Spatial and Temporal Evolution of Rural Settlement Landscape and Influencing Factors in the Border Areas of China, North Korea and Russia-Taking Hunchun City as an Example

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Abstract: Rural settlements are the basic spatial units of compact communities in rural areas, and scientific exploration of their spatio-temporal evolution and their influencing factors is an important prerequisite for the rationalization of spatial layout, and such an analysis can guarantee the rational planning and sustainable development of rural settlements in China and promote rural revitalization. Taking Hunchun City in Jilin Province as the research object, the spatial and temporal evolution characteristics of rural settlements in the region were analyzed by landscape index and spatial structure during the period of 1990-2020 by using ArcGIS spatial analysis tools. The results show that: (1) during the period of 1990-2020, the land scale of rural settlements in Hunchun City is characterized by expansion and then a small decrease, and the spatial distribution is in the state of agglomeration, and the density change is not significant. (2) The spatial and temporal evolution of rural settlement landscape is influenced by various factors such as nature, society and human beings. (3) Based on the ecological security protection pattern of the study area, the landscape pattern optimization of rural settlements was carried out, which was divided into four types of settlement landscape optimization.

Keywords: China-North Korea-Russia border; Hunchun City; Rural Settlement; Spatial and Temporal Evolution; Influencing Factors; Landscape Pattern

Introduction

As the main place of rural population activities, rural settlements have various functions such as production, life, ecology and cultural inheritance, and are formed by the joint action of rural residents and natural, economic and social factors in the course of development in a certain historical period[1]. As the main place for rural population activities, rural settlements have multiple functions, such as production, living, ecology and cultural inheritance, and they are the products of the joint interaction between rural residents and natural, economic and social factors during a certain period of historical development[2]. In recent years, with the acceleration of China's urbanization process and the continuous advancement of new rural construction, the spatial and temporal evolution of rural settlements, as an important carrier of human production and life, not only reflects the changes in the natural geographic environment, but also profoundly embodies the comprehensive impact of socio-economic development and policy orientation. In the context of implementing the strategy of rural revitalization and promoting urban-rural integration, analyzing the spatial and temporal evolution of the landscape of rural settlements is an important way to reveal the relationship between landscape changes and human activities, and the study is of great importance and practical significance[3-5].

The study of rural settlements began in the 19th century, and has gone through the development stages of germination, initial development, expansion and change, and transformation and reconstruction. Characterized by interdisciplinarity, the

study of rural settlements has integrated the theories of geography, economics, sociology, and ecology, forming an analytical framework with a multidimensional perspective[6]. For example, Chen Song et al. discuss the application of landscape ecology approach in rural settlement research and the impact of land use change on settlement pattern, taking Pingnan County of Fujian Province, China, as the study area[7]. The research content mainly focuses on the changes in the morphology and types of rural settlements[8, 9], the influencing factors and evolution [10] and the spatial pattern of rural settlements[11]. Qin, X et al. used quantitative economic modeling and machine learning techniques to prioritize infrastructure development, farmland circulation, and industrial integration to explain the factors that explain the evolution of traditional villages in northern Jiangsu [12].Zhu, X.-G et al. used entropy weighting to explore the overall characteristics of the synergy of growth and aggregation of the cultural landscape in traditional villages in Zhejiang Province, which provided valuable insights into the synergies of the traditional villages in terms of their siting, spatial morphology, and cultural landscapes produced valuable insights[13]. Analyzing the differences in geographic environment, resource utilization, and functional layout of different settlements through the spatial pattern of rural settlements helps to understand the spatial logic and planning needs of rural development[14]. This opens up new ways to realize rural revitalization and sustainable development, and at the same time provides a scientific basis for settlement culture protection and landscape restoration[15].

The study of rural landscapes is a multidimensional and interdisciplinary field that encompasses natural ecology, sociocultural, economic development and settlement landscapes[16]. With the introduction of GIS, RS and GPS technologies, the development of landscape pattern index model has made significant progress. The landscape pattern index is measured at three levels: patch, type and landscape, which can reflect the spatial pattern and heterogeneity of natural and humanistic landscapes in a more intuitive and comprehensive way[17]. For example, Zhang, LJ et al. analyzed the spatial and temporal evolutionary trends of land use and landscape patterns of 13 typical surface coal mines in Inner Mongolia from 2001 to 2020 by using the transfer matrix and landscape pattern index methods[18]. Sevenant et al. found that land-use patterns and settlement patterns were the main factors contributing to differences in rural landscapes [19]. Zomeni et al. found that changes in agricultural policies affect landscape pattern changes in regional rural settlements[20]. Paquette et al. analyzed the relationship between rural landscape evolution and landscape change based on land-use change data and economic and social data for rural settlements in southern Quebec over the past 30 years[21]. With the three major problems of population, resources and environment becoming more and more prominent, the research on the optimization of the layout of rural settlements has been paid attention to. McKenzie et al. analyzed the impact of the development of rural settlements on the ecosystem by using GIS through the grid random sampling method[22]. Wang, X et al. optimized street space, cultural space, landscape space and public facilities in the countryside, improved spatial layout, spatial accessibility and spatial compositing, effectively alleviated the contradictory relationship between urban development and rural revitalization, and promoted the sustainable development of China's society, economy and culture[23].Lu, M et al. took the layout of the rural settlement in Xinyi as an example, constructed the appropriateness-dominance perspective from an analytical framework of spatial optimization of rural settlements, and obtained the spatial optimization scheme of rural settlements under different suitable farming conditions[24].

According to the seventh population census, rural settlements are still the main form of population concentration in China, and it is of great significance to explore the evolution of rural settlements and the factors affecting them for the development of the countryside. Under the background of accelerated globalization and regionalization, rural settlements in border areas have unique spatial and temporal evolution characteristics and research value due to their special geographical location and diversified cultural backgrounds. On the one hand, the spatial distribution, scale and morphology of rural settlements are influenced by the transportation network, population flow and policy support; on the other hand, rural settlements in the border areas also face the combined effects of cross-border trade, border control and ecological protection. In this paper,

we apply the landscape pattern index research method in landscape ecology to explore the spatial and temporal evolution characteristics of rural settlements in the border areas of China, North Korea and Russia. Taking Hunchun City in Jilin Province as the study area and Landsat TM/ETM remote sensing imagery as the main data source, the spatial analysis tool of ArcGIS was used to quantify the spatial and temporal evolution of the rural settlements in Hunchun City from 1990 to 2020, and the spatial and temporal evolution of the rural settlements in Hunchun City from 1990 to 2020 was analyzed through ArcGIS. The spatial and temporal evolution of rural settlements in Hunchun City from 1990 to 2020 was quantitatively analyzed by using ArcGIS spatial analysis tools, and the spatial and temporal evolution of rural settlements in Hunchun City was analyzed by means of landscape index analysis, nearest-neighbor index analysis, and kernel density analysis, and the natural and humanistic factors affecting the evolution of the study area were analyzed by means of superposition analysis and buffer zone analysis, and the optimization of landscape pattern was carried out in the context of the local situation on the basis of the evolution characteristics and the influential factors. This study not only helps to deepen the understanding of the evolution law of rural settlements in the border area, but also provides assistance for the optimization of rural landscape pattern. It will provide support for the implementation of the rural revitalization strategy in the border areas.

2. Materials and Methods

2.1. Study area

Hunchun City is located in the lower reaches of the Tumen River in the southeastern part of Jilin Province, between longitude 130°03′21″-130°18′33″E and latitude 42°25′20″-43°30′18″N, and belongs to the Yanbian Korean Autonomous Prefecture in Jilin Province (Figure 1). Hunchun is the only border city in China located at the junction of China, North Korea and Russia, where China, North Korea and Russia are connected by land, and China, North Korea, Russia, South Korea and Japan are connected by water, which makes Hunchun a bridgehead for opening up to Northeast Asia, and also a strategic pivot for opening up China's "One Belt, One Road" to the north. It is also the strategic pivot point of China's "Belt and Road" opening to the north. Hunchun City has 4 streets, 4 towns and 5 townships under its jurisdiction, covering an area of 5,134 square kilometers, and inhabited by many ethnic groups such as Han Chinese, Korean, Manchurian, Hui and Mongolian.

