J. Resour. Ecol. 2023 14(1): 137-146
DOI: 10.5814/j.issn.1674-764x.2023.01.013
www.jorae.cn

The Landscape Pattern Characteristics and Spatial Distribution of the Rural Settlements in the Hejiang River Basin

YANG Baoqi[1], SONG Shuqiao[2,*], QIN Jing[1]

1. School of Geography and Planning, Nanning Normal University, Nanning 530001, China;
2. School of Environmental and Life Sciences, Nanning Normal University, Nanning 530001, China

Abstract: Analyzing the landscape pattern of rural settlements is an important way to reveal the relationships between landscape change and human activities. Based on Landsat TM/ETM/OLI satellite remote sensing images as data sources and Hejiang River Basin as the research area, this paper expounds the information on the spatial distribution of rural settlements at four time points in 1990, 2000, 2010 and 2020. Using the methods of landscape pattern analysis, GIS spatial analysis and spatial statistics, this paper analyzes the spatial characteristics of the rural settlements, such as scale, distribution and shape, and then discusses the influences of terrain, rivers, location and policy factors on the spatial characteristics of the rural settlements. The results show that with the advance of time, the number of rural settlement patches in Hejiang River Basin is decreasing, the patch area and average patch area are increasing, the patch density is decreasing, and the settlement pattern tends toward cluster development. In addition, the shapes of settlement patches tend to be complicated and irregular, so it is necessary to strengthen planning and guidance in order to promote the regular layout of the settlements. The overall distribution of settlements is dense in the Northwest and Southeast, but sparse in the Middle and West, with a high density in the plains and a low density in hills and mountains. This study found that the terrain, river and location factors have significant influences on the spatial pattern of settlements.

Key words: rural settlements; landscape pattern; spatial distribution; Hejiang River Basin

1 Introduction

Settlements are various forms of living places built by human beings for production and living, which can be divided into urban settlements and rural settlements. From the perspective of geography, rural settlements are the products of the development of agricultural society at a certain stage. They refer to the gathering places of the population that is living in rural areas and mainly engaged in agricultural production, and include two geographical types, villages and towns. Research on rural settlements has long been the core content of rural geography, and it is also one of the important fields of the regional system of man-land relationships (Wu, 1991). The discussion on rural settlements represents the implementation of the "rural revitalization strategy" proposed at the 19th National Congress of the Communist Party of China. In recent years, with the acceleration of China's urbanization process and the continuous advancement of the construction of the new countryside, the social and economic forms of the vast rural areas have undergone drastic changes and transformation. Space is the carrier of social and economic development and an important component of rural space. Analyzing the landscape pattern of rural settlements is an important way to reveal the relationships between landscape change and human activities.

Since the 19th century, research on rural settlements in the field of geography has gone through the stages of an

Received: 2021-07-11 **Accepted:** 2022-04-27
Foundation: The BaGui Scholars Program of Guangxi Zhuang Autonomous Region (2019BG04).
First author: YANG Baoqi, E-mail: ybaoqi66@163.com
***Corresponding author:** SONG Shuqiao, E-mail: sshuq@163.com

Citation: YANG Baoqi, SONG Shuqiao, QIN Jing. 2023. The Landscape Pattern Characteristics and Spatial Distribution of the Rural Settlements in the Hejiang River Basin. *Journal of Resources and Ecology*, 14(1): 137–146.

embryonic start, preliminary development, expansion and reform, and then entered the stage of transformation and reconstruction at the end of the 20th century. It mainly presents the following two characteristics. First, the research content has become increasingly diversified and involves a wide range of elements; and second, the research method has been transformed from spatial analysis into the social and humanistic direction and multidisciplinary integrated research (Li and Zhang, 2012). So far, the research contents of domestic and foreign scholars have focused on rural settlement types and forms (Beatrice, 1944; Marshall, 1966; Han and Cai, 2011), rural settlement land use (Vesterby and Krupa, 2002; Gan et al., 2004), rural settlement landscape (Young, 1999; Xie et al., 2003; Ren et al., 2016), rural settlement ecology (Liu et al., 2001; McKenzie et al., 2011), and rural settlement reconstruction (Kiss, 2000; Long, 2013), and related topics. The research methods include GIS spatial analysis (Tian et al., 2002; McCauley and Goetz, 2004), landscape pattern index analysis (Wu et al., 2013), linear regression analysis (Li et al., 2008), cluster analysis (Ma, 2011) and principal component analysis (Wang et al., 2015).

The Hejiang River Basin has been of great significance for the development of Chinese settlements and culture. During nearly one thousand years from the Qin and Han Dynasties to the early Tang Dynasty, the Hejiang River connected Lingnan with the Central Plains and was the main road of the "Maritime and Land Silk Road" in the south of China. The economy and culture of the Central Plains spread to Southeast Asia and other overseas countries through the Hejiang River. Since the Han and Tang Dynasties, there have always been several counties and county-level offices along the Hejiang River, which has been a typical area where the river and the ancient city depend on each other. However, the current research on the Hejiang River Basin is relatively simple in content, mainly focusing on the three aspects of the protection of ancient cities (He, 2004), dialect culture (Liu, 2015) and research on the status quo of soil and water conservation (Kong et al., 2019). The research on rural settlements from the spatial perspective is relatively weak. Therefore, taking Hejiang River Basin as an example, this study first obtained the spatial distribution information for the rural settlements in 1990, 2000, 2010 and 2020 based on Landsat TM/ETM/OLI satellite remote sensing images of the region. Then the methods of landscape pattern analysis, GIS spatial analysis and spatial statistics were used to analyze the overall pattern of rural settlements in the Hejiang River Basin from 1990 to 2020, and to explore the impacts of topography, river, location and policy factors on the spatial distribution of rural settlements, so as to reveal the spatial characteristics and landscape evolution law of the rural settlements. This study provides a reference for guiding rural landscape protection planning and promoting the spatial layout optimization of the rural settlements in the future.

