Analysis and Optimization Strategy of Spatial Evolution of Rural Settlement Land in Shandong Province

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Abstract: Due to the lack of unified planning and rectification in rural settlements, a large amount of land has been idle and wasted. Implementing the optimization of rural settlement layout and intensive and efficient use of land is a strategic choice to promote the construction of beautiful rural areas and coordinate urban-rural development. Scientific evaluation of development potential is the prerequisite and foundation for the optimization of rural settlement layout. The current classification optimization of rural settlements often only relies on the static status of the settlements, lacking a comprehensive consideration of the development and evolution laws and potential of rural settlements. To this end, it is planned to conduct a systematic study on the evolution, driving factors, and development potential of rural settlement spatial pattern in Shandong, revealing the characteristics and mechanisms of the evolution of rural settlement spatial pattern, and enriching the theoretical research on rural settlement spatial pattern in Shandong. At the same time, studying the evolution characteristics of rural settlement spatial pattern and proposing optimization types and corresponding strategies for rural settlement spatial pattern can make the research on rural settlement spatial pattern optimization more targeted and feasible, providing reference for the planning and layout of rural settlements in Shandong.

Keywords: Rural revitalization; Rural settlements; Spatial evolution; Fractal dimension; Shandong Province.

1. Research background and significance

1.1 Research Background

According to the third national land survey data released on August 25, 2020, as of the end of 2019, the total scale of village land use in China reached 2193.56 × 104ha, which is 4.20 times the size of a city and 4.28 times the size of an established town (with an area of 522.19, respectively) × 104ha and 512.93 × At the same time, there are structural imbalances, uncontrolled scale, and scattered layout issues in the utilization of rural settlements. Reasonable utilization and remediation of these settlements have always been one of the key issues of land use change in China. With the continuous acceleration of industrialization and urbanization in China, the land use structure has undergone rapid changes, and the unreasonable use of land resources has restricted the sustainable development of the social economy. This has forced people to pay attention to how to transform land use into a path of rational utilization.

Due to the lack of unified planning and rectification in rural settlements, a large amount of land has been idle and wasted. Implementing the optimization of rural settlement layout and intensive and efficient use of land is a strategic choice to promote the construction of beautiful rural areas and coordinate urban-rural development. Scientific evaluation of development potential is the prerequisite and foundation for the optimization of rural settlement layout. Shandong Province is located in the northern region of China, adjacent to the Bohai Sea and the Yellow Sea, and is a coastal province. The geographical characteristics of Shandong are very complex, with the Yellow River Alluvial plain in the west, mountains and hills in the middle, and Shandong Peninsula in the east. According to statistical data in 2016, agricultural land in Shandong accounted for 72.92% of the province's area, with arable land accounting for 66.07%, garden land accounting for 6.23%, and forest land accounting for 12.89%. The rural settlements in Shandong are mainly distributed in plain and hilly areas, forming different types and styles.

Studying the development challenges of rural areas in Shandong is of great significance for promoting the implementation of Shandong's rural revitalization strategy. On the one hand, it can deeply analyze the current development status and existing problems of rural areas in Shandong, providing a basis for formulating scientific and reasonable policies and measures; On the other hand, successful experiences and innovative practices at home and abroad can be borrowed to provide reference for the transformation, upgrading, and sustainable development of rural areas in Shandong.

1.2 Research significance

The National Rural Revitalization Strategic Plan (2018-2022) proposes to promote rural development by classification, and the optimization of rural settlements should also be differentiated. The current classification optimization of rural settlements often only relies on the static status of the settlements, lacking a comprehensive consideration of the development and evolution laws and potential of rural settlements. To this end, it is planned to conduct a systematic study on the evolution, driving factors, and development potential of rural settlement spatial pattern in Shandong, revealing the characteristics and mechanisms of the evolution of rural settlement spatial pattern, and enriching the theoretical research on rural settlement spatial pattern in Shandong. At the same time, studying the evolution characteristics of rural settlement spatial pattern and proposing optimization types and corresponding strategies for rural settlement spatial pattern can make the research on rural settlement spatial pattern optimization more targeted and feasible, providing reference for the planning and layout of rural settlements in Shandong.