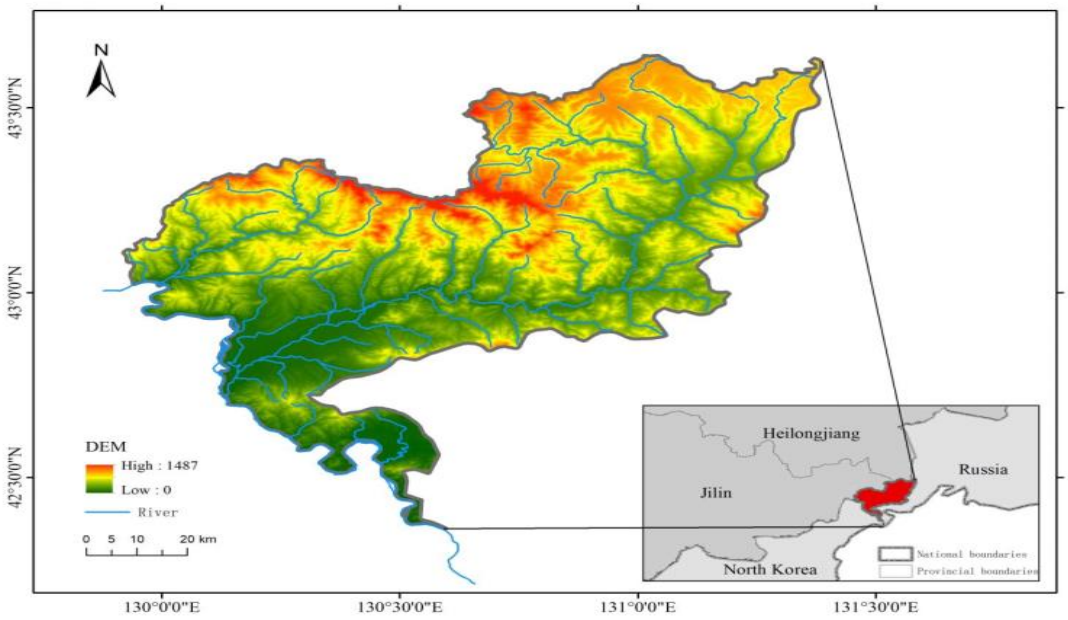

Figure 1.The study area.

2.2. Data sources

This study uses the Chinese multi-period land use remote sensing monitoring dataset (CNLUCC), which is obtained from the Center for Resource and Environmental Science and Data of the Chinese Academy of Sciences (http://www.resdc.cn). This dataset uses Landsat TM/ETM remote sensing images as the main data source, and spatial cropping is performed through the GIS platform to obtain four periods of land use data in Hunchun City in 1990, 2000, 2010, and 2020, with a resolution of 30 m×30 m. The CNLUCC employs a two-tiered classification system, with the first level divided into arable land mainly based on the land resources and their utilization attributes, forest land, grassland, waters, construction land and unutilized land in six categories, and the second level is divided into 23 categories mainly based on the natural attributes of land resources, including the land use types of rural settlements. Based on the land use data in the GIS platform, vector map patches of rural settlements were extracted as the current rural settlement patch data. Hunchun city area administrative boundary, traffic, river and DEM data were obtained from the Geospatial Data Cloud Platform of the Computer Network Information Center of the Chinese Academy of Sciences (http://www.gscloud.cn/), of which the traffic included national and provincial highways, and the DEM data (30m resolution) included elevation, slope, and topographic data. The planning policy information and socio-economic related data come from the website of Hunchun Municipal People's Government (http://www.hunchun.gov.cn/).

2.3. Research Methods

2.3.1. Landscape pattern index method

Using the landscape pattern index research method in landscape ecology, six landscape pattern indices, namely, number of patches (NP), patch area (CA), mean patch area (MPS), landscape shape index (LSI), perimeter-area-fractional dimension (PAFRAC), and patch area standard deviation (PSSD), were selected to quantitatively analyze the spatial and temporal evolution characteristics of the rural settlements of Hunchun City[25].

2.3.2. Average nearest neighbor index

Analyzing the degree of agglomeration of village settlement size through the Average Nearest Neighbor (ANN) index, comparing actual study points with theoretically randomly distributed points to determine the type of spatial distribution of traditional villages[26]. The Average Nearest Neighbor tool measures the distance between the center of mass of each element and the center of mass of its nearest neighboring elements, calculates the average of all these nearest neighbor distances, reflects the aggregation and disaggregation dynamics of the point elements in geographic space, and thus derives the spatial distribution characteristics of the point elements.

The calculation formula is as follows:

$$ANN = \frac{\overline{D_O}}{\overline{D_E}} = \frac{\frac{\sum_{i=1}^{n} d_i}{n}}{\frac{0.5}{\sqrt{\frac{n}{A}}}} \quad (1)$$

Where is the observed average distance between each element and the nearest neighbor element, is the expected average distance between the elements formulated in the random mode,n denotes the number of elements, and A denotes the area; if the nearest neighbor index is less than 1, the mode of performance is agglomeration distribution; if the index is greater than 1, the mode of performance is diffusion distribution. The average nearest neighbor yields an index of the specific degree of aggregation of a piece of data, with which it is possible to compare which of the different pieces of data has the greatest degree of aggregation.

Significance tests are conducted using P-values and Z-scores. When $Z > 1.96$ or $Z < -1.96$, $P < 0.05$, indicating that the resulting data are characterized by significant agglomeration; when $-1.96 < Z < 1.96$, then $P > 0.05$, indicating that the resulting data are characterized by a significant random distribution.

2.3.3. Kernel density analysis

Kernel density estimation is a nonparametric statistical method, which smoothes the values around the data points by applying a kernel function to them, so as to obtain a smooth density estimation curve for calculating the density of the elements in the surrounding domain. With the kernel density measure, the agglomeration of rural settlements within the study area can be calculated based on the input dataset of spatially distributed elements of rural settlements[27]. The calculation formula is as follows:

$$f(X) = \frac{1}{nh}\sum K\left(\frac{x-x_i}{h}\right) \tag{2}$$

Where f(x) is the density measure at point x, f is the kernel density measure, and a larger value of f indicates a denser distribution of point elements. n is the number of observations, h is the bandwidth (or smoothing parameter), k is the kernel function, and ∑ denotes the summation of all the observations[28].

2.3.4. Minimal Cumulative Resistance (MCR)

MCR refers to the cost from "source" landscape to landscape with different resistance[29, 30].

$$MCR = fmin\sum_{j=n}^{i=m}\left(D_{ij} \times R_i\right) \tag{3}$$

Where D_{ij} is the spatial distance of a mass point from source "j" to a landscape unit, and R_i is the resistance coefficient, the model can be used to reflect the potential possibilities and trends of rural settlement layout.

Results

3.1. Characteristics of spatial evolution of rural settlements

3.1.1. Overall evolution characteristics of rural settlement landscape

Using ArcGIS10.2 software to extract the raster data of rural settlements in four periods from the secondary land use data of Hunchun City in 1990, 2000, 2010 and 2020, to generate the distribution map of rural settlements patches, and applying Fragstats4.2 software to construct the spatial pattern index system from the three aspects of the number, scale and shape. Three indicators, namely, the number of patches (NP), the total area of patches (CA), and the mean patch size (MPS), were selected to characterize the evolution of the number and scale of rural settlements in the study area (Table 1); and three indicators, namely, landscape shape index (LSI), perimeter-area subdimension (PAFRAC), and the standard deviation of the patch area (PSSD), were selected to analyze the evolution of the shape of the rural settlements in the study area (Figure 2).

Table 1 General changes in the size of rural spatial settlements in Hunchun city.

Year	NP	CA/km2	MPS/km2
1990	159	22.93	0.14
2000	160	23.00	0.14
2010	262	52.53	0.20
2020	249	43.48	0.17

The results show that: (1) During the 30 years in the study area, the overall land scale of rural settlements showed the characteristics of first expansion and then a small decrease, and the total area of rural settlement patches, the number of patches and the average patch area first increased and then decreased. As can be seen from Table 1, from 1990 to 2010, the scale of rural settlements expanded, the number of patches and patch area continued to rise, the number of patches increased from 159 to 262, an increase of 103, an increase of 64.8%, and the total area of patches increased from 22.93km2 to

52.53km2, an increase of 29.6km2, an increase of 129.9%. Due to the large per capita and average household area of the settlements in Hunchun City, the degree of internal wandering is high, and the residence is dispersed, in accordance with the requirements of the new rural construction of Hunchun City, the land use master plan (2006-2020) proposes that the land for rural residents will be controlled at 4,693.0hm2 by 2020, and it can be seen in Table 1 that the area of rural spatial clusters in Hunchun City will be reduced in 2020 to 43.48km2 , which meets the overall expectation of land use planning. (2) Hunchun City in 1990, 2000, 2010, 2020, the four-period landscape shape index (LSI) shows a general trend of growth, the patches of rural settlements are gradually separated; perimeter-area fractional dimension number (PAFRAC), although converging to 1 indicates that the shape of the settlement is simple, but the value of the 30-year period is gradually increasing, and the shape of the boundary of the settlement is more irregular; through the four-period patches of the standard deviation of area (PSSD) can show that the distribution of colony patch area in the study area is not uniform.

