Spatio-temporal Differentiation Patterns and Influencing Factors of Rural Settlements in Three Provinces in Northeast China in the Context of Population Shrinkage

Spatial-temporal Differentiation Pattern and Influencing Factors of Rural Settlements

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Abstract. In recent years, the pace of economic development in Three Provinces in Northeast China has been slowing down, population shrinkage has been serious, and rural settlements, which are the space where various kinds of rural production activities are carried out, have also been affected to different degrees. Therefore, it is of great significance to study the spatial and temporal distribution pattern of rural settlements in Three Provinces in Northeast China under the background of population shrinkage and its influencing factors, in order to promote the rational layout of rural settlements, improve the living standard of rural residents, optimize the national land space, and comprehensively push forward the revitalization of the countryside and urban-rural integration, and help the implementation of Northeast China's revitalization. This paper selects Three Provinces in Northeast China as the study area, and utilizes landscape pattern index, nuclear density analysis, and entropy method to study the spatial and temporal differentiation pattern of rural settlement in Three Provinces in Northeast China from 2010 to 2020, and arrives at the following conclusions: ① During the period of 2010 to 2020, rural settlement in Three Provinces in Northeast China shows spatial shrinkage year by year. ② The spatial variability is significant, mainly distributed in the western and southwestern regions, with high distribution density of rural settlements in Dalian, Shenyang, Changchun, Harbin, Panjin, Jinzhou, Siping, Tieling and other places. ③ The added value of agriculture, forestry, animal husbandry and fishery has the greatest influence on the spatial and temporal pattern of rural settlement, and the urbanization rate has the least influence.④With the full implementation of the rural revitalization strategy in recent years, the youth labor force and urban population return, and there is a potential for the recovery of rural settlements.

Keywords: Population shrinkage; Rural settlement; Landscape pattern index; Nuclear density; Three Provinces in Northeast China.

1   Introduction

Rural areas have always been the focus of China's attention in building a modern socialist country. Since the reform and opening up, with the continuous promotion of the urbanization process, rural areas have undergone radical changes, and nowadays, China has comprehensively promoted rural revitalization and urban-rural integration development. between 2010 and 2020, the population of the three northeastern provinces of China has only shown a positive trend of population growth in three prefectural-level units, namely, Shenyang, Dalian, and Changchun. The remaining 33 prefecture-level units are population shrinkage cities, and the most serious population shrinkage prefecture-level unit, Siping City, has shrunk by 1,571,592 people in 10 years, accounting for 46.41% of the resident population. At the same time, the rural population of the Three Provinces in Northeast China also shows different degrees of contraction from 2010 to 2020[1]. This has also indirectly led to "rural diseases" such as "hollowing", rough and messy land use and disorderly expansion, irrational spatial layout, and serious loss of young and strong labor force in rural areas of Three Provinces in Northeast China, which is not conducive to the comprehensive promotion of rural revitalization and urban-rural integrated development. In 2022, the report of the 20th Party Congress pointed out the need to comprehensively promote rural revitalization; in 2023-2024, the No. 1 document of the Central Government pointed out the need to solidly promote the construction of livable and beautiful villages, and to adapt to the trend of changes in the rural population, optimize the layout of villages, industrial structure, and the allocation of public services. Rural settlement is also known as rural settlement, and the change of rural settlement has an important impact on the spatial layout and the quality of production and life of villagers in the village area. Rural settlement is also a place of residence for various forms of population in rural areas[2], which is the spatial basis for all kinds of factors to carry out activities in the village, and the population is the most active among all kinds of factors, and the population shrinkage in the countryside often represents the change in the scale of rural settlements, and the attenuation of the vitality of the countryside. Therefore, studying the spatial and temporal distribution pattern of rural settlements in Three Provinces in Northeast China and its influencing factors based on population shrinkage is of great significance in promoting the rational layout of rural settlements, improving the living standards of rural residents, optimizing the national land space, comprehensively promoting the revitalization of the countryside and the integration of urban and rural areas, and assisting the implementation of the revitalization of Northeast China.