2. Research status

2.1 Domestic research status

The research on rural settlements in China is relatively late. In the 21st century, the construction of new rural areas in China has rapidly developed nationwide. The contradiction between the reasonable layout of rural settlement land and the disorderly expansion of historical settlements has prompted people to focus more on the research of the process and influencing factors of rural settlement expansion.

Xu Qian et al. proposed an optimization strategy for the spatial pattern of rural settlements based on their research on the types and evolution mechanisms of rural settlements in the Yangtze River Delta region, which coordinates differentiation to guide rural development and reshape regional style; Li Qianguo and others studied the spatial pattern characteristics and evolution mechanism of rural settlements in Qilihe District of Lanzhou City, and divided the settlements into three types of spatial pattern optimization: urban consolidation, agglomeration and development, and migration; Lv Mengting divided the oasis rural settlements in the Ebi Lake basin into four optimization types based on the characteristics of spatial pattern and the construction of ecological security pattern, and proposed differentiated optimization strategies; Based on her research on the spatial pattern characteristics of rural settlements in northern Guangxi, Qin Liqiong sorted out the current development status of settlements, proposed strategies to strengthen the distribution density of rural settlements, improve the development speed of slow developing areas, and encourage the development of small towns to optimize the spatial pattern.

2.2 Research on the Current Situation Abroad

Foreign scholars have already begun to study rural settlements, with European countries such as the Czech Republic, Germany, and the Netherlands conducting research on rural settlements between 1940 and 1950. Firstly, MeitzenA published the theoretical foundation of settlement geography research; Afterwards, Trewartha and Ahmad conducted research on the formation process and distribution characteristics of different types of rural settlements. With the continuous broadening of research perspectives on rural settlement land, scholars have begun to use social and humanistic theoretical backgrounds to explain the problems in the development process of rural settlements.Carl

O. Sauer (1889-1975), a Geography of the United States, was one of the founders of rural settlement geography. In 1931, he published The Morphology of Landscape in Human Ecology. He put forward the concept of settlement form and divided it into three basic types: core type, linear type and scattered type.

3. Data sources and research methods

3.1 Data sources

The research data includes DEM data, road network data, and other basic data from Shandong Province. The DEM data is sourced from the Geospatial Data Cloud Platform with a resolution of 30m, and slope is extracted through surface analysis in ArcGIS. The road network data and other basic data are sourced from the statistical yearbooks on the local government information disclosure network, mainly social and economic data. The land use status data is sourced from GlobeLand30: Global Geographic Information Public Product and OpenStreetMap Extract rural settlements, roads, rivers, construction land, and cultivated land from it. Please refer to the table below for specific annotations (Table 1)

Table 1 Initial Data Source Information

Data category	Data Name	Time	Resolution Ratio	Data Sources
raster data	n503020101c030.tif	2010	30m	Globeland30
	n51352010lc030.tif		30m	
	n50352010lc030.tif		30m	
	n503020201c030.tif	2020	30m	
	n51352020lc030.tif		30m	
	n50352020lc030.tif		30m	
vector data	gis_osm_road_free_1.shp	2010/2020	30m	OpenStreetMap
	Map of Administrative division at prefecture level and city level in Shandong	2010/2020	30m	Geospatial Data Cloud

3.2 Research Methods

3.2.1 Fractal dimension

The spatial distribution of settlements exhibits statistical fractal characteristics due to their scale-free nature. Fractals are the optimized structures of nature, and they can most effectively occupy space. The Self-similarity of the spatial distribution system means that the self-organization evolution of the human geographical system is dominated by some implicit rules with an optimization trend. Therefore, revealing the fractal geometric characteristics and their governing laws of urban systems has significant theoretical significance and practical value.

The effective parameter of describing fractal is Fractal dimension, which is an important parameter reflecting spatial phenomena.