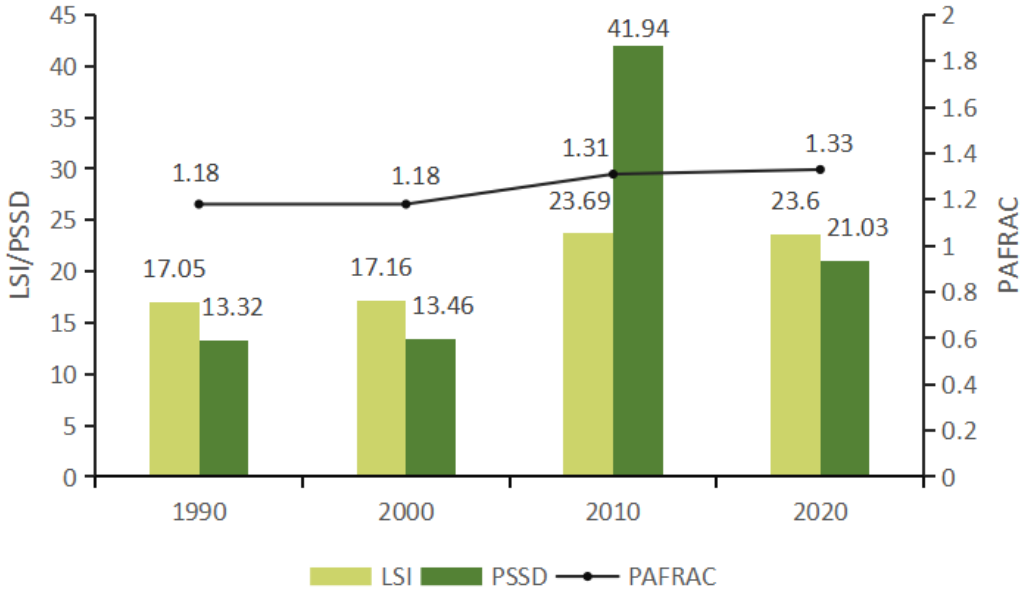

Figure 2 Characteristics of the evolution of the shape of rural settlements in Hunchun City

3.1.2. Characteristics of the evolution of the degree of clustering of rural settlements

ArcGIS10.2 software was used to extract the center of mass of rural clusters in Hunchun City, and the extraction results were analyzed by the average nearest neighbor index, and the significance test was conducted using the P-value and Z-score (Table 2).

Table 2 ANN index of rural settlement distribution in Hunchun City, 1990-2020

	1990	2000	2010	2020
Average observed distance (m)	2495.56	2533.98	1725.32	1810.81
Expected average distance (m)	4379.11	4379.11	3434.17	3531.38
Nearest neighbor index	0.57	0.58	0.50	0.51
z-score	-10.63	-10.42	-16.10	-15.32
p-value	0	0	0	0

Table 2 shows that the nearest neighbor index of rural settlement distribution in Hunchun City from 1990 to 2020 is less than 1, with a P-value of 0, and the Z-value is less than -2.18, which indicates that the clustering trend is significant, and

the spatial distribution of rural settlements in the study area is in the state of clustering. The average observed distance and the expected average distance during the 30-year period show a decrease in the average distance in general, and the nearest neighbor index decreases, which reflects that the spatial distribution range of the patches is expanding but the degree of clustering is increasing. The average observed distance and the expected average distance decreased during the 30-year period, and the nearest neighbor index decreased, reflecting that the spatial distribution of the patches expanded but the degree of agglomeration increased.

3.1.3. Characterizing the evolution of size differentiation in rural settlements

The rural settlement land was extracted from the land use data of Hunchun City in 1990, 2000, 2010 and 2020 respectively, and the center of mass of the land patches was extracted by ArcGIS10.2, and the search radius of 3KM was used to generate the density maps of the rural settlements in the four different periods, which can visualize the difference in the distribution of the rural settlements during the same period and the changes in the distribution in the different periods as shown in Figure 3.