The research of foreign scholars on rural settlements mainly focuses on rural settlement landscape, rural settlement morphological changes, and historical changes of rural settlements, and the research methods mainly focus on mathematical and statistical analysis and descriptive analysis. For example, Angelo Castrorao Barba et al.[3] utilized spatial and statistical analyses of GIS and used a series of topographical and ecological factors to illustrate the complex dynamics of change in the western Sicilian countryside from the Roman settlement system to the formation of the landscape in the Islamic era; Gabriel Kuczman[4] utilized cluster analysis to examine the roadside vegetation in the streetscapes of the rural settlements in the western Slovakia. Functions,

woody plant values and ecosystem services were quantitatively evaluated. China's countryside, like its cities, is a complex mega-system, and rural issues are linked to national policies, regional development and other realities. Therefore, the research hotspots of domestic scholars on rural settlements mainly focus on the spatio-temporal pattern, spatial optimization and reconstruction and driving mechanism of rural settlements, and rationally plan the national land space to comprehensively promote the strategy of rural revitalization by combining the relevant national policies and the current situation of regional development[5-8]. For example, Tao Shijun[9] utilized the type mapping method, spatial clustering method and other methods to portray the regional differentiation pattern of village characteristics in China; for example, Wu Tao and Li Chuanwu[10] utilized the land use data of three periods from 1980 to 2020, and used mathematical statistics and spatial analysis methods such as kernel density estimation to explore the spatial evolution characteristics and driving mechanism of rural settlement in the coastal plains of Jiangsu Province; for example, Liu Rongping[11] et al. based on the impact of the policy of poverty alleviation and relocation on the The spatial and temporal evolution of rural settlements in karst mountainous areas was quantitatively analyzed. For the distribution of rural settlements in terms of spatio-temporal pattern evolution, landscape pattern index method, kernel density estimation, spatial autocorrelation analysis, nearest neighbor index method and other methods are commonly used, and buffer analysis, geographic detector and other methods are commonly used for the study of influencing factors.

Comprehensive research status at home and abroad, the research on rural settlement is mostly focused on micro and typical regions, and there are fewer studies on rural settlement in Northeast China, where rural population shrinkage is a serious problem. Based on the background of population shrinkage, this paper starts from the provincial space of Three Provinces in Northeast China, and utilizes the kernel density estimation method, spatial autocorrelation analysis and nearest-neighbor index method to study the spatio-temporal differentiation pattern of rural settlement in the Three Provinces in Northeast China from 2010 to 2020, and utilizes the entropy method to explain the weights of the dynamically evolving factors, in order to provide reference for comprehensively advancing the strategy of revitalizing the Northeast and rural settlement, and to supplement the research on the rural settlement of Three Provinces in Northeast China in the academic community. Three Provinces in Northeast China.

2   Overview of the Study Area, Research Methodology and Data Sources

2.1   Overview of the Study Area

The Three Provinces in Northeast China are located in northeastern China, bordering Russia to the north, the Bohai Sea to the south, and North Korea to the east, and generally refer to the 36 prefectural-level administrative units of Liaoning, Jilin, and Heilongjiang Provinces in China. Most of the Three Provinces in Northeast China have a temperate monsoon climate, with a few areas at higher latitudes, with long, cold winters

and short, warm summers, with high snowfall and low evaporation in winter, mostly in the mesothermal zone, and a few in the frigid and warm temperate zones, the humid and semi-humid zones, and with a terrain dominated by plains and mountains.

With reference to the data from China's sixth population census (2010) and seventh population census (2020), the rate of change in the resident population of prefecture-level units in Northeast China was calculated, and those with a negative rate of change in the resident population were defined as population shrinkage cities[12]. Between 2010 and 2020, only three prefecture-level units in Northeast China, namely, Shenyang, Dalian, and Changchun, had a positive trend in population growth, and the remaining 33 The remaining 33 prefecture-level units are population shrinkage cities, and Siping City, the prefecture-level unit that accounts for the most serious population shrinkage, has shrunk 15,715,092 people in 10 years, accounting for 46.41% of the resident population. Meanwhile, referring to the research results of Dong Chaoyang and other scholars, during 2010-2020, the rural population of Heilongjiang Province shows a state of heavy contraction, and Jilin Province and Liaoning Province are in a state of moderate contraction. In recent years, the economic development of the Three Provinces in Northeast China has been slowed down, the rural population loss is serious, and the changes of rural population have caused the rural settlement in the Three Provinces in Northeast China to continue to change spatially.

