less than 100 m. The southern parts of Nancheng County and northern regions of Nanfeng County, as well as Le'an County, also have a noticeable but lesser density of traditional villages.

ArcGIS Pro can apply the closest proximity point index method, which displays traditional villages as abstract points to distinguish spatial types. We consider three types of spatial distribution which are typical in nature and society: random, dispersed, and clustered. Z-score (Z), or standard score, is the number of standard deviations a given data point lies above or below the mean. When $-1.65 < Z < 1.65$, the distribution is considered random; when $Z > 1.65$ it is a dispersed distribution and when $Z < -1.65$ it is a clustered distribution. Calculation of the closest proximity index for the 11 counties and districts showed that the highest proximity index of the traditional villages in the Fuzhou area was 0.813, signifying a random distribution. Statistical results (Table 1) of each county and district show that the traditional village distribution in Jinxi County is clustered and Nanfeng

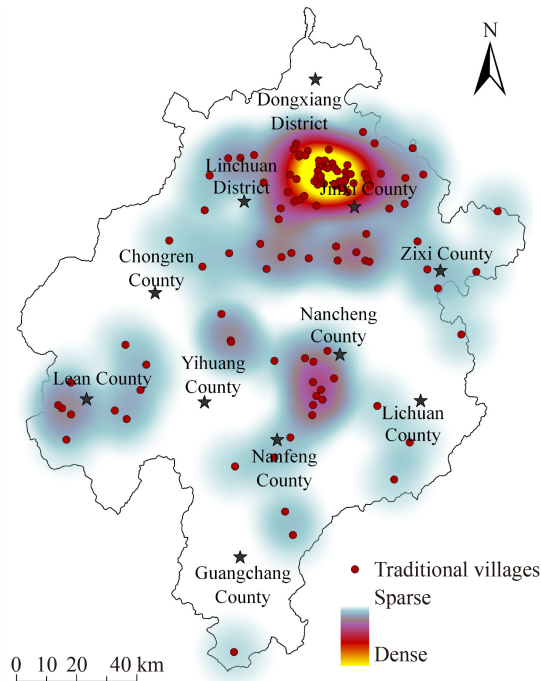


Fig. 2 Heat map of traditional villages in the Fuzhou area.

Table 1 Proximity index of the distribution of traditional villages in Fuzhou area

Name	Proximity ratio	Z score	P Value	Pattern
Chongren County	3.033539	7.780605	0.000000	Dispersed
Dongxiang District	1.918774	4.650383	0.000003	Dispersed
Linchuan District	1.450503	2.985517	0.002831	Dispersed
Le'an County	1.422900	2.427114	0.015219	Dispersed
Jinxi County	0.856687	-1.957948	0.050236	Clustered
Lichuan County	2.787669	6.839874	0.000000	Dispersed
Nancheng County	1.483323	2.923939	0.003456	Dispersed
Nanfeng County	1.290969	1.472744	0.140820	Random
Yihuang County	19.280350	60.572572	0.000000	Dispersed
Zixi County	2.412359	6.041724	0.000000	Dispersed

County is random, while the distribution in the other counties is classified as dispersed.

3.2 The relationship between landform and the spatial distribution of traditional villages

Altitude has a fundamental influence on the distribution of traditional villages, as increases of altitude bring decreases in air temperature and pressure. Settlements are thus constrained by ranges of temperature and pressure, they are “suitable” for human habitation. The east, south and west of Fuzhou area is surrounded by mountains, while central Fuzhou alternates between hills and basin valleys. The terrain is high in the north and low in the south, inclining gradually toward the plains of Poyang

Lake. The landforms here are complex, formed primarily of hills interspersed by mountains, hillocks, and valley plains. Mountainous areas with an altitude over 500 m account for 30% of the total area, hills between an altitude of 200–500 m account for 50%, and hillocks and valley plains below 200 m account for 20%.

ArcGIS Pro was used in combination with an elevation map to compare the spatial distribution of traditional villages in Fuzhou region, binning the results as a thematic map of elevation distribution between 0 and 200 m, 200–500 m, 500–1000 m and over 1000 m (Fig. 3). The average altitude of all traditional villages in the Fuzhou area is 258 m, lower than the area’s overall average altitude. 86% (98 villages) of the traditional villages in Fuzhou area are found in the hillocks and valley plains below 200 m, while 8% (9 villages) are found in the hilly areas between 200 and 500 m and around 6% (7 villages) are distributed in the mountainous areas between 500 and 1000 m. Plain areas and the low-lying slopes of hillocks are much better for construction and there are more resources of cultivatable land; therefore, the site selection of these villages and the suitability of these sites for human existence show clear connections.

3.3 Relationships between water systems and the spatial distribution of traditional villages

Water is one of the most important resources for human survival. When selecting a village site, people would therefore need to consider the relative abundance of water sources, and not exposing themselves to excessive flooding risk. Water systems provide humans with vital water sources, and they were also an important mode of transportation in traditional agricultural societies; therefore, there is a remarkably close relationship between the distribution of traditional villages and water systems.

Fuzhou area has well-developed water systems. The major water system of the region is Fuhe River and its tributaries, which cover the entire area. Tributaries of Ganjiang River and Xinjiang River are also prominent in Fuzhou. The Fuhe River is second only to Ganjiang River in Jiangxi Province, with a length of 349 km and a drainage area covering 15800 km². ArcGIS Pro was applied to map the current water systems in the Fuzhou area at the 500 m, 1000 m and 1500 m buffer boundaries and these maps were then combined with the traditional village distribution data to explore the relationships between traditional villages and water systems (Fig. 4). The majority of traditional villages in Fuzhou area are located beside water systems, with 84% (96 villages) found within a 500 m buffer zone from rivers. The remaining 16% of traditional villages are found within a range between 500 and 1500 m. Thus, all traditional villages are located within 1.5 km from water systems or tributaries.