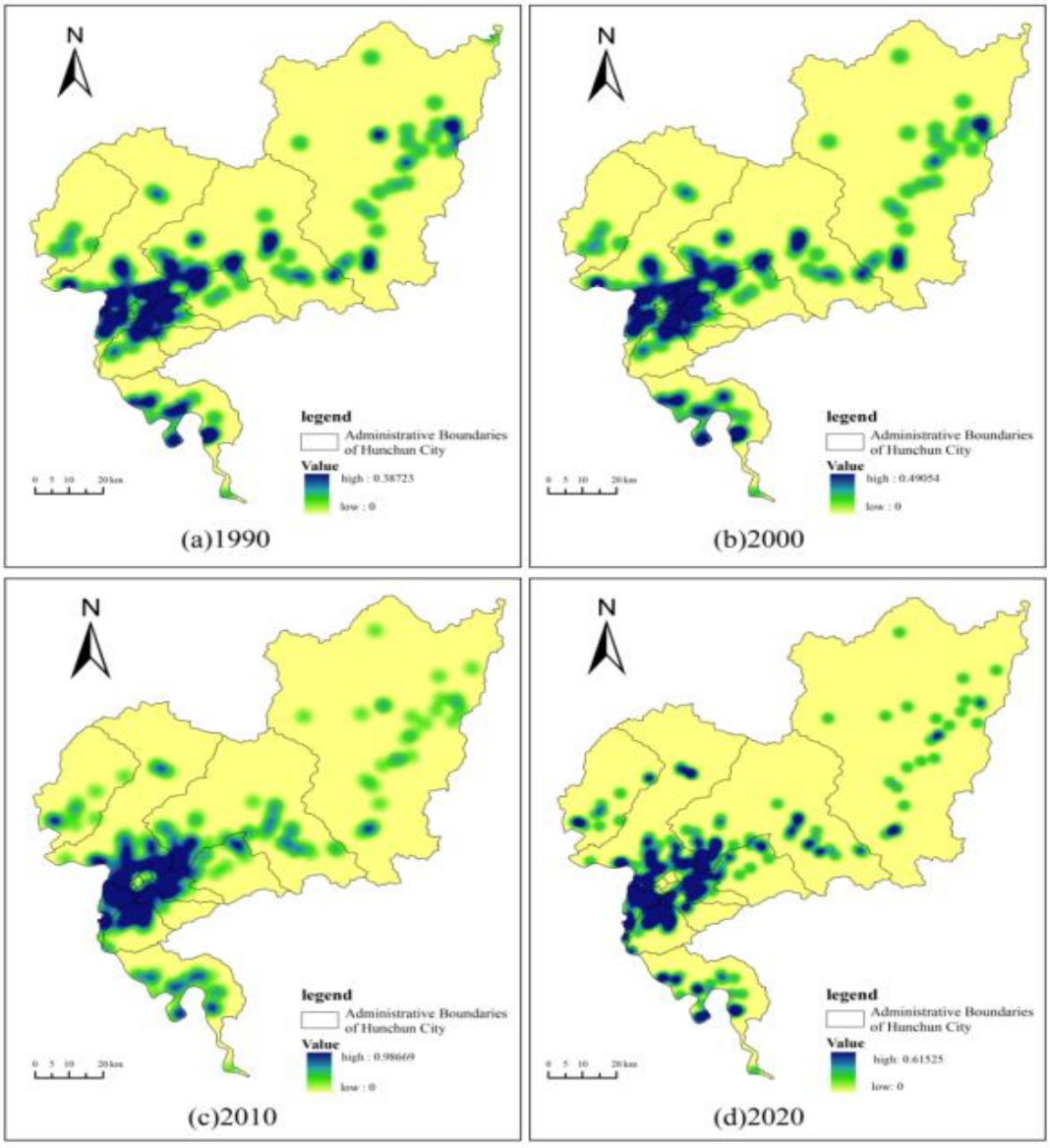

Figure 3 Distribution of kernel density of rural settlements in Hunchun City

It can be seen from the figure:(1)During the 30 years, the density of rural settlements in the study area did not change significantly. The highest values of the kernel density of rural settlements in the four phases from 1990 to 2020 were 0.39/km2, 0.49/km2, 0.99/km2, 0.62/km2, respectively, and the kernel density showed a trend of change from increasing to decreasing, and the concentration and dispersion of the rural settlements coexisted with the overall concentration and dispersion of spatial characteristics. Distribution of spatial characteristics. (2) From the viewpoint of spatial distribution, the distribution map of rural settlements in the study area from 1990 to 2020 has a similar distribution pattern, and the higher density of rural settlements is mostly distributed in the southern part of the study area, and the overall spatial distribution of the study area shows the spatial distribution of "dense in the south and sparse in the north", i.e., with the southwest as the dense center to develop in all directions. The overall spatial distribution of the study area shows a "dense south and sparse north" spatial distribution, i.e., the dense center in the southwest gradually becomes sparsely distributed in all directions. There are obvious high-density "nuclear" areas in the study area, which are distributed around Hunchun city and along the Hunchun River, concentrated in Ying'an Township, Sanjiazi Township, Hadamen Township and Machuanzi Township, and most of the rest of the area is a low value area for nuclear density measurement. (3) In 2010, the nuclear density value was the highest among the four periods, and compared with 20 years ago, the range of high nuclear density areas contracted in 2010, and the high value areas showed a tendency of aggregation and distribution, concentrating around Hunchun City, which is related to the requirements of the new rural construction to guide the concentration of rural dwellings in the central villages and towns, and to promote the transformation of the rural residential land use from the natural form to the planned form, as well as the advancement of the Hunchun land use master plan (2006-2020), and the promotion of the new rural construction plan. This is related to the requirement of new rural construction to guide the concentration of rural dwellings in centralized villages and towns and the promotion of the transformation of rural residential land from natural form to planned form, as well as the advancement of the Hunchun General Land Use Plan (2006-2020).

3.2. Analysis of Impact Factors

3.2.1. Slope

Slope is one of the conditions affecting agricultural production and infrastructure construction, the lower the slope, the more suitable for planting crops, and at the same time conducive to the construction of infrastructure; the higher the slope, the more unfavorable for planting crops, thus affecting the spatial distribution of rural settlements [21]. The slope information was extracted from the DEM data of the study area using ArcGIS10.2 software, and the slope was classified into five levels of <2°, 2-6°, 6-15°, 15-25° and >25°, and overlaid with the distribution map of rural settlements patches of the four phases to obtain Figure 4, Figure 5 and

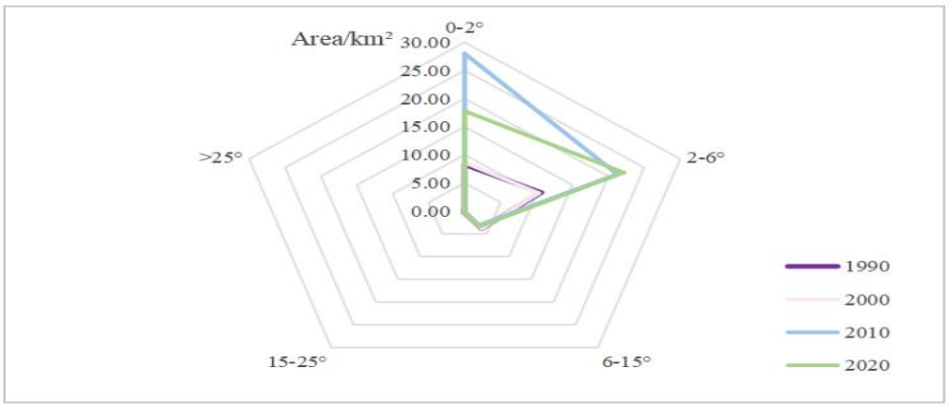

Figure 5 Statistical map of the results of the analysis of the four phases of rural settlements in Hunchun City under different slopes

Table 3.

From Figure 4 and Figure 5, it can be seen that the slope of Hunchun City shows an increasing trend from south to north, and the difference of slope is relatively large, with the minimum slope of 0° and the maximum of 62.28°. From the distribution of rural settlements at different slopes in the four periods of 1990, 2000, 2010, and 2020, it can be seen that the settlements are mainly concentrated in the location of the slope of <6°, and the distribution of the four periods of rural settlements in Hunchun City is not significant. The distribution changes were not significant. As can be seen from Table 3 Changes in the area of rural settlements with slope in Hunchun City in four phases, the distribution of rural settlements in 1990, 2000, 2010 and 2020 was most concentrated in the area of slope 2-6°, accounting for 40.96%, 40.74%, 34.26% and 42.69% of the total area, respectively. The spatial distribution characteristics of rural settlements in Hunchun City vary greatly at different slopes. Due to the demand for convenient traveling conditions and food production, the number of rural settlements becomes smaller and smaller with the increase of slope, and rural settlements in the area of slopes with gentle gradient are distributed more and densely, while those in the area of steeper gradient are distributed less and dispersed. The number of rural settlements is zero because slopes >25° are open limiting slopes, which are not conducive to farming.

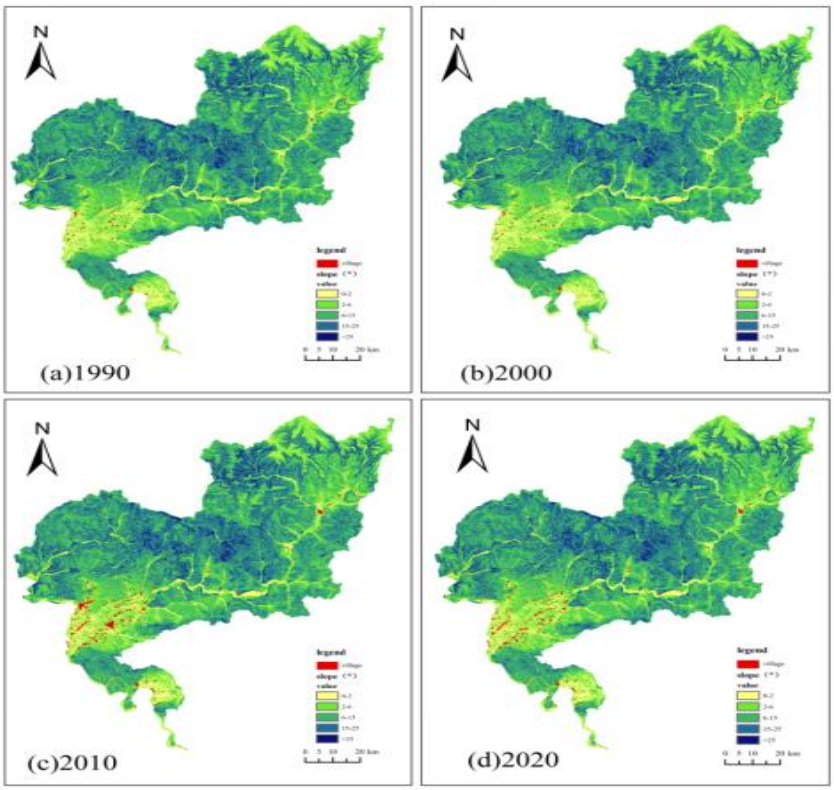

Figure 4 Distribution of rural settlements under the effect of gradient

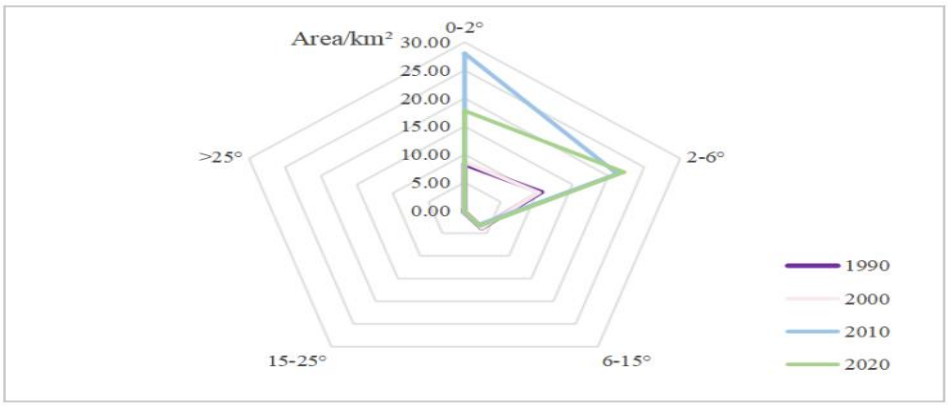

Figure 5 Statistical map of the results of the analysis of the four phases of rural settlements in Hunchun City under different slopes

Table 3 Changes in the area of rural settlements with slope in Hunchun City in four phases

Slope (°)	1990		2000		2010		2020	
	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%
0-2	8.27	36.05	8.65	37.60	28.01	53.33	17.78	40.91
2-6	10.63	46.35	10.31	44.83	21.22	40.40	22.15	50.95
6-15	3.83	16.72	3.84	16.69	3.12	5.95	3.37	7.75
15-25	0.20	0.88	0.20	0.88	0.17	0.32	0.17	0.39
>25	0	0	0	0	0	0	0	0

3.2.2. Rivers

The distribution of rural settlements is affected by the distance from rivers. Using ArcGIS10.2 software multi-ring buffer tool to establish the river buffer zone, divided into five levels, buffer distance were 0-1000m, 1000-2000m, 2000-3000m, 3000-4000m, >4000m, and overlay with the rural settlement layer, to get the different buffer zones of the four rural settlements. 4000m, >4000m, and superimposed with the rural settlement layer, the distribution and changes of different buffer zones of the four rural settlements were obtained (Table 4).