2.2   Research Methodology

2.2.1 Landscape Pattern Index.

The landscape pattern index is used to describe and analyze the landscape spatial structure characteristics, reflecting the composition and spatial arrangement of the landscape. In this paper, the landscape pattern index[6], combined with ArcGIS, was used to quantify the rural settlement patches extracted from the land use data of Three Provinces in Northeast China in 2010, 2015, and 2020, in order to reflect the changes in the overall scale of rural settlements in Three Provinces in Northeast China from 2010 to 2020. The selected indicators and their meanings are shown in Table 1, and the process and results of the calculation of each indicator are reflected in Fragstats software.

Table 1. Selected indicators and meanings for landscape pattern analysis

Norm	Meaning of the indicator
Number of plaques (NP)	Measuring the number of rural settlement patches
Total patch area (CA)	Measuring the total area of rural settlement patches
Plaque density (PD)	Measuring the distribution density of rural settlement patches
Landscape Shape Index (LSI)	Measuring the characteristics of morphological change in rural settlements

2.2.2 Nuclear Density Analysis.

Referring to the related research of Shi Yanwen et al. on the settlement space in typical areas of agricultural industrialization[13] , nuclear density analysis is a method used for statistical nonparametric density, which can reflect the spatial distance decay

effect of geographic phenomena. The nuclear density analysis can reflect the spatial distribution characteristics of rural settlements in Three Provinces in Northeast China on the map, and the nuclear density analysis of different years can also show the spatio-temporal evolution characteristics of rural settlements. The 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 the kernel function, and $x-x_I$ is the valuation point x is the distance from the valuation point tox_I is the distance from the valuation point, and ''h' is the bandwidth, with a value greater than 0.n is the total number of rural settlements. The nuclear density analysis method in this paper is implemented in ArcMap software in ArcToolbox - Spatial Analyst tool - Density analysis - Nuclear density analysis was realized in the ArcMap software.

2.2.3 Average Nearest Neighbor Analysis.

Average nearest neighbor analysis is an analytical method to determine the spatial distribution and agglomeration trend of rural settlements in Three Provinces in Northeast China based on the average nearest neighbor index, with the formula:

$$R=\frac{\overline{D}_0}{\overline{D}_E}\times\frac{\sum_{i=1}^{n} d_i/n}{0.5/\sqrt{n/A}}$$

where R is the average nearest neighbor index, and$\overline{D}_0$ is the average observed distance between the rural settlement patch and the nearest point, and$\overline{D}_E$ is the expected average distance of random distribution, andd_i is the distance between rural settlements in Three Provinces in Northeast China, and$n$ is the number of rural settlement patches; and A is the total area of the patches.

2.2.4 Entropy Method.

The entropy value is a measure of uncertainty. The larger the amount of information, the smaller the uncertainty and the smaller the entropy; the smaller the amount of information, the larger the uncertainty and the larger the entropy[15-17]. Referring to the relevant research results about rural settlements within the academia, it can be concluded that the influencing factors of the spatial and temporal distribution of rural settlements are mainly the gross regional product, per capita GDP, urbanization rate, rural residents' income and so on. In this paper, we take GDP (X1), GDP per capita (X2), urbanization rate (X3), rural population (X4), rural employees (X5), primary industry output (X6), agriculture, forestry, animal husbandry and fishery added value (X7), rural residents' income (X8) as the factors affecting the spatial and temporal distribution of rural settlement in Three Provinces in Northeast China, and calculate the weights of these factors by using the entropy method. The entropy value method was used to calculate the weight of each influence factor, and the degree of influence of the above influence factors on the distribution of rural settlements was derived.

2.3   Data Sources

The research data used in this paper mainly include administrative district data, digital elevation data, land use data, and socio-economic data. The administrative district data in this paper comes from the standard map service system of the Ministry of Natural Resources (mnr.gov.cn), and the base map comes from Gaode Map (Review No. GS(2023)4677), without modification. The digital elevation data comes from the worldwide 30-meter resolution digital elevation model released by the European Space Agency (ESA). In order to show the spatial and temporal changes of rural settlements in Three Provinces in Northeast China from 2010 to 2020, this paper selects the land use data of 2010, 2015 and 2020, and extracts the patches with the name of "Rural Settlement" as the patches of rural settlements in ArcMap software, so as to represent the rural settlements in this paper. represent the rural settlement in this paper. The above three periods of land use data were obtained from the China Multi-Period Land Use Remote Sensing Monitoring Dataset (CNLUCC)[14] of the Data Registration and Publication System of the Institute of Geographic Sciences and Resources, Chinese Academy of Sciences. Socio-economic data were obtained from Heilongjiang Statistical Yearbook, Jilin Statistical Yearbook and Liaoning Statistical Yearbook.