2 Study area, data, and methods

2.1 The study area

Hejiang River, a tributary of the Xijiang River system in the Pearl River Basin, originates in Fuchuan Yao Autonomous County of Guangxi Zhuang Autonomous Region, flows through 12 counties (districts) of Hunan, Guangxi and Guangdong provinces, and joins the Xijiang River in Fengkai County of Guangdong Province. The main stream has a total length of 338 km and a basin area of 11600 km^2. It is located at 23°36'N–25°11'N and 111°16'E–112°19'E, as shown in Fig. 1. The elevation is high in the northwest and low in the southeast, with widely distributed mountains and hills. Hejiang River Basin has a subtropical monsoon humid climate, abundant sunlight, abundant rainfall, luxuriant forests and developed agriculture. The ethnic minorities have a large population, including the Yao, Zhuang, Miao and Dong ethnic groups. In 2013, the population of the basin was 1923 million, the cultivated area was 128000 ha, and the GDP was 46.01 billion yuan. The proportions of primary, secondary and tertiary industries were 25:45:30 (Kong et al., 2019).

2.2 The data sources

The research period of this paper is 1990 to 2020, and the research data mainly includes three components. 1) Rural settlement patch data. Using Landsat TM/ETM/OLI remote sensing images as the basic data, the rural settlement distribution information was extracted using supervised classification and classification accuracy evaluation after being preprocessed in ENVI 5.1 by projection transformation, geometric correction, data fusion and boundary trimming. In order to ensure the accuracy of the data, the classified rural settlement patches were compared with Google Earth (https://earth.google.com) images to improve the patch information and finally generate the distribution map of rural settlements in the Hejiang River Basin (Fig. 2). 2) Data of the main rivers, traffic trunk roads and urban centers. By scanning the paper maps over the years and correcting their geographical registration in ArcGIS 10.2, vector elements such as rivers, traffic arteries and urban government stations were extracted. The main traffic routes that have a greater impact on rural settlements in the Hejiang River Basin are railways, expressways, national highways and provincial highways. 3) DEM data, derived from the geoscience data cloud (http://www.gscloud.cn), with a spatial resolution of 30 m, were used to obtain elevation and slope information of the basin.

2.3 Research methods

2.3.1 Landscape pattern analysis

Landscape pattern analysis is one of the main methods used to study the spatial characteristics of rural settlements. It has