The rivers in Hunchun City are mainly distributed in low-slope areas, and the closer the rural settlements are to the rivers, the more rural settlements there are. As the distance from the river buffer zone increases, the patch area of rural settlements in Hunchun City shows a decreasing trend. Rural settlements are mainly concentrated in the range of 1000-2000m from the river, and the density of rural settlements in the range of >2000m from the river is low, with the area of the settlements accounting for less than 10%. In the buffer zone of 1000m, rural settlements are the most dense, and the area of rural settlement patches accounts for about 60%, and the area of rural settlement patches within the buffer zone of 1000m increased by 13.90km² from 1990 to 2020, accounting for 67.66% of the newly added area.

Table 4 Statistics on river buffer zones of rural settlements in Hunchun City

buffer distance/km	1990		2000		2010		2020	
	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%
0-1	14.66	63.93	14.67	63.47	33.38	63.55	28.56	65.70
1-2	6.83	29.79	6.96	30.27	12.16	23.14	11.82	27.19
2-3	1.30	5.66	1.30	5.64	6.69	12.74	2.80	6.43
3-4	0.14	0.62	0.14	0.61	0.18	0.35	0.18	0.41

>4	0	0	0	0	0.11	0.22	0.12	0.27

3.2.3. Cultivated land radius

Cultivated land, as the main farming object of farmers, has a certain correlation between its resource distribution and the layout of rural settlements. Based on the cropland data in the four periods of land use data in Hunchun City in 1990, 2000, 2010 and 2020, the cropland buffer zone was established by using the Arcgis 10.2 software multi-ring buffer tool, and was divided into five levels, with buffer distances of 0-100m, 100-200m, 200-300m, 300-400m and >400m. The distribution and changes of rural settlements in each buffer zone were obtained by overlaying them with rural settlement patches, drawing the distribution map of rural settlements in the four-phase cropland buffer zone in Hunchun City (Figure 6), and counting the area of rural settlement patches within the four-phase rural settlement cropland buffer zone in Hunchun City (Table 5).

Within 100 meters from the cultivated land buffer zone, the area of rural settlements in Hunchun City was almost unchanged from 1990 to 2000, and the area of rural settlements began to increase after 2010, and the area of rural settlements in this range accounted for 46.59% and 45.45% of the total area in 2010 and 2020, respectively. In the range of 100-200 meters from the buffer zone of cultivated land, rural settlements were mainly distributed in 1990 and 2000, with 47.72% and 48.91% of the rural settlement area, respectively, and the area of rural settlements in this range gradually decreased after 2010. As can be seen from Figure 6, most of the cultivated land is concentrated and continuous, mainly distributed in the southwestern part of Hunchun City, where the terrain is flat. Despite technological progress and changes in villagers' living concepts, the cultivated land still influences the distribution of rural settlements, which are mainly distributed in the vicinity of the cultivated land and within 200m of the cultivated land buffer zone.

Table 5 Statistics on Cultivated Land Buffer Zones of Rural Settlements in Hunchun City

buffer distance /m	1990		2000		2010		2020	
	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%	Area/km2	Ratio/%
0-100	6.81	29.68	6.87	29.84	24.47	46.59	19.76	45.45
100-200	10.94	47.72	11.25	48.91	16.40	31.22	15.59	35.85
200-300	3.16	13.77	2.84	12.33	5.37	10.23	5.24	12.06
300-400	0.39	1.68	0.39	1.67	0.44	0.84	1.07	2.47
>400	1.64	7.15	1.66	7.23	5.84	11.12	1.81	4.17

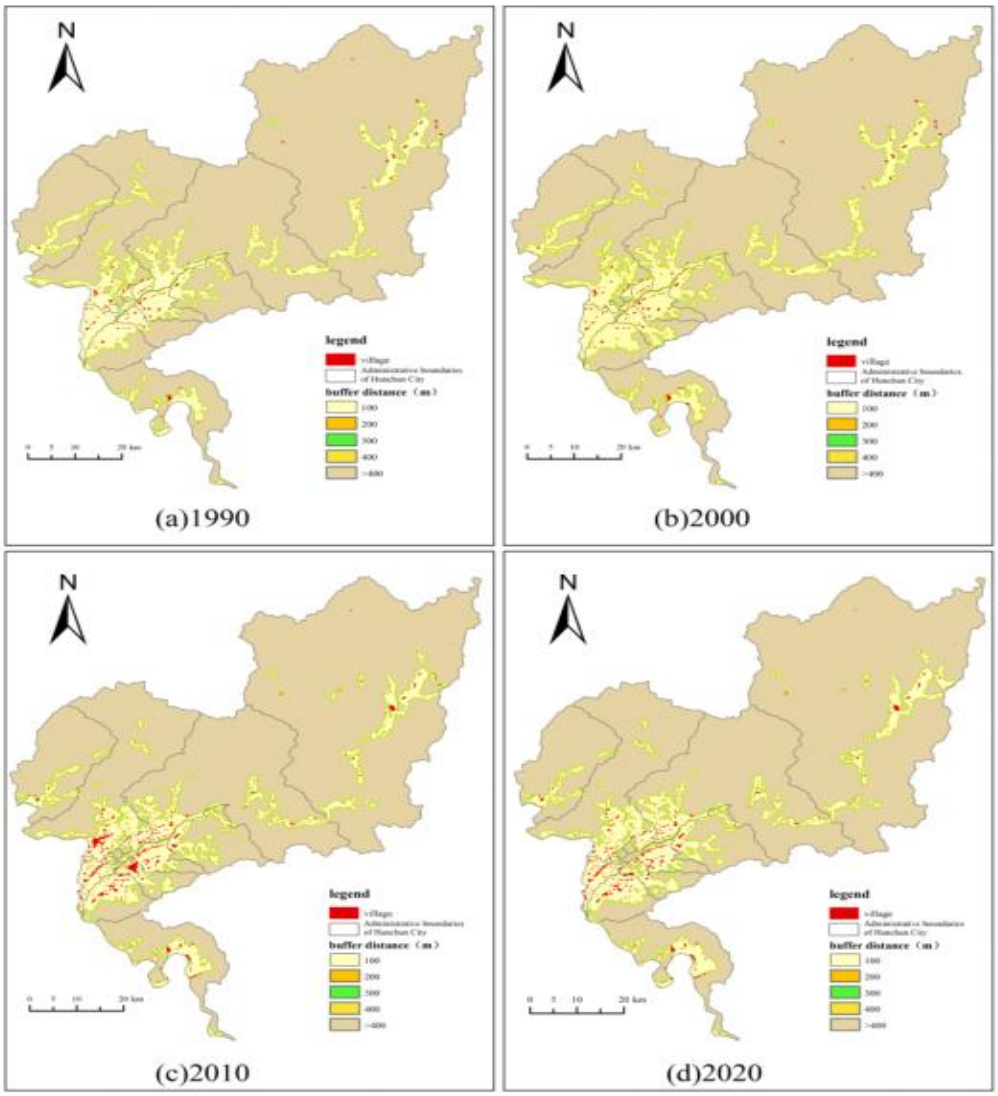

Figure 6 Distribution of rural settlements in the cultivated land buffer zone of Hunchun City

3.2.4. Roads

The Hun-Wu Expressway (G21) in Hunchun City was opened in 2010, and by identifying the rural settlements along the 2000m buffer zone before and after the construction of the expressway (2010 and 2020), a map of the evolution of settlements around the expressway was obtained (Figure 7). The analysis of Figure 8 shows that the village settlements in the 2000m buffer zone of the highway realized further agglomeration and expansion on the basis of the original spatial basis, and the total area of the surrounding settlements increased by 3.89km²; the construction of Hui-Wu highway enhanced the connectivity between the village and the external environment, and the area of the settlement patches increased substantially after 2010, and the transportation hub has the advantage of convergence of people flow, which can prompt the villagers to reorganize their production and production activities in the brand-new facility environment. The transportation hub has the advantage of convergence of people flow, which can encourage the villagers to re-select the production and living space in the new facility environment.