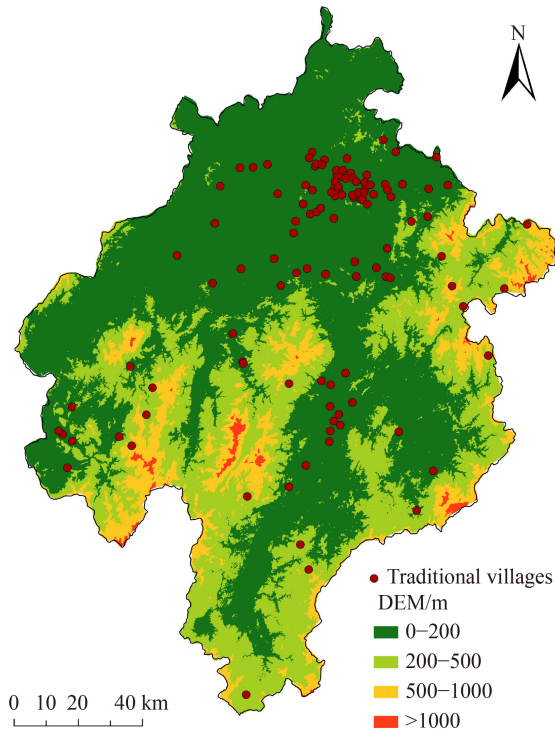


Fig. 3 Elevation distribution map of traditional villages in Fuzhou area.

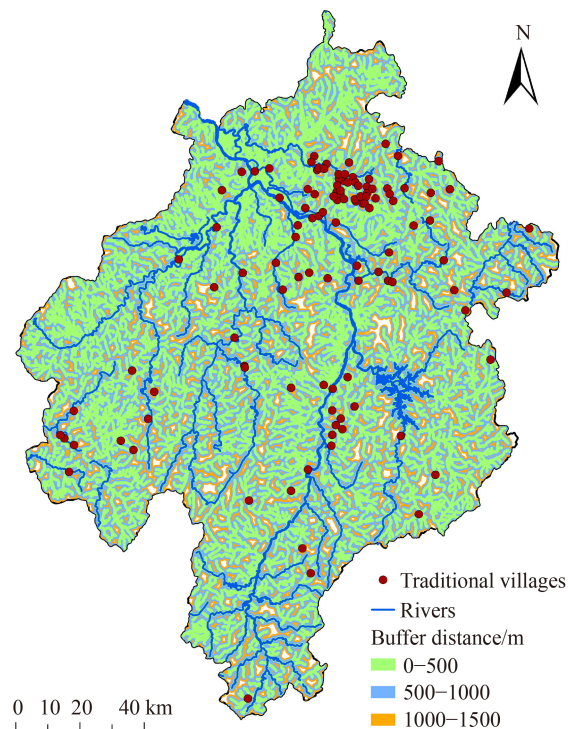


Fig. 4 Distribution map showing the relationship between traditional villages and water systems in Fuzhou area.

3.4 Spatially stratified heterogeneity analysis

Geographic detectors are statistical tools which can

explore spatial heterogeneity and reveal their determining factors (Wang et al., 2017). Geographic detectors are used here to study the main driving factors of traditional village distribution in Fuzhou. Geographic detectors employ multiple methods, including the measurement of stratified heterogeneity among data, testing of the coupling between two variables X and Y , and the investigation of the interactions between two explanatory variables $X1$ and $X2$ to a response variable Y , without any specific form of interaction. Each of the tasks can be accomplished by the Geodetector q -statistic:

$$q = 1 - \frac{\sum_h^L N_h \sigma_h^2}{N \sigma^2}, \quad (1)$$

where $h = 1, 2, \dots, L$ is the strata of variables X or Y , N and σ^2 represent the number of units and the variance of Y in, respectively. The value of q is limited to the interval of $[0, 1]$. The larger the value of q , the stronger the impact of independent variable X on dependent variable Y . This method is used to study the main driving factors which influence the distribution of traditional villages. The DEM ($X1$) and the river system ($X2$) are used to investigate the spatially stratified heterogeneity of the traditional villages. These results show that both DEM and water system distribution significantly affect the spatial distribution of traditional villages, and the influence of elevation is greater than that of water system proximity (Table 2). In other words, people first prefer to settle in a flat area, and then consider the distance of the water system.

4 Microscopic (individual) level: morphological characteristics of traditional villages in Fuzhou area

From the micro level or the individual level, we study the four aspects of the traditional village morphology, the village scale, the village landing appearance, the village boundary form and the village living patterns.

4.1 Village scale

The morphological contours of the 114 villages are sketched on Google Earth and input into the GIS system to determine the scale of each village. The size distribution of the scale of traditional villages in Fuzhou area is split into 0–10, 10–20, and 20–40 km² and classified as small, medium, and large, respectively. Statistical results show that the majority of traditional villages in the Fuzhou area are of medium or small scale, with large-scale villages accounting for only around 10%. An example of a medium-scale village, Dongyuan Village in Jinxi County, is shown in Fig. 5. The majority of counties and districts have on average one or two large-scale

Table 2 Geographical detection of influencing factors affecting the spatial distribution of traditional villages

	Dem	River system
<i>q</i> statistics	0.54	0.10
<i>p</i> value	0.000	0.000

settlements which are relatively equally distributed regionally. There are 11 large-scale villages in total, including Huwan Village in Jinxi County, Liyang Village in Dongxiang District, Shangtang Village in Nancheng County, among others. The majority of these 11 traditional villages are located in market towns. The scale of settlements is determined by physical geographic conditions, and as the area is limited by its landform, cultivated land resources, and other conditions. Overall, the majority of settlements considered here are medium to small.