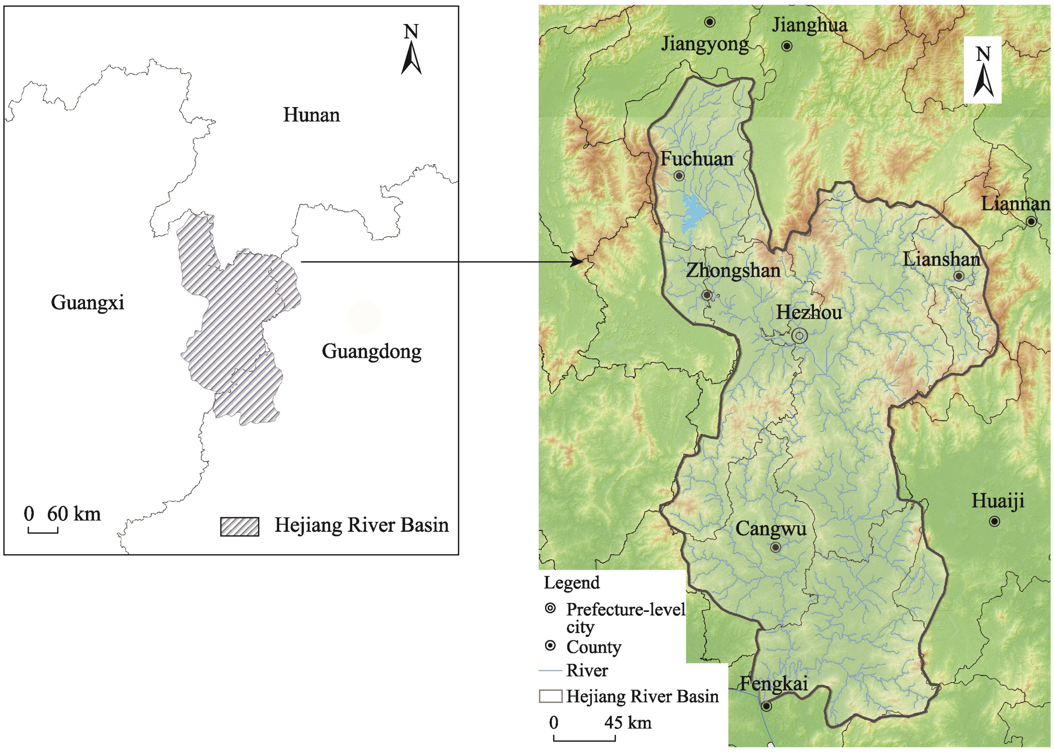

Fig. 1 Geographical location of Hejiang River Basin

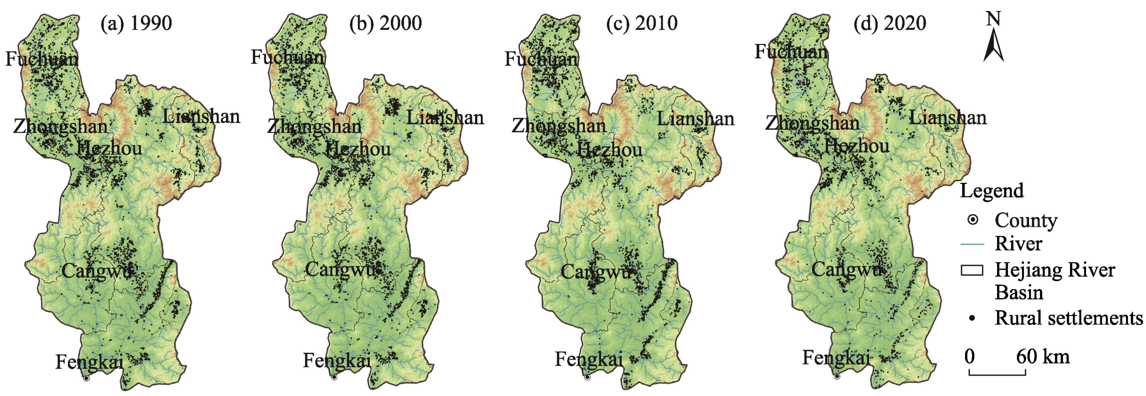

Fig. 2 Spatial distribution of rural settlements in Hejiang River Basin

been widely used because it can effectively explore the structural characteristics and spatial configuration of the rural landscape. According to the meaning of the landscape pattern indexes and the actual situation of Hejiang River Basin, this paper selected six indexes to describe the landscape pattern characteristics of rural settlements in Hejiang River Basin. The descriptions of the indexes are shown in Table 1.

In ArcGIS 10.2, the vector information of the rural settlements in Hejiang River Basin was transformed into ArcGird raster images by using data format Conversion Tools, and then the various indexes were loaded in Fragstats 4.2 and the patterns were generated.

2.3.2 Kernel Density Estimation

In a macroscopic region, rural settlements can be regarded as point-like elements, and the Kernel Density Estimation method can be used to study the changes of rural settlement clustering characteristics from 1990 to 2020. It is assumed that geographical events can occur at any location in space, but their incidence is high in point-dense areas and low in point-sparse areas. This approach is called the Kernel Density Estimation method, which can simply reflect the probability of the occurrence of events in different areas in space (Dehnad, 1987). The calculation formula is:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where $K\left(\frac{x - x_i}{h}\right)$ is a kernel function; h is the bandwidth, and $h > 0$; $x - x_i$ represents the distance from x

Table 1 Descriptions of the landscape pattern indexes

Type	Index name	Meaning	Unit
Size characteristics	NP, number of patches	Represents the total number of rural settlement patches	–
	CA, total class area	Represents the total area of a patch of rural settlements	ha
	MPS, mean patch size	Represents the average size of a rural settlement patch	ha
Distribution characteristics	PD, patch density	Represents the number of rural settlement patches per unit area	n km^{-2}
Shape features	LSI, landscape shape index	Reflects the degree of irregularity and fragmentation of rural settlement patches	–
	PAFRAC, perimeter-area fractal dimension	Reflects the complexity of rural settlement patches	–

to x_i; and n is the number of rural settlements. The larger $f(x)$ is, the more concentrated the point elements and the higher the probability of occurrence.

In order to further explore the spatial differentiation characteristics of the number and area scale of rural settlement patches in Hejiang River Basin, this paper used the ArcGIS10.2 factor transition tool to extract the central points of settlement patches in each period, and then used the "Kernel Density" function to make patch density distribution maps and patch size density distribution maps with 5 km bandwidths.

3 Results

3.1 Landscape pattern characteristics of rural settlements

We used the landscape pattern analysis method to calculate the landscape pattern index of rural settlements, and the results are shown in Table 2.

Table 2 Landscape pattern index of rural settlements in Hejiang River Basin

Index	1990	2000	2010	2020
NP	3066	3414	2778	2433
CA (ha)	6045.12	7354.80	9666.27	12021.21
MPS (ha)	1.97	2.15	3.48	4.94
PD (n km^{-2})	50.85	46.42	28.74	20.24
LSI	71.39	89.98	73.61	73.10
PAFRAC	1.36	1.55	1.40	1.43

(1) Size characteristics: The NP and the MPS indexes can both reflect the scale characteristics of rural settlements. From 1990 to 2020, the number of rural settlements in Hejiang River Basin increased at first and then decreased, while both the patch area and average patch area continued to expand. The number of plaques increased from 3066 in 1990 to 3414 in 2000 and then began to decrease, with a decrease of 636 in 2010 and 345 in 2020. At the same time, the patch area was continuously increasing, and its expansion rate was only 130.97 ha yr^{-1} from 1990 to 2000 but nearly doubled from 2000 to 2020, with increases of 231.15 ha yr^{-1} from 1990 to 2000 and 261.66 ha yr^{-1} from 2010 to 2020. The average patch area also increased from 1.97 ha in 1990 to 4.94 ha in 2020. With the advance of time, the area and scale of rural settlements in Hejiang River Basin continued to expand, the number of patches showed a decreasing trend, and the spatial layout of settlements developed toward agglomeration.