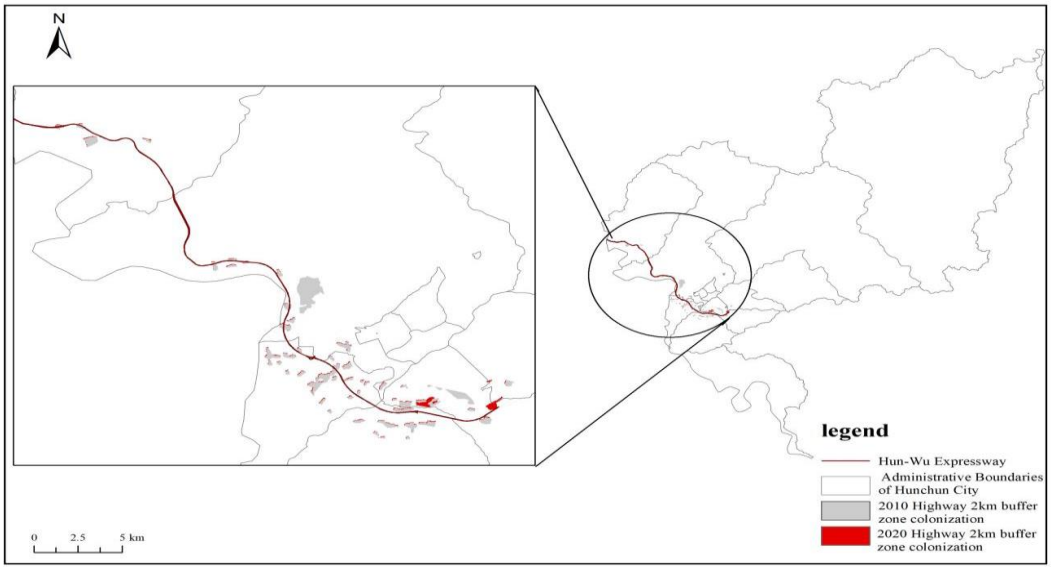

Figure 7 Evolution of rural settlements in Hunchun City due to highway construction map

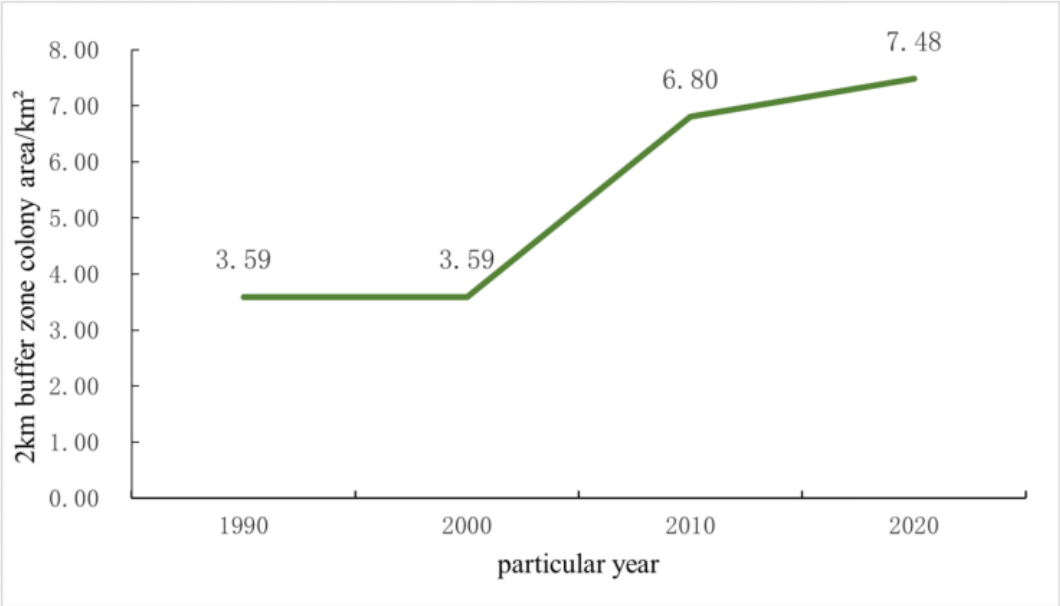

Figure 8 Statistical map of the evolution of the area of rural settlements in Hunchun City caused by the highway

3.2.5. Population and Economy

The rural population of Hunchun City declined from 70,117 to 34,114 between 1990 and 2010, and will grow to 48,135 by 2020. As urbanization accelerates, some rural populations in Hunchun City are moving to the cities, leading to a decline in the population of some remote rural settlements that are relatively backward in terms of economic development, and the phenomenon of rural settlements merging or disappearing. The rise of service industry and tourism has promoted the new development of Hunchun's rural economy and increased farmers' income, which has led to the diversification of farmers'

employment and the return of talented people from the city to the countryside to start their own businesses and work, thus making rural settlements even more clustered on the basis of the previous situation.

Since 1990, the GDP of Hunchun City has continued to rise from 243.11 million yuan, and by 2020 the GDP will be 8940.28 million yuan. Since 1992, when it was approved to become a further open city along the border and set up the Hunchun Border Economic Cooperation Zone, Hunchun has been pushing forward its economic and social development with all its strength, and started to undertake the task of opening up China's border areas to the outside world, and has gradually become an important gateway city of opening up the Northeast region from a border town. The leading industries in Hunchun are mainly resource-intensive and labor-intensive, and it is easy to develop agriculture, industry and tourism, such as textile and garments, energy and minerals, agricultural and sideline product processing, and border tourism. Hunchun City, relying on local resources, aiming at the international market, vigorously develop the rural export-oriented economy, realize the strategic transfer of the rural economy, according to “a township an industry, a village a product” development ideas to determine the production base, start the implementation of the Yanbian cattle centralized breeding breeding Demonstration Park, the cold-water fish Global Tour Industrial Park, Sanjiazi Manchu Township strawberry planting project and a number of key projects to foster the development of the industry. A number of key projects such as the project, cultivate and develop a large number of characteristics of farming and rural tourism and other advantageous agricultural industries, change the traditional layout of rural settlements. Hunchun City, relying on the existing shed economy and courtyard economy, develops a new form of agro-tourism fusion in the form of picking, viewing, experience, etc., which attracts a large number of tourists and drives the development of local catering, accommodation and other services, and makes the function of the rural settlement more diversified from a single function of agricultural production to the multi-functional transformation of the production, tourism, leisure, cultural heritage and other functions.

3.2.6. National Policy

In 1994, the Tenth Meeting of the Standing Committee of the Eighth Jilin Provincial People's Congress adopted the Regulations on the Administration of the Hunchun Border Economic Cooperation Zone, encouraging Chinese and foreign investors to set up export-processing industries, high-tech industries and corresponding tertiary industries in the zone. During this period, Hunchun City began to attract the establishment of some small township enterprises, mainly in the fields of agricultural product processing and timber processing, and the layout of rural settlements changed. In 2009, the State Council approved the “Outline of China's Tumen River Regional Cooperation and Development Plan - Changjitu as the Pilot Zone for Development and Opening Up”, and Hunchun assumed the function of “window” and bridgehead for the development and opening up of Changjitu to promote economic and trade cooperation between China's northeastern region and neighboring countries. Promoting economic and trade cooperation between China's northeastern region and neighboring countries. The development of Changjitu has brought development opportunities for the grain industry, agricultural product processing industry, tourism industry, etc., and the development of rural specialty industries has also been emphasized.