4.2 Village landscape

Early settlers in China placed utmost importance on the landscape of the area. On one hand, the village's surroundings were influenced by physical geographic features, and on the other hand, people were influenced by traditional Chinese concept of *feng shui*. The concept of *feng shui* embodies ancient Chinese understanding of physical geography and the rational utilization of terrain, wind, water, etc., which advocates a harmonious coexistence with nature. The ideal model for selecting the site of a village under the *feng shui* perspective is "mountains behind and water in front" (Chen and Song, 2009). Thus, many village sites were selected with a mountain to the back or built beneath a hillock, with a natural water source in front or excavated ponds, which can form a three-way spatial landscape consisting of a water body, followed by the village itself, and then the mountains or raised land behind it.

We use ArcGIS Pro to convert the DEM raster data (12.5 m resolution) in Fuzhou City into contour lines with a spacing of 50 m, to display the terrain elevation around traditional villages. The buffer analysis tool of ArcGIS Pro is used to limit the distance to 1 km around the traditional village as a buffer, and environmental factors

**Fig. 5** A medium-scale village example: Dongyuan Village.

such as the water system and mountains within 1 km of the village are considered. Fuzhou area has a complex topography and geomorphology, and a large overall elevation range. Thus, we here define three distinct classifications. When the absolute elevation of the surrounding environment of the village is less than 500 m and the relative height difference within the 1 km buffer area around the village is less than or equal to 50 m, it is a "flat" (D1) village. When the absolute elevation is less than 500 m and the relative elevation difference in the surrounding 1 km buffer area is greater than 50 m, it is a "hilly" (D2) village. When the absolute elevation of the surrounding environment of the village is greater than 500 m, it is a "mountain" (D3) village. The water system in Fuzhou is well-developed, and the location of traditional villages is highly correlated with water bodies. Villages with rivers and lakes within 1 km are classified as villages W1, villages with ponds within 1 km are classified as villages W2, and villages without water systems or ponds within 1 km are classified as villages W3. With the overall consideration of elevation and water systems, we classified Fuzhou's traditional village environments into eight modes: D1W1 (flat river banks), D1W2 (flat land with ponds), D1W3 (flat land on all sides), D2W1 (river bank hillocks), D2W2 (hillocks behind and ponds in front), D2W3 (hillocks on all sides), D3W1 (mountains behind and water in front) type, D3W3 (mountains on all sides). Figure 6 shows examples of each of these types.

4.3 Village boundary morphology

The boundary of the spatial shape of the village can be quantitatively described by the cluster shape, the band shape, and the shape index. The value of the aspect ratio of the village boundary (indicated by λ) is expressed as the length and narrowness of the village boundary (Xie, 2015). We extract the various endpoints of village elements such as buildings, courtyard walls, and structures, and connect the enclosed two-dimensional closed figure planes as the village boundary (Cao and Zhu, 2019). We use "b" to represent the longest axial distance between any two endpoints of the boundary and "a" to represent the shortest distance between the two ends of the boundary; the intersection angle between the long axis and the short axis is constrained to be between 70° and 110°. The specific calculation of λ is:

$$\lambda = \frac{b}{a}, \quad (2)$$

When the traditional village boundaries are round or square, the value of λ of the village is closer to 1 (Xie et al., 2015); when the value of λ is larger, the village boundary graphics tends to be more banded. Therefore, we set $\lambda = 2$ as a critical point. If the value of λ is greater than 2, the spatial morphology of the village tends to be band-shaped;