(2) Distribution characteristics: The PD index can reflect the spatial distribution density of settlement patches. The larger PD is, the more fragmented the patches and the more discrete the distribution. As shown in Table 2, the density of rural settlements has been decreasing year by year in the past 30 years, with values of 50.85 km^{-2} in 1990, 46.42 km^{-2} in 2000, 28.74 km^{-2} in 2010 and 20.24 km^{-2} in 2020. Among them, the patch density decreased the fastest from 2000 to 2010, with a decrease of 17 patches per square kilometer, which was the period of the fastest rural settlement agglomeration rate. On the whole, from 1990 to 2020, the fragmentation of rural settlements in the Hejiang River Basin decreased, the connectivity increased, and the distribution became more intensive.

(3) Shape features: The LSI and PAFRAC indexes can both reflect the complexity of patch shapes of the rural settlements. The larger the value is, the more complex and irregular the shapes of rural settlements tend to be. As can be seen from the index changes, LSI and PAFRAC generally increased at first and then decreased, indicating that the complexity of rural settlement patches increased at first and then decreased. In addition, the zigzag degree of the border became smaller and the shape became more regular, but the value was still higher than that in 1990. In 2000, LSI and PAFRAC had the highest values, which were 89.98 and 1.55, respectively, indicating the highest patch complexity of rural settlements in 2000. From 2000 to 2020, the LSI and PAFRAC of the settlement patches decreased, and the shape developed to the rule. However, PAFRAC was still on the rise from 2010 to 2020. Therefore, planning and guidance should be strengthened to promote the regularity of the settlement layout.

3.2 Evolution of rural settlement layout based on Kernel Density

Based on the patch density distribution map and patch size density distribution map made based on ArcGIS 10.2, the distribution of rural settlements in Hejiang River Basin is obviously variable within the region. The overall layout features are dense in the northwest and southeast, sparse in the middle and west, high density in the plain and low density in the hilly region. The areas centered on Fuchuan Yao Autonomous County, Zhongshan County and Hezhou City are high density areas with clustered distributions. In addition, there are several hot spots of patch distribution at the junction of Cangwu County, Babu District and Fengkai County. However, in Lianshan Zhuang Yao Autonomous County, Liannan Yao Autonomous County, Cangwu County, the southern part of Babu District and the central part of Pinggui District, due to the high altitude and steep slope, the rural settlements are scattered and have been in a state of low density for a long time. By comparing Fig. 3 and Fig. 4, it can be seen that the area density of patches is also high in the area where the number of patches is distributed with a high density.

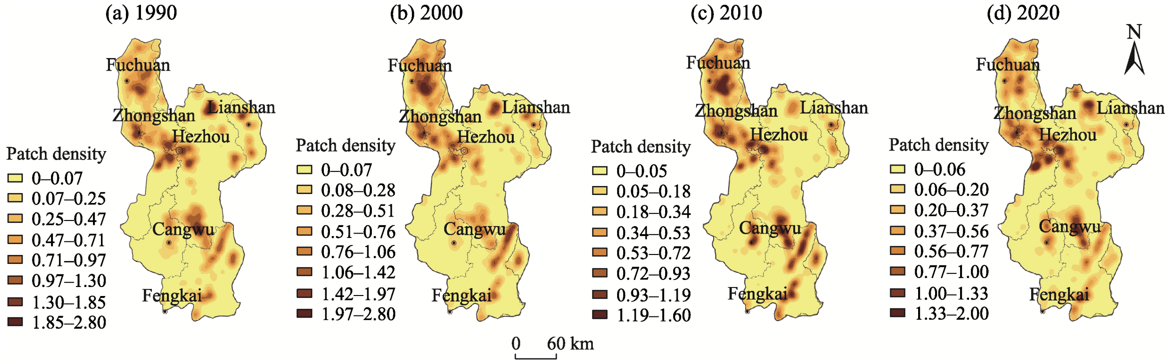

Fig. 3 Patch density distribution of rural settlements in Hejiang River Basin

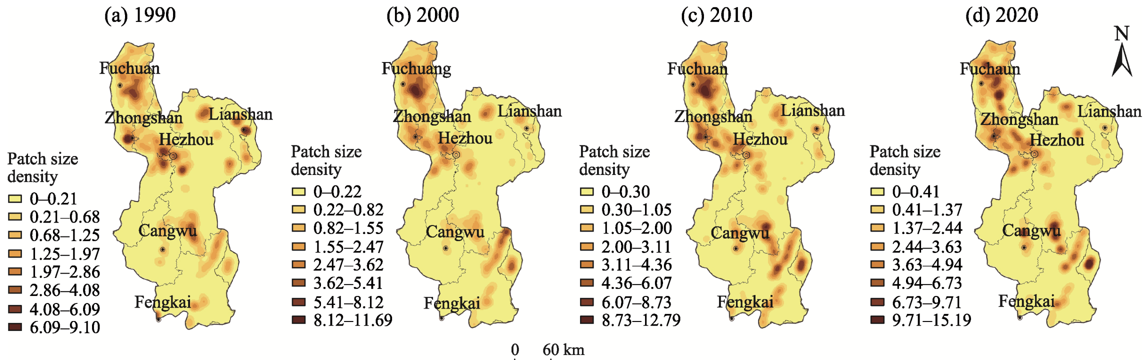

Fig. 4 Patch size density distribution of rural settlements in Hejiang River Basin

3.3 Analysis of the factors influencing the spatial distribution of rural settlements in Hejiang River Basin

3.3.1 Terrain factors

Terrain not only provides space for the existence and development of settlements, but also restricts the expansion of settlements. In this paper, elevation and slope were selected to study the influence of topographic factors on the spatial evolution of rural settlements.