The Hunchun City Land Use Master Plan (2006-2020) adjusts the layout of urbanization in accordance with the requirements of new urbanization development, moderately withdraws scattered natural villages, and guides the rural population to focus on key townships such as Ying'an Township, Banshi Township, and Machuanzi Township, leading to an overall concentration of the distribution pattern of countryside settlements in urban areas. Hunchun City has made every effort to implement the strategy of rural revitalization, giving priority to the development of agriculture and rural areas, stepping up the cultivation of characteristic industries, and expanding the whole agricultural industry chain; it has also pushed forward the comprehensive improvement of the environment of villages and townships, deeply implemented the “seven must be demolished”, cleaned up the “fake greenhouses”, and built the “Four Good Rural Roads”. “Four Good Rural Roads”, and strive to create a livable and beautiful countryside. Relying on the local characteristics of culture and natural and human

resources to vigorously develop rural tourism, efforts to create a beautiful environment of human settlements boutique villages, cultivate a strong local characteristics of rural tourism products, such as ornamental agriculture, field search, ecological picking, etc., and gradually establish a “township, a product” development pattern, to achieve the differentiation of rural tourism, personalization and specialization of rural tourism.

3.3. Rural settlement landscape pattern optimization

3.3.1. Direction of rural settlement landscape pattern optimization

Forest land and waters were selected as the ecological source points, and according to the influencing factors of rural settlement landscape pattern in Hunchun City, elevation, slope, road and land use classification were taken as resistance factors, and their polarity standardization was carried out; the minimum cumulative resistance surfaces of forest land and waters were calculated by using the cost-distance model, and the ecological security and protection pattern was constructed, so as to explore the direction of optimizing the landscape pattern of the rural settlements in the study area. The optimization direction of the pattern was explored. The ecological protection pattern was reclassified and divided into protection levels, and the optimization type map of rural settlement landscape in the study area in 2020 was obtained (Figure 9). The ecological security protection pattern of the study area was superimposed on the rural settlement patches, and divided into four optimization types: key remediation type, restriction of expansion type, moderate construction type, and centralized development type.

3.3.2. Countermeasures to optimize the landscape of rural settlements

The area and proportion of each type of rural settlement patches in Hunchun City are shown in Table 6, and the statistical results are as follows:(1) Key remediation type. This type of rural settlement has a total land area of 3.03km², accounting for 6.99% of the total scale; it is distributed in the ecological safety protection zone, which is the main source of forest land and waters, and the core location for maintaining the ecological balance; this type of settlement is scattered in layout and small in scale; from the point of view of ecological protection, it adopts the measures of relocating and merging the settlements that have greater damage to the ecological environment, to enhance the restoration function of the land's natural ecosystem itself as well as the ability to resist external infringement, and to construct a new landscape. To improve the repair function of the natural ecosystem of the land and its ability to resist external aggression, so as to build a solid ecological security defense line. At the same time, uphold the principle of moderate development, and actively lead the development of specialty industries within the carrying capacity of resources and environment. (2) Restriction of expansion type. This type of rural settlement has a total land area of 16.27km², accounting for 37.55% of the total scale; the patches are distributed in a medium scale, with a high degree of agglomeration, and are distributed in the ecological security control area, with rich arable land and water resources, and good agricultural production conditions, suitable for living and production. For this type of rural settlement, it should improve the infrastructure construction on the original basis, control environmental pollution, optimize the ecological environment, and limit its disorderly expansion; develop the local characteristics of culture and industry, and accelerate the modernization of agriculture. (3) Moderate construction type. This type of rural settlement has a total land area of 8.76km², accounting for 20.22% of the total scale; it is distributed in the ecological safety transition area, with sufficient water sources, convenient transportation, good ecological environment, meeting the daily life and production needs of farmers, and can be used as a relocation area for the expansion-restricted rural settlements. The potential should be fully tapped to develop characteristic industries based on geographical advantages and promote local economic development. The existing villages should be remodeled, supporting facilities should be improved, and the space of rural settlements should be rationally distributed. (4) Centralized development type. This type of rural settlement has a total land area of 15.27km², accounting for 35.24% of the total scale; the patches are distributed on a large scale with a high degree of agglomeration, and are distributed in non-ecological safety protection zones, far away from forests and waters, and close to urban areas. This optimization type is suitable for the government to promote the

construction of "central villages" and attract the scattered settlements in the surrounding areas to concentrate in this area. It is also suitable for ecological restoration of the land of annexed villages, promoting resource conservation and environmental protection, realizing a scientific layout within the cluster and promoting local economic development.

Table 6 Statistics on optimization of landscape pattern of rural settlements in Hunchun City in 2020

Optimization Type	Area/km²	Ratio（%）
Key Remediation Type	3.03	6.99
Restriction Of Expansion Type	16.27	37.55
Moderate Construction Type	8.76	20.22
Centralized Development Type	15.27	35.24

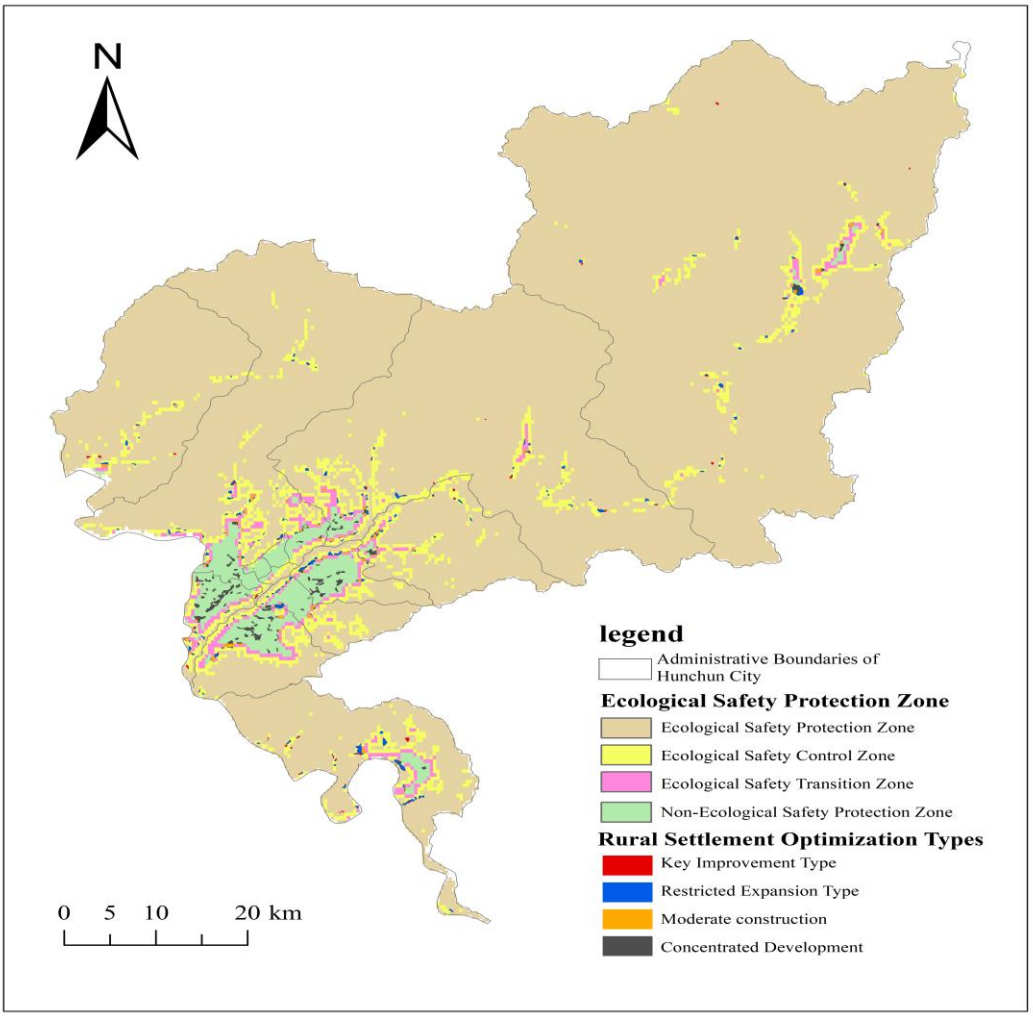

Figure 9 Optimization type map of landscape pattern of rural settlements in Hunchun City in 2020

4. Discussion

This study conducted an in-depth analysis of the spatio-temporal evolution of rural settlement landscapes in Hunchun City and its influencing factors, revealing significant changes in the spatial distribution, morphological changes, and influencing factors of rural settlements over a period of 30 years. The research shows that rural settlements in Hunchun City experienced a remarkable process of expansion and agglomeration from 1990 to 2020. The scale of settlements, the number of patches, and the area continued to increase. The rural settlements expanded in scale, had simple shapes, and their spatial

distribution was uneven. Through the analysis of the nearest neighbor index, it was found that the agglomeration degree of rural settlements in Hunchun City increased, especially during the period from 1990 to 2010. However, with the advancement of the new rural construction, the area of rural settlements decreased in 2020. The results obtained are consistent with the general conclusions of existing studies. Rapid urbanization has profoundly changed the spatio-temporal patterns of land use in China. With the development of urban-rural integration, it is imperative to combine land consolidation with new rural construction, which has led to changes in rural settlements in terms of quantity, location, composition, and configuration. This phenomenon can also be seen in other regions of China.