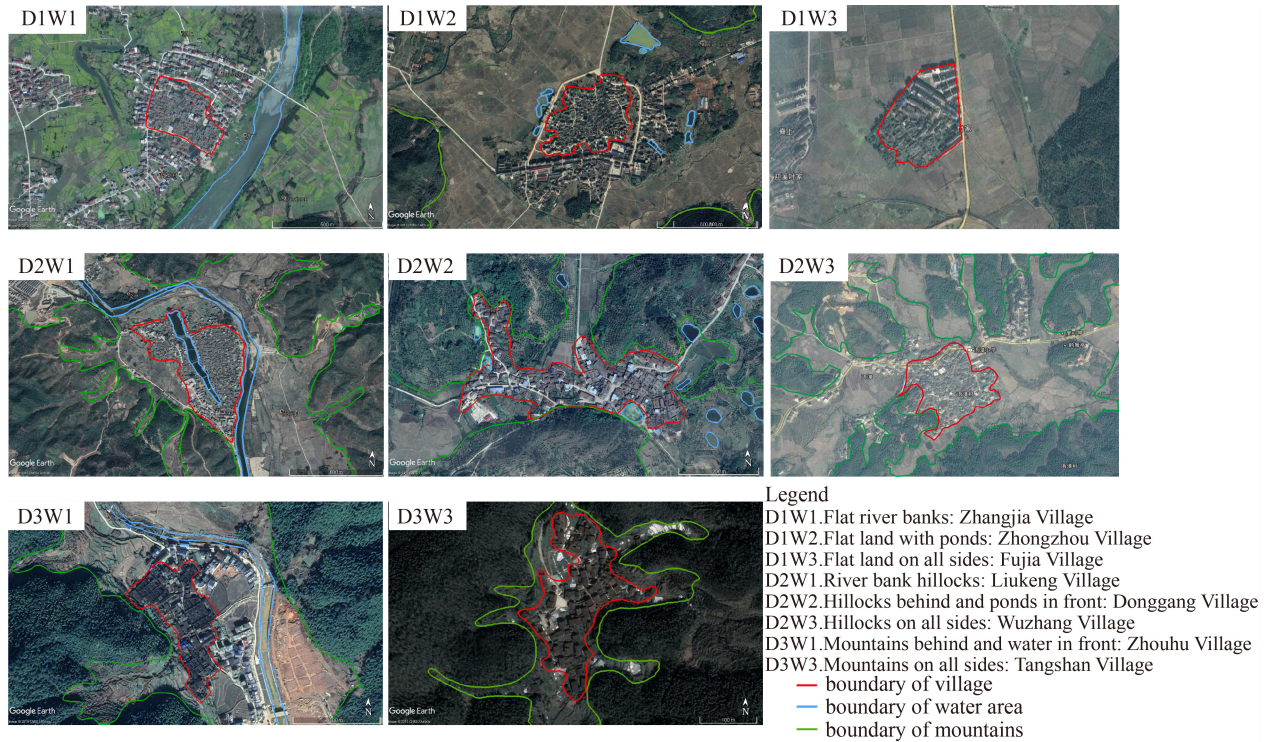


Fig. 6 Examples of landscape classifications of traditional villages.

if the value of λ is less than 2, the spatial morphology of the village tends to be cluster-shaped.

The village shape index can reflect the unevenness of the village boundary and the overall irregularity. The larger the value of the shape index, the more irregular the village boundary, according to

$$S = \frac{P}{(1.5\lambda - \sqrt{\lambda} + 1.5)} \sqrt{\frac{\lambda}{A\pi}}, \quad (3)$$

where S is the shape index of the village boundary, P is the perimeter of the village boundary shape, λ is the aspect ratio of the village boundary shape, and A is the area of the village boundary shape (Li et al., 2018b). The minimum value of the shape index, S , is 1. When the value of the shape index is close to 1, the shape of the village boundary approximates a circle; when the value of the shape index is greater than 1, the shape of the village boundary is more complex and irregular (Wang, 2006). Our results in Fuzhou area show that when the shape index is greater than 1.5 ($S > 1.5$), the village boundary shape has a finger-like divergence pattern. Therefore, the village with a shape index greater than 1.5 ($S > 1.5$) is defined as a finger-shaped village.

The combination of the above-defined indicators leads to four rough categories, “lumpy villages”, “banded villages”, “finger-like villages with banded features”, and “finger-like villages with cluster characteristics” (Fig. 7; Table 3).

According to statistical analysis of all the traditional

villages, 41% of the villages are generally finger-shaped and have the largest number. Lumpy shaped villages and band shaped villages divide the remaining part equally.

4.4 Village living patterns

The general form of traditional villages in Fuzhou area is based on a history of clans living together with a centralized distribution. The theory of spatial syntax can be used to select several distinct types of typical villages to draw axis models, and villages can be roughly divided into “comb”, “row”, “crisscross” and “freestyle” living forms according to their synergy values (Table 4). Synergy represents the relationship between local integration degree ($R = 3$) and global integration degree ($R = n$), expresses the degree of connection between local space and overall space and measures the degree of synergy via correlation analysis using scatterplots. The closer the correlation value (R^2) of synergy is to 1, the closer the space tends to be a single core space, and if closer to 0, the overall layout and optimization strategy is weaker (Chen et al., 2018). When R^2 is about 0.7, there is a significant correlation between the two variables, and the village living pattern is closest to a single-core space layout. When R^2 is about 0.5, there is a general correlation between the two variables, and the village living pattern is relatively close to a single core. When R^2 is about 0.3, there is a lower correlation between the two variables, the village residence pattern is a crisscross layout close to a multicore space, and when R^2 is about

Name	Village boundary	Parameter index	Shape type
Qiawan Village		$S=1.0605$ $\lambda=1.4234$	Lumpy village
Menloulijia Village		$S=1.0697$ $\lambda=3.6520$	Band village
Chenfang Village		$S=1.8323$ $\lambda=4.7809$	Finger-like village with banded features
Dulan Village		$S=2.4686$ $\lambda=1.5587$	Finger-like village with cluster characteristics

Fig. 7 Schematic diagram of four typical village boundary morphologies.

Table 3 Dividing parameters of village boundary morphology

Parameter index	Shape type	Proportion
$1 < \lambda < 2, S < 1.5$	Lumpy village	29.82%
$1 < \lambda < 2, S > 1.5$	Band village	28.95%
$\lambda > 2, S < 1.5$	Finger-like village with banded features	20.18%
$\lambda > 2, S > 1.5$	Finger-like village with cluster characteristics	21.05%

Table 4 The synergy of village living patterns

Morphological types of residence	Typical villages	Synergy ($R = 3$ intake)
Comb	Youdian village	0.5304
	Zhuqiao village	0.4870
	Shukou village	0.5110
Row	Meikeng village	0.7317
	Diaoyuan village	0.7699
	Wenshi village	0.8240
Crisscross	Zhongzhou village	0.2936
	Wangjia village	0.3003
	Yixi village	0.2859
Free-style	Guzhu village	0.1236
	Chouxu village	0.1564
	Tangshan village	0.1167

0.1, the village living form is a freestyle layout closest to a multicore space. In summary, traditional villages can be divided into four types of living patterns: comb (i.e., columns), rows, crisscross, and freestyle (Fig. 8).