(1) Elevation factor: The terrain of Hejiang River Basin is high in the northwest and low in the southeast. There are more mountainous areas and hills in the basin, but less plains. The areas of mountainous areas and hills account for 53% and 28%, respectively, while the area of plains is only 19%. In order to explore the relationship between the spatial distribution of rural settlements and the elevation, the elevation was divided into five groups of <100 m, 100–200 m, 200–300 m, 300–400 m and >400 m. By superposition analysis with the spatial distribution of rural settlements in 1990, 2000, 2010 and 2020, the NP and CA in different elevation ranges were counted. As shown in Table 3, rural settlements in the Hejiang River Basin are mainly concentrated in the area at elevation ⩽ 200 m, and the settlement areas in the four time points account for 66.21%, 70.20%, 73.78%, and 71.68%, respectively. Among the elevation groups, rural settlements in the areas with an elevation of 100–200 m are the most widely distributed. The number and area of patches in the areas with an altitude of 200 m or more decreased with the elevation. In general, the areas of rural settlements at all elevations show upward trends, especially in the areas of elevation <100 m and 100–200 m, which have more than doubled in the past 30 years. Therefore, the rural settlements in Hejiang River Basin have been mainly expanding into the gentle terrain areas, and the number of settlements decreases significantly with the rise in the elevation.

Table 3 Distribution characteristics of rural settlements at different elevations in Hejiang River Basin

Year	Elevation									
	<100 m		100–200 m		200–300 m		300–400 m		>400 m	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
1990	1324.80	829	2677.58	1248	1336.91	600	629.85	328	75.98	61
2000	1518.76	834	3644.14	1449	1471.87	702	649.20	370	71.03	59
2010	2578.64	826	4553.01	1053	1749.01	503	613.81	300	171.80	96
2020	3052.95	629	5564.34	1075	2287.59	430	865.14	234	251.19	65

(2) Slope factor: According to the slope characteristics of Hejiang River Basin, and in combination with the slope grade regulations of the Geomorphological Survey and Geomorphological Cartography Committee of the International Geographical Society on the application of detailed geomorphological maps, the slope of Hejiang River Basin was divided into five grades: 0°–0.5° (plain), 0.5°–2° (microslope), 2°–5° (gentle slope), 5°–15° (slope) and 15°–35° (steep slope), and overlayed with the settlement distribution layer. As can be seen from Table 4, the spatial distribution pattern of rural settlements is closely related to slope. Within the range of 0°–0.5° slope, the rural settlements have the largest number and the widest distribution area. From 1990 to 2020, the number of rural settlements first increased and then decreased, while the proportion of this patch remained almost unchanged, decreasing only slightly from 45.86% in 1990 to 44.64% in 2020. However, the patch area continued to increase, with the proportion rising from 44.66% in 1990 to 49.92% in 2020, indicating that the rural settlements in this area have been expanding. In addition, the number and area of settlements in the slope ranges of 0.5°–2° and 2°–5° also have large proportions in the basin. In 2020, the area of settlements in the slope range was 5304.73 ha, accounting for 44.13% of the total area of settlements. The settlement area of within the range of 15°–35° was the smallest at less than 150 ha, and the distribution of settlements is significantly affected by the slope.

3.3.2 River factors

The river not only provides abundant water resources for the formation and development of rural settlements, but it also serves as an important traffic corridor. There are Hejiang River, Dong'an River, Daning River, Lisong River and other branches in the Hejiang River Basin. During the Republic of China period, materials were mainly transported by these rivers. Waterway transportation was relatively developed, and numerous settlements formed on the banks of the river. Based on a buffer analysis of the main rivers in the basin at 1 km intervals, they were overlaid with the distribution layer of rural settlements to explore the influence of rivers on the spatial distribution of rural settlements. As shown in Table 5, rural settlements are concentrated within 1 km of the main rivers. The farther the distance from the main rivers, the fewer the number and smaller the area of patches of settlements. In general, the areas of rural settlements in each buffer area increased from 1990 to 2020, while the numbers of patches mostly increased to 2000 and then began to decline, which was basically consistent with the change of rural settlements in the whole Hejiang River Basin.

Table 4 Distribution characteristics of rural settlements in different slope ranges in Hejiang River Basin

Year	Slope									
	0°–0.5°		0.5°–2°		2°–5°		5°–15°		15°–35°	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
1990	2699.51	1406	1128.83	485	1445.41	677	700.42	439	70.95	59
2000	3433.36	1531	1531.94	591	1353.37	736	936.94	484	99.19	72
2010	4434.67	1208	1844.31	413	2247.40	652	1027.21	420	112.68	85
2020	6001.43	1086	2572.48	432	2732.25	573	659.99	299	55.06	43

3.3.3 Geographical factors

With the development of economy and society, the scale and layout of rural settlements are deeply affected by the location conditions. This paper selected traffic factors, urban factors and industrial park factors to study the influences of location conditions on the spatial evolution of rural settlements.