3.2.2 Spatial aggregation dimension

The relationship between the number of rural settlements N (r) distributed within the circle, centered around the central settlement or the first settlement, and the radius r, and the corresponding radius is as follows:

In the formula, D is the spatial aggregation dimension, and D can be obtained by logarithmic linear regression from ln [N (r)] to ln r. To avoid the instability of D calculated by different r values, the average radius Rs is used instead of r, as shown in the formula:

$$Rs = \langle (\frac{1}{S}\sum_{i=1}^{s} r_i^2)^{\frac{1}{2}} \rangle$$

If the spatial structure of rural settlement land has spatial aggregation fractal characteristics, then it meets the following requirements:

$$Rs \propto S^{\frac{1}{D}}$$

In the formula: Rs is the average radius; S is the number of rural settlements; R_ I is the Euclidean distance from the i-th rural settlement to the central settlement; To find the average value; D is the spatial aggregation dimension. The spatial aggregation dimension D can be obtained by fitting the coefficients in the univariate linear regression equation with ln S and ln Rs. If D<2, the spatial distribution of rural settlement land is clustered, and the smaller the value, the greater the degree of clustering; If D=2, the spatial distribution of rural settlement land is evenly distributed; If D>2, the spatial distribution density of rural settlement land increases from the center to the periphery, which is an abnormal state. The greater the value, the greater the Statistical dispersion of its distribution.

3.2.3 Spatial correlation dimension and crow to cow dimension ratio

$$C(r) = \frac{1}{N^2}\sum_{i,j=1}^{N} H(r - d_{ij})(i \neq j)$$

In the formula: C (r) is the spatial correlation dimension of rural settlement land; R is the given distance scale; D_ Ij is the European distance between two rural settlements; H is the Heaviside Step function, that is

$$H(r - d_{ij}) = \begin{cases} 1, & r \leq d_{ij} \\ 0, & r > d_{ij} \end{cases}$$

If the spatial distribution of rural settlement land is fractal, it should have scale invariance, that is

$$C(r) \propto r^{D}$$

Draw a (r, C (r)) scatter plot and obtain the spatial correlation dimension DD by fitting the linear regression equation, which is the spatial correlation dimension (crow dimension).

The D value range of crow dimension is between 0 and 2, and when D → 0, it indicates that the spatial relationship of rural settlement land in the region is close; When D → 2, it indicates that the spatial distribution of rural settlement land is uniform. In formula (4), if d_ Ij takes the actual transportation mileage, which is the distance between cows, and the spatial correlation dimension D 'obtained is the cow dimension. Cow crow dimension ratio ρ= D '/D, if ρ＜ 0.5 indicates poor spatial accessibility of rural settlement land; If 0.5< ρ＜ 1. It indicates that the spatial accessibility of rural settlement land is good; When ρ → 1 indicates that the distance between rural settlement land is close to a linear distance, and the spatial accessibility tends to be ideal.

4. Research results on the spatial form of rural settlements

4.1 Analysis of the spatial form of rural settlements

4.1.1 Spatial aggregation dimension analysis

Based on the statistical characteristics of frequency histogram of fractal dimension value, the spatial structure dimension and cattle crow dimension value of rural settlement land in each township are classified by using ArcGIS natural fracture method, as shown in Fig.1. The higher the level, the weaker the spatial correlation or the lower the traffic accessibility. The spatial aggregation dimension D values of each city in 2010 and 2020 are listed in the following tables (Fig. 1and Fig.2, with images output through natural fracture method), indicating different trends in the spatial evolution of rural settlement land in each city of Shandong.

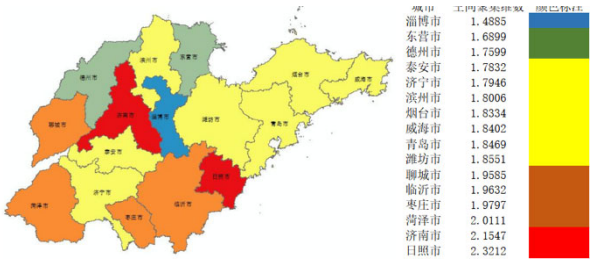

Fig. 1 Spatial Aggregation Dimensions of Shandong Province in 2010.