Comb-type settlements have been extensively studied in Guangdong Province (Hong, 2018). However, Fuzhou area of Jiangxi Province has not received as much attention. Comb settlements in Fuzhou area of Jiangxi Province have similar morphological characteristics to the comb settlements in Guangfu area of Guangdong

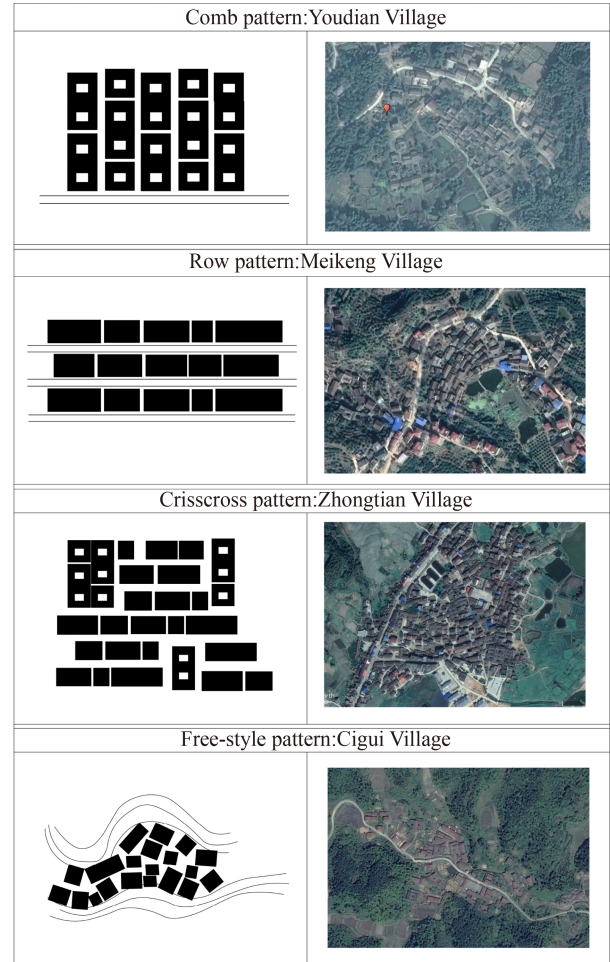


Fig. 8 Schematic diagram of the living patterns of traditional villages in the Fuzhou area.

Province, with a structured shape. The street texture is in a “one horizontal, many vertical” layout, with a main street in front of the village and several lanes distributed perpendicular to the main street, parallel to the prevailing wind direction in summer and planned so as to adapt to the local climate. Another feature of the comb layout is that living units are arranged in depth, with the layout of living units running parallel in the direction that the lanes extend. This layout is suitable for an environment that has mountains behind and a water system in front, and where the terrain is low in front and high in back, as it helps drain the water into the excavated ponds in front of the village. The layout of row settlements is neat and orderly and differs from comb settlements in that the living units are arranged in horizontal rows, with the lanes orientated in the same direction as the rows of living units and the living units face the streets. Planning for the layout of crisscross settlements has characteristics of both the comb and row patterns, with the lanes distributed in a grid shape and present at either side of or in front of living units. The freestyle layout is when the layout of the

buildings is more dispersed with lanes irregularly distributed at random.

The traditional villages in the Fuzhou area are primarily of the comb pattern and distributed over most of the Fuzhou area. There are only two traditional villages of a row pattern in Fuzhou and neighboring Ji'an area. The layout of row pattern villages is more traditional in the Ji'an area. Crisscrossing layout villages occur primarily in mountainous areas and are also relatively small in number.

5 Relationships between the macroscopic regional level and microscopic individual level of traditional villages

The characteristics of traditional villages in Fuzhou were analyzed above from a macro-regional distribution perspective (topography and water system) and a micro-village morphology perspective (the scale, the village landscape environment, the village boundary morphology and the village living form). However, there are many factors that can affect the morphology of the traditional villages. These include natural and geographical factors, social and human factors, and policy factors. Temporal correlations of macro-distribution characteristics, micro-morphological characteristics and influencing factors are investigated here to determine formation patterns of traditional villages. Its formation mode is determined, and its spatial distribution and its relationship with the natural environment are revealed.

We first combine the scale distribution map with elevation maps, water system maps and ancient road maps (Fig. 9). Although most traditional villages in Fuzhou are small and medium-sized, larger villages are generally located in flat areas with lower elevations and are located close to water systems and traffic arteries. This is due to the fact that ancient transportation relied on water and land transportation. The economy was highly developed with convenient transportation and the population was concentrated, and large-scale villages were able to develop.

We next compare village landscape maps with elevation, water systems and ancient post roads. There are six types of village landscape patterns found in low elevation areas (average elevation <500 m), while two main types were generally found in relatively higher elevation areas (average elevation >500 m). The low elevation types are D1W1, D1W2, D1W3, D2W1, D2W2, D2W3, while the relatively high elevation types are only D3W1 and D3W3. Thus, the microscopic landscape of the village is consistent with the macroscopic topography, but different kinds of landscapes exist in different places due to the differences in the micro-topography.

Next, we compare living patterns map combined with elevation, water system and ancient post roads (Fig. 10). This investigation shows that free-style settlements are mainly located in areas with higher altitudes and are greatly affected by topographical factors. The other three kinds of patterns were mostly distributed in low-altitude areas.