3   Results and Analysis

3.1   Landscape Pattern Analysis

From the calculation results of landscape pattern index, the number of patches (NP) started to decline from 2010 to 27144 in 2020, the total area of patches (PD) declined from 2010 to 230033867.1141 hectares in 2020, and the density of patches (PD) and the landscape shape index (LSI) showed a decreasing trend of different degrees. It can be seen that the number, area and density of rural settlements in Three Provinces in Northeast China showed a decreasing trend during 2010-2020, and rural settlements showed a spatial shrinkage year by year.
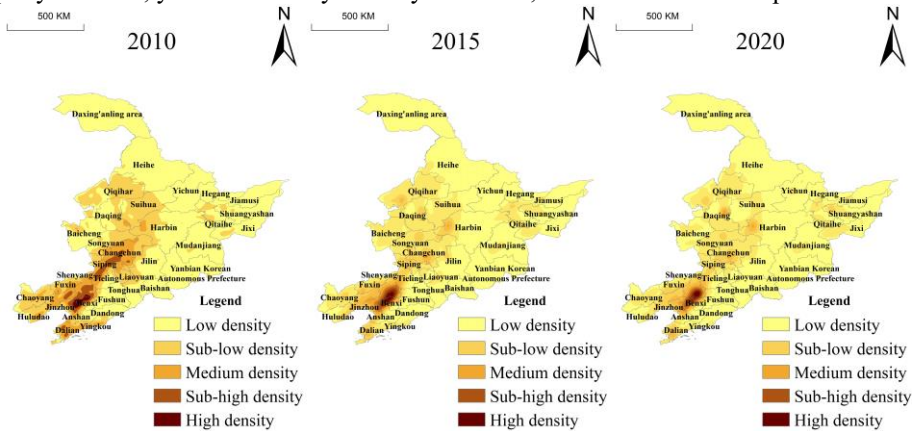
3.2   Nuclear Density Analysis

After the nuclear density analysis in ArcGIS, the calculation results were categorized into five categories by the natural breakpoint method: low-density area, second-low-density area, medium-density area, second-high-density area, and high-density area (Figure 1). Overall, in the context of population shrinkage in Three Provinces in Northeast China, there is a massive exodus of rural youth labor to the south of China, where the level of economic development is good and attractive, and the rural population is declining year by year, and the size and density of rural settlements in Three Provinces in Northeast China show a trend of shrinkage in the period from 2010 to 2020 and are mainly distributed in the western and southwestern regions, and rural settlements are distributed in the higher density of the city of Dalian, Liaoning Province, Shenyang City in Liaoning Province, Changchun City in Jilin Province, and Harbin City in Hei-

longjiang Province have higher levels of socio-economic development, and the construction of rural settlements is better than that in other areas of the Three Provinces in Northeast China, and their neighboring prefectural-level units, such as Panjin, Jinzhou, Siping, Tieling and other places are subjected to radiation, and the densities of rural settlements are better than that in other areas of the Three Provinces in Northeast China.

The spatial distribution of rural settlements in the Three Provinces in Northeast China is significantly differentiated. In 2010, in the southwest of the Three Provinces in Northeast China, a "Northeast-Southwest" oriented belt space was formed, around which were distributed sub-high-density zones and high-density zones, which mainly included the cities of Dalian, Panjin, Siping, and Changchun in Liaoning Province, with the density decreasing towards the north, and a large number of low-density zones were distributed in the northwestern and northeastern parts of the country. and northeastern Liaoning Province, and a large number of low-density zones are distributed in the rest of the area. In 2015, high-density zones, sub-high-density zones, medium-density zones, and sub-low densities in the southwestern part of the province shrink, and high-density zones and sub-high-density zones are still distributed in the Liaoning Province and the southern part of the Jilin Province. In 2020, high-density zones, sub-high-density zones, medium-density zones, and sub-low densities continue to shrink and high-density zones and sub-high-density zones are continued to be distributed in the Liaoning and southern Jilin Provinces.

Half Width Figures.

Figure 1 is an example of a figure and caption spanning the half-page width (one column in a two column format) with the styles applied. If your figure contains third-party material, you must clearly identify it as such, as shown in the example below.