(1) Traffic factors: Traffic conditions influence the spatial layout and evolution of rural settlements by changing the

Table 5 Distribution characteristics of rural settlements in different areas of influence of the rivers

Year	Distance from main river									
	<1 km		1–2 km		2–3 km		3–4 km		>4 km	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
1990	2009.16	908	887.3	516	756.52	373	683.83	326	1708.31	943
2000	2360.74	963	1264.17	597	973.89	434	752.79	406	2003.21	1014
2010	3063.98	818	1859.39	539	1404.12	349	938.69	267	2400.09	805
2020	4245.76	845	2198.11	448	1442.41	302	1349.38	279	2785.55	559

location of rural settlements. In recent years, the Luoyang-Zhanjiang Railway, the Guilin-Wuzhou Expressway, the Guangzhou-Hezhou Expressway, and the Guiyang-Guangzhou High-speed Railway have been put into operation one after another, which has improved the transportation conditions of many settlements and enhanced their geographical advantages. Taking the interval of 1 km as the analysis radius, the buffer zones of railway, expressway, national road and provincial road in Hejiang River Basin were determined, and then overlaid with the rural settlements to study the distributions of settlements in the different road buffer zones. As shown in Table 6, with the increase in the distance from the main road, both the number and area of rural settlement patches showed decreasing trends. In 1990, 2000, 2010 and 2020, the proportions of rural settlements in patch areas were 18.43%, 28.11%, 35.31% and 46.30%, respectively. At the same time, the proportions of the number of rural settlements in the four time points were 19.54%, 25.45%, 31.68%, and 39.83%, which indicates that the rural settlements in this area have been continuously expanding and developing toward agglomeration, and it is the best location for the layout of rural settlements.

Table 6 Distribution characteristics of rural settlements in the areas affected by different road buffers

Year	Distance from main road									
	<1 km		1–2 km		2–3 km		3–4 km		>4 km	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
1990	1114.26	599	693.41	361	492.13	260	354.51	175	3390.80	1671
2000	2067.39	869	1331.58	516	736.90	322	499.65	258	2719.28	1449
2010	3413.46	880	1656.89	486	800.66	263	699.45	262	3095.82	887
2020	5565.26	969	1934.25	428	796.75	118	592.38	121	3132.57	797

(2) Urban centers' factors: The urban center has good traffic conditions and service facilities, and its radiation can promote the development of the surrounding areas, so the rural settlements tend to gather in the township centers. The residences of each county and township government were regarded as the town centers, and a multi-ring buffer zone of the town center was established with a radius of 2 km. Table 7 shows that there is a close spatial relationship between rural settlements and towns in the Hejiang River Basin, and they are mainly distributed within 6 km of the urban center, which is reflected by the small number of patches, large patch size and rapid change of rural settlements. In the area more than 6 km away from the urban center, the patch quantity and patch size were lower, and the change was slow. Among the buffer zones, the number and area of rural settlements distributed within 2–4 km of the urban center are the largest, and the change is the most obvious. In the past 30 years, the number of patches has decreased by 295, but the area has increased by 2190.53 ha, and the settlements in this region have become more densely distributed.

(3) Industrial factors: By virtue of the scale effect of production space, industrial parks obtain huge economic benefits, play important roles in attracting population aggregation, solving employment problems and promoting regional economic growth, and can directly change the spatial layout of rural settlements. In the 1990s, Hejiang River Basin built a batch of industrial parks, including the Wanggao industrial park, Dongrong industrial park, Huarun industrial demonstration zone of circular economy, Zhongshan industrial park and others as autonomous region level industrial parks, in addition to the autonomous region class A industrial park of Hezhou electronic science and technology of ecological industrial park and the class B industrial park of the Fuchuan industrial clusters. Industrial parks effectively promote the aggregation of major local industrial enterprises, and their total output value accounts for a significant proportion of the total industrial output value of the region. Multi-ring buffers were created at 1 km intervals and superimposed with the rural settlements at each time point to study the influence of industrial parks on the evolution of settlements. As shown in Table 8, with the

Table 7 Distribution characteristics of rural settlements in different areas of influence of urban centers

Year	Distance from urban center									
	<2 km		2–4 km		4–6 km		6–8 km		>8 km	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
1990	1737.16	724	2138.01	1136	1329.65	728	626.48	354	213.81	124
2000	1941.14	720	2785.86	1257	1672.77	837	672.82	405	282.21	195
2010	2510.88	670	3826.48	997	2161.37	632	792.41	276	375.13	203
2020	3250.35	505	4328.54	841	2870.42	614	1016.39	262	555.49	211

Table 8 Distribution characteristics of rural settlements in the different influence area buffers of industrial parks

Year	Distance from industrial park									
	<1 km		1–2 km		2–3 km		3–4 km		>4 km	
	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP	CA (ha)	NP
2000	3.00	4	27.28	16	17.67	11	55.27	15	7251.58	3368
2010	80.60	19	238.35	45	307.42	65	723.76	100	8316.14	2549
2020	135.86	14	426.21	38	421.59	64	867.01	98	10170.54	2219

increase in the distance from the industrial park, the number and area of rural settlements showed upward trends. Compared with traffic factors and urban factors, the construction of industrial parks has little influence on rural settlements in the Hejiang River Basin. Within the range of 4 km from the industrial park, the number of patches and the size of settlements are small, and the development and construction of industrial parks and rural construction do not effectively form a benign interactive development mode.