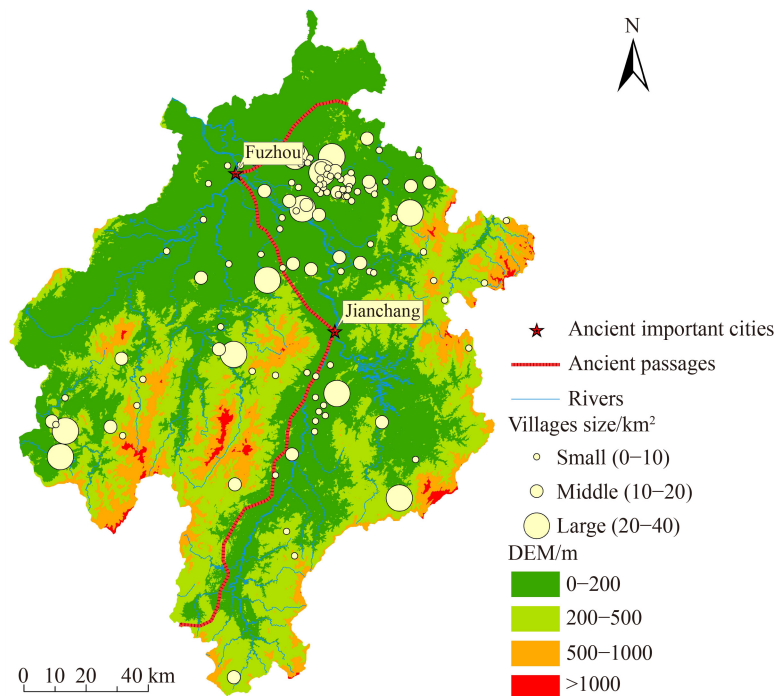


Fig. 9 Schematic diagram of the scale distribution of traditional villages in Fuzhou.

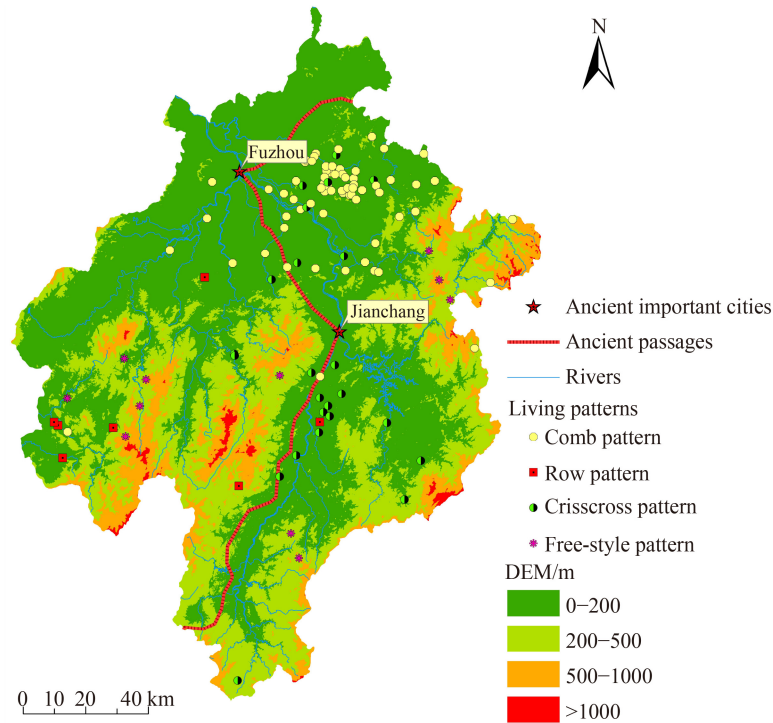


Fig. 10 Living patterns of traditional villages related to their surrounding natural environments in the Fuzhou area.

We sum the number of different village scales in different living patterns to study the relationship between village scale and living patterns (Table 5). Villages with crisscross patterns are mostly found in middle or large-scale villages, as these village patterns are mostly located along rivers or close to traffic arteries which are economically developed, and because village construction was mainly affected by different cultural and economic factors, which, over time, led to larger village size. The scale of free-style patterned villages is mostly small, due to surrounding terrain restrictions and insufficient arable area.

The percentage of different living landscapes in different living patterns is presented as a pie chart in Fig. 11. Most of the villages with crisscross patterns are of the D1W1, D1W2, and D2W1 types, generally close to water systems. Freestyle-patterned villages were mainly found in mountainous regions and are affected by topographical factors. Comb and row patterned villages were widely distributed among mountain and water environments, meaning that topography was not the decisive factor for these village patterns.

There are two major factors affect living patterns: the natural geographical factors and social or human factors. Fuzhou is part of the greater Linchuan cultural area, and Jiangxi Province was the birthplace of neo-Confucianism thought. Thus, this area was profoundly affected by Confucian ritual culture with a corresponding importance given to compact layouts, a keen sense of order. The orderly formation of the comb layout of traditional villages is a material reflection of the spatial order of

Table 5 Counts of different village scales in different living patterns

Living patterns	Small	Middle	Large
Comb	49	17	3
Row	3	5	1
Crisscross	12	6	7
Free-style	10	1	0

ritual culture, and a spatial expression of social order. This area has also been heavily influenced by cultural communication. Linchuan, Jinxi, and Dongxiang belonged to the core area of Linchuan culture, while Le’an, Guangchang, and Lichuan belonged to marginal areas of culture. Le’an County is greatly influenced by the adjacent culture of Luling. Comb pattern villages were the main living pattern used in the Linchuan Cultural Area which reflected its distinctive regional cultural characteristics. Row pattern villages are mainly located in Le’an County, which is adjacent to the Luling Culture Area, and is influenced by this culture.

A superposition analysis of the village landscape environment, village boundary morphology, and village scale found that 90% of the villages in Fuzhou are located in areas near water systems and are in flat and hilly areas with an altitude of less than 500 m; very few are located in the mountains. Areas far away from water systems are still found at lower elevations (below 700 m,) and the distance to water systems is always within 1500 m. The landscape environment type of the most villages in Fuzhou is D2W1(river bank hillocks), accounting for