Fig. 1. Distribution of nuclear density of rural settlements in Three Provinces in Northeast China, 2010-2020

3.3   Entropy Method Calculation Results and Analysis

As shown in Table 2, the entropy method is used to calculate the weights of a total of 8 items such as gross regional product (X1), as can be seen from the above table: gross

regional product (X1), gross regional product per capita (X2), urbanization rate (X3), number of rural population (X4), number of people working in the countryside (X5), the percentage of output value of the primary industry (X6), the value-added of agriculture, forestry, animal husbandry, fishery and fisheries (X7), disposable income of rural residents (X8). The weights of the eight items are 0.086, 0.087, 0.010, 0.031, 0.025, 0.030, 0.462, 0.269, respectively, and the weights of the items are different, among which the weight of the value-added of agriculture, forestry, animal husbandry and fishery (X7 billion yuan) is the highest, and the weight of the urbanization rate (X3) is the lowest. The lowest weight is 0.010.

The added value of agriculture, forestry, animal husbandry and fishery services and the proportion of output value of the primary industry determine the scale of development of the primary industry, which requires a spatial basis for activities, and their values are positively correlated with the scale and density of rural settlement distribution. The disposable income of rural residents, per capita gross regional product, and gross regional product determine the level of socio-economic development of the region, and the higher the level of socio-economic development of the region, the higher the importance attached to the construction of the countryside, and the higher the size and density of the distribution of rural settlements. However, there are also cases where the high level of socio-economic development and the high rate of urbanization have resulted in the transfer of the rural population and labour force to the cities, leading to the hollowing out of the countryside and the shrinking of the size and density of rural settlements.

Against the background of population shrinkage, the Three Provinces in Northeast China have a high level of urbanization, but the pace of socio-economic development is slower than that of China's southeastern coastal and southern regions, and a large number of rural populations and laborers have flowed to the southern regions, resulting in a large number of rural buildings being left unused, and the rural settlements are shrinking; at the same time, as the process of urbanization develops, the rural populations are also transferring to the cities, which further speeds up the trend of shrinking rural settlements. However, with the full implementation of the rural revitalization strategy in recent years and the return of young laborers and the urban population, there is potential for the recovery of rural settlements.

Table 2. Weights assigned to each influencing factor

factor	The information entropy value e	Information utility value d	Weighting factor w
Value added of agriculture, forestry, animal husbandry and fishery services (billion yuan)	0.8957	0.1043	46.24%
Disposable income of rural residents (yuan)	0.9394	0.0606	26.89%
Gross regional product per capita (yuan)	0.9804	0.0196	8.69%
Gross regional product (billions of dollars)	0.9806	0.0194	8.59%
Rural population (persons)	0.993	0.007	3.12%
Share of primary sector output (%)	0.9932	0.0068	3.00%
Number of rural employees (persons)	0.9944	0.0056	2.50%
Urbanization rate (%)	0.9978	0.0022	0.97%

4   Conclusions

① The number, area and density of rural settlements in Three Provinces in Northeast China during 2010-2020 showed a downward trend, and rural settlements in space showed a shrinkage year by year. ② rural settlements in Three Provinces in Northeast China during 2010-2020 the size and density of rural settlements showed a shrinking trend, significant spatial variability, mainly distributed in the western and southwestern regions, rural settlements with high distribution density are Dalian City, Shenyang City, Changchun City, Harbin City, Panjin, Jinzhou, Siping, Tieling and other places. ③ The added value of agriculture, forestry, animal husbandry and fishery has the greatest influence on the spatial and temporal pattern of rural settlement, and the urbanization rate has the least influence. ④ With the full implementation of the rural revitalization strategy in recent years, the youth labor force and urban population return, and there is a potential for the recovery of rural settlements.

In recent years, the 19th and 20th CPC National Congresses have successively proposed the comprehensive implementation of the strategy of rural revitalization, and grasping the current situation of the distribution of settlements and the existing problems in this context is of great significance in guiding the construction of a modern socialist country. In order to make rural settlements in Three Provinces in Northeast China develop for the better, the government can take advantage of the overall planning of land space to carry out the preparation of rural planning, develop the rural economy, improve the infrastructure, and introduce relevant policies to attract talents to return. The main focus is on the transformation of old villages, exploring the potential for rural development, intensifying land use and improving the efficiency of land use.

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