In addition, the study also indicates that the spatial distribution of settlements in Hunchun City presents an obvious feature of being "dense in the south and sparse in the north", which is different from the concentration trend of rural settlements in many regions. This is because the terrain in the southern part of Hunchun City is flat, the soil is fertile, and there is sufficient water supply, which is suitable for agricultural production and human habitation. Areas with flat terrain and gentle slopes can ensure sufficient sunlight and natural water source irrigation, which are suitable for the production of grain crops such as corn and rice in Hunchun City's traditional planting industry and are conducive to the construction of rural pastoral complexes in Hunchun City, thus changing the layout of rural settlements. Moreover, the urban area is located in the south. As the economic center of Hunchun City, the industrial development of the urban area can have a radiating and driving effect on rural areas. Enterprises will extend their industrial chains to rural areas, develop agricultural product processing, rural tourism, and other industries, and promote the development of the rural economy. The construction of the G21 Expressway has also increased the area of nearby rural settlements. Good road facilities have shortened the time for people to reach their destinations and improved people's quality of life. The construction of "every household accessible" village roads and "four-good rural roads" in Hunchun City has transformed the dirt roads within rural settlements into highways. And being close to the urban area makes the transportation more convenient, facilitating the rapid transportation of agricultural products to the market for sale and increasing farmers' economic income. Therefore, rural settlements gather around the urban area. The infrastructure construction in the urban area is relatively complete. Rural areas close to the urban area can share these infrastructure and public service resources, improve the living conditions of rural residents, and enhance the quality of life. Policy factors are one of the reasons that distinguish the changes in rural settlements in Hunchun City from those in other regions. From 1990 to 2020, the Hunchun Municipal Government successively issued a series of policies and measures, such as the "Overall Land Use Planning of Hunchun City (2006 - 2020)", "Implementation Opinions on Promoting the Optimization and Integration of Rural Settlements", and "Several Provisions on Strengthening the Management of Rural Homesteads". In the process of promoting urban-rural integrated development, it has increased its support for rural areas, gradually optimized the layout and management of rural settlements, promoted rural infrastructure construction and environmental improvement, and gradually formed a pattern of rural settlements that combines concentration and dispersion, which not only maintains traditional rural characteristics but also meets the requirements of modern agriculture and rural development, thus promoting urban-rural integrated development.

At the same time, due to the geographical particularity of Hunchun City as a border city, Hunchun City has advantageous industries such as Yanbian yellow cattle, cold-water fish, green rice, selenium-containing apples, edible fungi, and Chinese herbal medicines. The products are not only sold to major domestic cities but also exported to Southeast Asian countries such as Japan and South Korea. The future development of Hunchun City can make full use of its geographical advantages in the border area to promote the development of rural settlements and achieve the integrated development in multiple fields such as agriculture, tourism, and trade. Relying on open platforms such as the Marine Economic Development Demonstration Zone, Border Cooperation Zone, and Cross-border E-commerce Comprehensive Pilot Zone, it vigorously develops advantageous business forms such as cross-border e-commerce and processing of goods from border trade, driving the development of border rural areas. Meanwhile, Hunchun City is also a region where multiple ethnic groups live

together. The cultures of ethnic groups such as the Manchu, Korean, Han, and Hui ethnic groups complement each other. Unique rural tourism and cultural areas can be developed by combining ethnic minority customs, retaining the uniqueness of multi-ethnic cultures, highlighting the characteristics of "border, ecology, and folk customs", making it a major business card of Hunchun City's tourism resources and attracting more tourists to come and enjoy.

Based on the influencing factors of the rural settlement landscape pattern in Hunchun City, this study calculated the minimum cumulative resistance surface, constructed an ecological security protection pattern, explored the optimization direction of the rural settlement landscape pattern in the study area, and divided it into four types of rural settlement landscape patterns (key remediation type, restriction of expansion type, moderate construction type, and centralized development type). It revealed the different needs and optimization strategies of the spatial distribution of rural settlements in different regions. The proposal of these strategies is helpful for further understanding the complex mechanism of the evolution of rural settlement landscapes, especially the coordination between the optimization of settlement forms and factors such as ecological security and land use.

5. Conclusions

(1) During 1990-2010, the scale of rural settlements in Hunchun City expanded, and the number of patches and patch area continued to rise; in accordance with the requirements of the new rural construction Hunchun City Land Use Master Plan (2006-2020), the area of rural spatial clusters in Hunchun City in 2020 is reduced. During the period of 30 years, the shape of settlements was simple, and the distribution of the area of settlements and patches was not uniform.

The nearest-neighbor index of rural settlement distribution in Hunchun City were all less than 1, the P value was 0, the Z value was less than -2.18, and the spatial distribution of rural settlements was in the state of agglomeration. The average observed distance and the expected average distance in the past 30 years showed a general decrease, and the nearest-neighbor index decreased, and the range of the spatial distribution of the patches was enlarged but the degree of agglomeration was enhanced. The kernel density of rural settlements showed a trend of change from increasing to decreasing, and the density change was not significant, and the distribution pattern of rural settlements in Hunchun City was similar. The higher density of rural settlements is mostly distributed in the southern part of the study area, and the overall spatial distribution of rural settlements in the study area shows a spatial distribution of “dense in the south and sparse in the north”, i.e., with the southwestern part of the area as the dense center, the spatial characteristics of the sparse distribution gradually change to the sparse distribution in the surrounding area.

(2) The spatial and temporal evolution of rural settlements is influenced by a number of factors, including geographic conditions, transportation facilities, population changes, economic development and national policy support, and is the result of the integration of natural, human and social factors. Natural conditions lay the foundation, and human and social factors dominate its development. Rural settlements in Hunchun City are concentrated along roads and transportation hubs, in locations with slopes of less than 6°, within a buffer zone of 2,000 m from rivers, and within a buffer zone of 200 m from arable land; population, economic changes, and national policy support also influence the evolution of settlements.

(3) Based on the ecological security protection pattern of the study area, the landscape pattern optimization of rural settlements is carried out, which is divided into four types of settlement landscape optimization: key remediation type, restriction of expansion type, moderate construction type, and centralized development type. The key remediation type of rural settlements is distributed in the ecological security protection zone, which is the main source of forest land and waters, and the core location for maintaining the ecological balance. Restriction of expansion type is distributed in the ecological security control area, with rich arable land and water resources, good agricultural production conditions, suitable for living and production. The moderate construction type is distributed in the ecological security transition area, with sufficient water sources, convenient transportation, good ecological environment, meeting the daily life and production needs of

farmers, and can be used as the relocation area of the restricted expansion type of rural settlements. The centralized development type is distributed in non-ecological safety protection zones, far away from forests and waters, and close to urban areas.

6. Limitations and Future Directions

Although this study provides an analysis of the spatial and temporal evolution of rural settlements in Hunchun City, it still has some limitations. The study mainly relies on spatial analysis methods such as landscape pattern index, kernel density analysis, and nearest neighbor index, which can effectively reveal the spatial distribution characteristics of settlements but fails to comprehensively capture the deeper influence of socio-cultural factors on the evolution of rural settlements. In the future, by introducing social survey data and combining social and cultural backgrounds, we can deeply explore how cultural and historical factors affect the evolution of rural settlements, and propose strategies for optimizing and restructuring rural settlements according to local conditions.

Author Contributions: Conceptualization, C.G.; methodology, C.G.; software, C.G.; validation, C.G; formal analysis, C.G.; resources, C.G.; data curation, C.G.; writing—original draft preparation, C.G.; writing—review and editing, C.G. and S.C.; visualization, C.G.; supervision, S.C.; project administration, S.C.; funding acquisition, S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Social Science Research Projects of the Jilin Provincial Department of Education, (grant number JJKH20220512SK).

Institutional Review Board Statement: Not applicable for studies not involving humans or animals.

Data Availability Statement: The information provided in this research can be accessed by contacting the author who is responsible for this study.

Conflicts of Interest: The authors declare no conflict of interest.

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