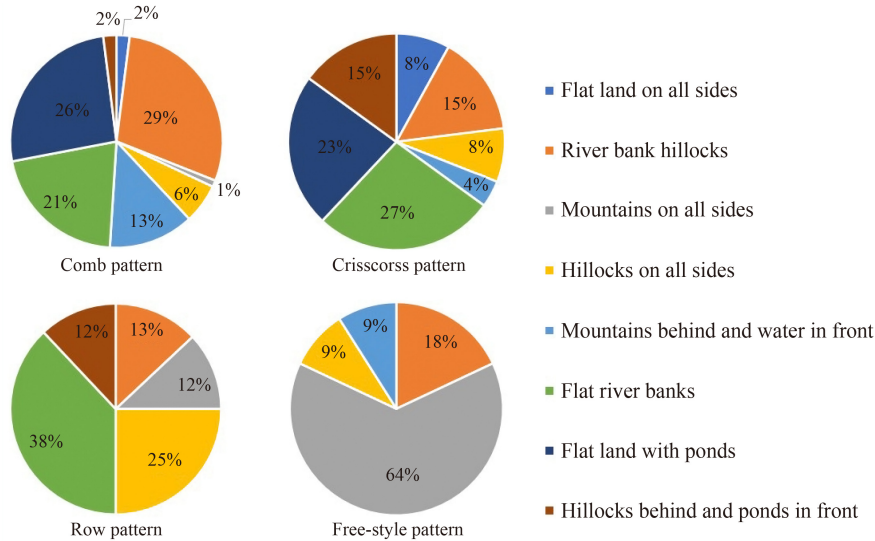


Fig. 11 Living landscapes in different living patterns of traditional villages.

40.36%, the second is D2W2 (Hillocks behind and ponds in front), accounting for 28.07%, and D1W1 (flat river banks) is next, accounting for 15.78%. The D1W3 (flat land on all sides) type is the least common, which only accounts for 0.87%. This is due to the fact that the topography of Fuzhou area is dominated by hillocks. Even if it is far away from rivers and lakes, there are usually common ponds found around the villages.

Most of the traditional villages in Fuzhou have the forms of finger-shape boundaries. 76.6% of the finger-shaped villages are surrounded by hilly landform, and 23.4% of the finger-shaped villages are located in flat areas. Due to its cohesive nature within the settlement and because it is not restricted by the topography during the expansion process, the irregularity of the village boundary is weaker, and the boundary of the village in the flat terrain is often more “lumpy”. Villages in the form of “belt” are generally affected by water systems. They are built along the river, and their expansion is limited by the water system, presenting a zonal boundary shape. The boundary morphology of villages in hilly areas or mountain areas tends to be finger-shaped due to the influence of topography, especially in mountainous environments and river ravine areas. The elevation difference limits the free expansion of the village boundary and even the village size, which will also result in small village sizes in general.

If we only consider large-scale villages, we find 12 large villages with an area of more than 20 km², which are all located in hilly or flat areas, and 92% are close to water systems. There are four types of landscape environment found for large-scale villages: D1W1 (flat river banks), D2W1 (riverbank hillocks), D2W2 (hillocks behind and ponds in front), and D2W3 (Hillocks on all sides). There are also a sizable number of large-scale villages of the D2W1 (riverbank hillocks) type, and the D2W2 (hillocks behind and ponds in front) type. The

low-altitude hill landform has little restriction on the expansion of the village, and sufficient water resources ensure the environmental capacity of the village. Villages near rivers can also meet the transportation needs of the villages. Therefore, hills near the water system are the environmental foundation for the development of most large villages in Fuzhou. Flat land is relatively rare in the macro-topography of Fuzhou, but it is the environment where most large villages are found (Fig. 12). We thus conclude here that the location of large villages in Fuzhou is biased toward low-altitude, hillock, or flat land near water systems.

Finally, there is an uneven spatial distribution of traditional villages in the counties and districts of Fuzhou, with Jinxi County forming a high-density cluster. This is due to two main reasons. First, this area is located on plains and hillocks, and the number of traditional villages here was high to start with. Second, there was a special fund of 220000 yuan each year to reward individuals who repair ancient buildings and a total of more than 100 million yuan was secured for the protection of various cultural relics which led to the restoration of a large number of ancient buildings in Jinxi County. Thus, effective government policies and a variety of energetic approaches helped to formulate this “Jinxi model”, which has helped to preserve a large quantity of traditional villages.

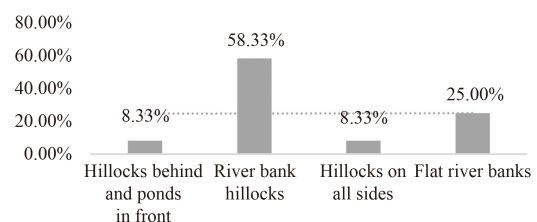


Fig. 12 Types of landscapes in villages larger than 20 km².

6 Conclusions

The spatial relationship of traditional villages developed over thousands of years was the combined result of people adapting to production and living, their spiritual, social, and cultural needs, and specific physical geographic conditions. We have here applied GIS technology using qualitative and quantitative methods to conduct analyses on both macroscopic and microscopic levels to the morphological characteristics of the traditional villages in the Fuzhou area. Our study found the following conclusions.

1) The spatial distribution of traditional villages on the macroscopic regional level is unevenly distributed, generally found at low elevation, and typically seen in close proximity to water systems. A high-density area is found in Jinxi County, owing to strong protection and restoration policies. The majority of traditional villages on a microscopic (individual) level are medium to small scale, with eight different landscape classifications. Village layouts are primarily comb-like patterns.

2) Village scales are limited by physical geographic conditions and economic and cultural factors. The limitations of the hilly terrain and dense population led to the majority of traditional villages in this area being medium to small scale, with the majority of large-scale villages appearing as market towns located in the low altitude and being close to water areas and traffic arteries.

3) The micro landscape environment of village site selection is consistent with the macro topography, but due to the difference of micro landforms, village landscapes are primarily dictated by the rich variety of landforms in Fuzhou area. However, the majority of villages were based on the “mountains behind, water in front” model, which is influenced by the traditional Chinese concept of *feng shui* and the desire to build habitats that are suitable for living.