3.3.4 Policy factors

The regulatory behavior of the government guides the spatial development of rural settlements, which can change the layout of settlements in a short time, and show sudden characteristics. For example, Hezhou is an important city in the Hejiang River Basin that has completed the renovation of 122000 rural dilapidated houses by 2020 after it was included in the national pilot scope of dilapidated house renovation in 2009. The increase of residential land has promoted the rapid expansion of rural settlements. During the “13th Five-Year Plan” period, a total of 12000 households in Hezhou took advantage of the policy of relocation for poverty alleviation from inhospitable areas. In addition, 61620 poor households were relocated to 25 centralized resettlement sites, where the large-scale construction of basic supporting facilities and public service facilities such as waterways, power grids, public sports and sports, as well as employment, entrepreneurship and poverty alleviation workshops were carried out, and the original house sites were reclaimed. During the 12th Five-Year Plan period, Hezhou completed 163 large-and medium-sized reservoir resettlement new village construction projects, with more than 4200 households resettling from the benefited reservoir areas with a population of more than 20000. A number of new village demonstration sites, including Shangchengtou Migrant Village in Fuchuan County and Southwest Migrant Village in Babu District, have had a profound impact on the evolution of the spatial pattern of rural settlements.

4 Discussion

This paper analyzed the overall pattern and spatial differentiation characteristics of rural settlements in the Hejiang River Basin from 1990 to 2020, and the influences of topographic factors, river factors, location factors and policy factors on the spatial distribution of rural settlements were discussed. The main conclusions focus on five aspects of the rural settlements. 1) In terms of the scale, the number of patches of rural settlements in Hejiang River Basin increased at first and then decreased, while the patch area and average patch area increased continuously, indicating that the spatial distribution of rural settlements tended to become more concentrated. 2) In terms of distribution, the patch density of rural settlements decreased year by year, the degree of fragmentation decreased, the connectivity increased, and the distribution became denser. 3) In terms of shape, the complexity of rural settlement patches increased at first and then decreased, the boundary tortuosity decreased and the shape became more regular, but the index remained at a high value. Therefore, planning and guidance should be strengthened to promote the regularity of settlement layout in the future. 4) There were obvious regional differences in the distribution of settlements, which were denser in the northwest and southeast, sparser in the middle and west, higher density in the plains and hills, and lower density in the mountains. The area density of patches was also high in the high-density region. 5) Terrain factors, river factors and location factors all have significant effects on the spatial pattern of settlements. Among them, terrain affects the formation and expansion of rural settlements. The settlements are mainly concentrated in the plain areas with an elevation less than or equal to 200 m and a slope range of 0°–0.5°. With the rise in altitude and the increase in slope, the number of settlements decreases significantly. The Hejiang River Basin has well-developed waterway transportation, and many rural settlements have formed along the river banks, which are concentrated within 1 km of the main rivers. Under the influence of the radiation of the traffic and administrative centers, rural settlements in the regions up to 1 km away from the main roads and 6 km away from the urban centers expand rapidly, but the development and construction of industrial parks and rural construction have failed to form a benign interactive development mode. The government has organized and implemented the relocation of households from inhospitable areas, the renovation of dilapidated houses, the construction of new villages for reservoir migrants and other works, which have had a profound impact on the evolution of the spatial pattern of rural settlements.

5 Conclusions

The village is a more complete slice of people's social life, so paying attention to the evolution of the rural settlement space can provide a better understanding of the development of the area (Fei, 1991). Hejiang River Basin, as a minority area and a poverty-stricken area, has a weak economic foundation and is relatively underdeveloped in South China. At present, many rural settlements are still expanding to places with poor terrain and location conditions. In addition, under the influence and drive of the rapid urbanization and industrialization of metropolitan areas, the evolution of rural settlements to a high-level is an inevitable trend. In the process of that evolution, the ecology and traditional settlement patterns of rural settlements will inevitably have contradictions and conflicts with economic development (Zhu et al., 2017). In future development, attention should be paid to scientifically guiding the population to the key towns, specialized towns and other areas with good production conditions, integrating the layout of scattered villages with fragmented landscapes, and promoting the intensive, efficient and green ecological development of urban and rural areas, so as to achieve regional sustainable development.

References

Beatrice M S. 1944. Dispersion and agglomeration of rural settlement in Somerset. *Geography*, 29(1): 1–8.

Dehnad K. 1987. Density estimation for statistics and data analysis. *Technometrics*, 29(4): 296–297.

Fei X T. 1991. Revisit the three villages in Yunnan. *Social Sciences in China*, 1: 169–178. (in Chinese)

Gan Z M, Gan R, Yue D P, et al. 2004. Study on the land use of rural settlementsin the Loess hill-gully area of Yanan and Yulin. *Journal of Arid Land Resources & Environment*, 18(4): 101–104. (in Chinese)

Han F, Cai J M. 2011. The evolution and reconstruction of peri-urban rural habitat in China. *Geographical Research*, 30(7): 1271–1284. (in Chinese)

He Y. 2004. The protection of ancient cities in the regional view—The value evolution and the overall protection of ancient cities in the Hejiang River Basin. Proceedings of the 2004 Urban Planning Annual Conference (Part 1). Beijing, China: Urban Planning Society of China.