4) The boundary morphology and scale of villages are greatly affected by proximity to water systems and elevation of the surrounding environment. Village boundaries in flat areas tend to be clumped or finger-shaped, while village boundaries near water systems tend to be belt-shaped. When the village is located in mountains and hills, the border of the village has a high degree of irregularity due to the influence of the topography, and is also affected by local water systems, especially river gulleys. Thus, the overall border morphology of these villages which often are finger-like villages with cluster characteristics.

5) The primary living pattern of traditional villages in Fuzhou is the comb pattern. Free-style and crisscross pattern villages are greatly affected by terrain factors. Crisscross patterns are often found in large scale villages, while free-style patterns are often found in smaller villages located in high-altitude areas, as their expansion is limited by local landform environments. Conversely, comb and row pattern villages are more affected by

cultural factors. Comb pattern villages are typically located in the core cultural area, while row pattern villages are typically located in the cultural outskirts areas.

Acknowledgments This work was supported by the National Natural Science Foundation of China (Grant Nos. 41701514 and 52068034), Natural Science Foundation of Jiangxi (No. 20161BAB213074), and Key Laboratory of Poyang Lake Wetland and Watershed Research (Jiangxi Normal University), Ministry of Education (Nos. PK2021007 and PK2017005).

References

- Chen D B, Song Y H (2009). On the ecological significance of the *Feng shui* ideal living model in China. *Shanxi Archit*, (35): 22–23
- Chen J K, Wang T W, Liang Z Y (2018). Business layout of traditional villages based on spatial analysis and optimization strategies – a case study of Zhaji village in Anhui Province. *Archit Culture*, (8): 165–167
- Chen Y H (2021). Analysis of the spatial structure of traditional villages from the perspective of space syntax: taking Gaotiankeng Village as an example. *Beauty and Times (Urban Edition)*, (10): 35–37
- Cao W, Zhu P H (2019). Quantitative evaluation of town master planning boundary based on fractal theory. *Urban Develop Res*, 26(8): 18–22
- Deng Y Y, Fu X X, Zheng W W, Zhang H B (2021). Representation, measurement and attribution of spatial order of traditional villages in southern Hunan. *Geogr Res*, 40(10): 2722–2742
- Entrikin J N, Paul C Adams, Karen E Till (2001). *Exploring Humanist Geographies*. Chicago: University of Minnesota Press
- Ebert D (2004). Applications of archaeological GIS. *Can J Archaeol*, (28): 319–341
- Fu J, Huang D (2016). Research on the traditional villages morphology pattern of Zengcheng, Guangzhou City based on the GIS spatial analysis. *South Architect*, (4): 80–85
- Hu Y, Chen S, Cao W, Cao C Z (2014). The concept and cultural connotation of traditional villages. *Urban Stud*, (21): 10–13
- He S Y, Zheng H, Tang Z (2018). A research on the construction of urban historical and cultural heritage management information system based on GIS. *Guangdong U Techn*, (35): 38–44
- Hong Y L (2018). Research on the comb shape villages in canton conference during the Qing dynasty. Dissertation for the Doctoral Degree. Guangzhou: South China University of Technology
- Liu D J, Hu J, Chen J Z, Xu X T (2014). Research on the spatial distribution pattern of Chinese traditional villages. *Chin Populat Resour Environ*, (24): 157–162
- Li D H, Xu C, Yang L, Ruan Y R (2018). (2018). Study on the spatial morphology of Lahu ethnic villages in Lancang County based on the quantitative analysis of settlements. *J Yunnan Agricult U (Social Science)*, 12(6): 22–28
- Li M, Rui Y, Wang C X, Ji Y, Li Y N (2018). Spatial distribution and influencing factors of traditional villages: a case of Wuyue Culture Region. *Res Environ Yangtze Basin*, (27): 1693–1702
- Li W D, Wang G Q (2002). View on the development of country fairs

- of Fuzhou in Ming and Qing Dynasties. *J Jiangxi Agricul U*, 1(2): 88–92
- Li Y T, Zhu Y Q, Zhou Y, Sun Z Q (2020). Quantitative study of the spatial morphological characteristics of villages based on fractal theory: Nanning Village as an example. *Southern Archit*, (5): 64–69
- Lv M J, Guo W J (2016). The dynamic hierarchy and spatial differentiation of rural settlements in resource-based region. *Econ Geogr*, (36): 126–134
- Sun J T, Niu J J, Zhang K K, Shao X Y (2017). Spatial distribution and influential factors of traditional villages in Shanxi. *Human Geogr*, (32): 102–107
- Tong Y Q (2014). Research on the spatial differentiation of Chinese traditional village based on GIS. *Human Geogr*, 29(4): 44–51
- Tan Q X (1982). *The Historical Atlas of China*. Beijing: SinoMaps Press
- Wang T (2006). Comparative study on the landscape pattern of different restoration watersheds in hilly-gully region of loess plateau. Dissertation for the Doctoral Degree. Yangling: Northwest A&F University
- Wang X W, Zhou J (2011). The evolution of traditional village pattern: case study of Liang Village in Shanxi. *Modern Urban Res*, 26(4): 30–36
- Wang H Q, Yuan J D, Meng X J (2017). Spatial distribution and its influencing factors of level-a scenic spots in Northeast China. *Sci Geograph Sin*, 37(6): 895–903
- Xie D (2015). Study on spatial morphology of rural settlement in northern Dissertation for the Doctoral Degree. Haikou: Hainan University
- Xie D, Pei B J, Yang D H (2015). Quantitative research on the spatial form of rural settlement in northern Hainan. *Nat Sci J Hainan U*, 33 (3): 277
- Yang X (2020). Advances in quantitative research methodologies for the spatial layout of rural settlement in recent 20 years. *Urban Plann Inter*, 35(4): 72–80