Kiss E. 2000. Rural restructuring in hungary in the period of socioeconomic transition. *GeoJournal*, 51(3): 221–233.

Kong L, Ding F L, Zhu Y. 2019. Study on water and soil conservation planning in Hejiang River Basin. *Water Resources Planning and Design*, 6: 1–4. (in Chinese)

Kong L, Xiao X M, Zhu Y. 2019. Analysis of the present situation and problems of Hejiang River Basin under the concept of ecological civilization. *Water Resources Planning and Design*, 3: 9–12. (in Chinese)

Li D Y, Zhang A D, Zhang S W. 2008. Characteristics and driving forces analysis of residential area expansion in the north of Shandong Peninsula coastal area. *Journal of Natural Resources*, 23(4): 612–618. (in Chinese)

Li H B, Zhang X L. 2012. A review and trend on rural settlement geography abroad. *Human Geography*, 27(4): 103–108. (in Chinese)

Liu S Q, Chen G J, Chen Z J. 2001. Ecological and environmental warning on rural habitat ecosystem—A case study of group 5 of Cizhu Village in Wanxian City. *Acta Ecologica Sinica*, 21(2): 295–301. (in Chinese)

Liu Z Y. 2015. Overview on the phonetic researches on the Chinese dialects within the watershed of the Hejiang River. *Journal of Hezhou University*, 31(4): 54–58. (in Chinese)

Long H L. 2013. Land consolidation and rural spatial restructuring. *Acta Geographica Sinica*, 68(8): 1019–1028. (in Chinese)

Ma X D. 2011. A research on pattern characteristics and type classification of rural settlement in northern Jiangsu Province. *Human Geography*, 26(4): 66–72. (in Chinese)

Marshall W. 1966. Rural settlement patterns and social change in Latin America. *Latin American Research Review*, 1(2): 5–50.

McCauley S, Goetz S J. 2004. Mapping residential density patterns using multi-temporal Landsat data and a decision tree classifier. *International Journal of Remote Sensing*, 25(6): 1077–1094.

McKenzie P, Cooper A, McCann T, et al. 2011. The ecological impact of rural building on habitats in an agricultural landscape. *Landscape and Urban Planning*, 101(3): 262–268.

Ren G P, Liu L M, Fu Y H, et al. 2016. Analysis of characteristic and influencing factors of rural settlement landscape pattern in metropolitan suburbs. *Transactions of the Chinese Society of Agricultural Engineering*, 32(2): 220–229. (in Chinese)

Tian G J, Liu J Y, Zhang Z X, et al. 2002. The scale distribution characteristics of Chinese rural settlements by remote sensing and GIS. *Journal of Remote Sensing*, 6(4): 307–312, 326. (in Chinese)

Vesterby M, Krupa K S. 2002. Rural residential land use: Tracking its growth. *Agricultural Outlook*, 8: 14–17.

Wang C C, Li X K, Xie L, et al. 2015. Coordination analysis on man-land system of rural settlements in the Three Gorges Reservoir of Chongqing. *Research of Soil and Water Conservation*, 22(4): 298–304. (in Chinese)

Wu C J. 1991. On the research core of geography: The man-earth relation area system. *Economic Geography*, 11(3): 1–6. (in Chinese)

Wu J G, Zhang X L, Ji Y Z, et al. 2013. Transports influence on rural settlement landscape pattern at County scale—A case study of Yongqiao of Suzhou. *Human Geography*, 28(1): 110–115. (in Chinese)

Xie H L, Liu L M, Li L. 2003. Preliminary study on the correlative problem of the rural landscape planning. *Chinese Landscape Architecture*, (3): 39–41. (in Chinese)

Young R. 1999. Landscapes of settlement: Prehistory to the present. *Journal of Rural Studies*, 15(2): 224–226.

Zhu Q Q, Zheng X Y, Liu Y, et al. 2017. Spatial distribution and types of rural settlements in Guangzhou. *Economic Geography*, 37(6): 206–214, 223. (in Chinese)

贺江流域乡村聚落景观格局特征与空间布局研究

杨宝琪[1]，宋书巧[2]，覃　静[1]

1. 南宁师范大学地理科学与规划学院，南宁 530001；
2. 南宁师范大学环境与生命科学学院，南宁 530001

摘　要：乡村聚落景观格局是揭示景观变化与人类活动相互关系的重要途径。本文以 Landsat TM/ETM/OLI 卫星遥感影像为数据源，以贺江流域为研究区域，在对 1990 年、2000 年、2010 年和 2020 年 4 个时间点乡村聚落的空间分布信息进行阐述的基础上，综合运用景观格局分析法、GIS 空间分析法以及空间统计方法，通过分析乡村聚落的规模、分布、形状等空间特征，并探讨地形、河流、区位及政策因素对乡村聚落空间布局的影响。研究结果表明：随着时间的推进，贺江流域乡村聚落斑块数量呈减少的趋势，斑块面积及平均斑块面积扩大，斑块密度下降，聚落向集聚发展；聚落斑块形状趋向复杂化与不规则化，须加强规划与引导来促进聚落布局规整；聚落分布存在明显的区域差异，整体表现为西北与东南密集、中部与西部稀疏，平原密度高、丘陵山地密度低；地形、河流、区位及政策因素对聚落空间格局影响显著。

关键词：乡村聚落；景观格局；空间分布；贺江流域