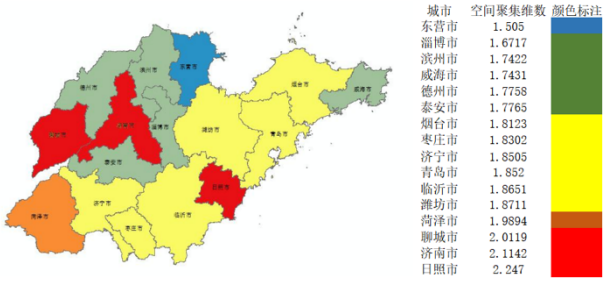

Fig. 2 Spatial Aggregation Dimensions of Shandong Province in 2020

4.1.2 Spatial correlation dimension analysis

According to the calculation principle of spatial correlation dimension, the correlation function value C (r) - size r of rural settlement land in each city of Shandong is plotted on the double logarithmic coordinate map. It can be seen that there is a clear scale-free interval in the logarithmic coordinate map, with measurement coefficients R2 greater than 0.85. The linear correlation between the two is significant, and other calculation results also indicate that the fractal characteristics of the spatial structure of rural settlement land in various cities in Shandong are obvious. The spatial correlation dimension values in 2010 and 2020 are respectively listed in the following tables (Fig. 3 and Fig.4, with images output through natural fracture method), indicating that the spatial fractal characteristics of rural settlements in the study area are relatively stable, and the rural settlements traffic accessibility in most Prefecture-level city is constantly optimized.

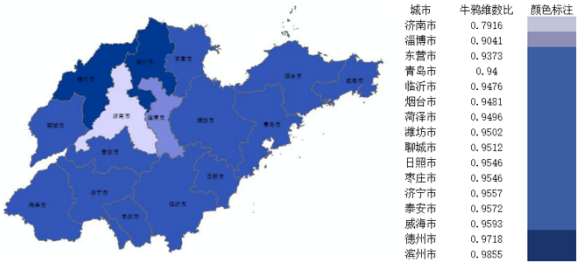

Fig. 3 Dimension ratio of cattle and crows in Shandong Province in 2010.

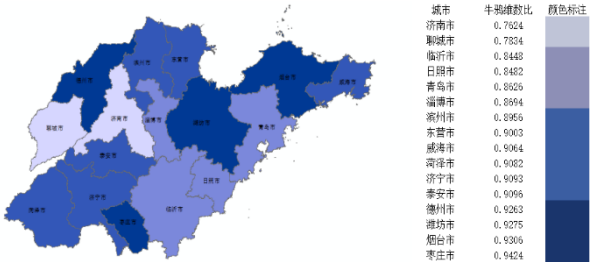

Fig. 4 Dimension ratio of cattle and crows in Shandong Province in 2020

4.2 Strategies for optimizing the spatial form of rural settlements

With the help of ArcGIS Spatial analysis function, the above classification maps of rural settlement spatial agglomeration and traffic network accessibility are superimposed and analyzed. At the same time, combined with the results of satellite remote sensing map survey, the research city is divided

into advantageous development area, spatial structure optimization area, traffic network optimization area and spatial structure and traffic network optimization area, as shown in Table 2.

Table 2 Classification Types of Research Areas

City	Area Type
枣庄市 济宁市 东营市	Traffic structure optimization zone
济南市 临沂市 潍坊市 德州市 滨州市	Space structure optimization zone
淄博市 日照市 泰安市	Traffic structure and spatial structure optimization zone
菏泽市 聊城市	Restricted Development Zone
青岛市 烟台市 威海市	Advantage development zone

(1) Advantage development zone

The characteristic of the advantageous development zone is that the spatial structure correlation of rural settlement land and the accessibility of transportation network have shown good fractal characteristics in the decade from 2010 to 2020, that is, rural settlements are relatively clustered and the accessibility of transportation network is high, forming a certain advantageous scale. It has advantages such as location, high quality living environment, and high concentration of rural settlement land, which will attract residents to live here. The main problem in this area is that there is a large number of migrant population and a high concentration of population. This type of area is a key benchmark area for future urban-rural coordination, with a focus on inheriting and promoting the unique landscape of local rural settlements and developing characteristic cultural industries, guided by living functions, and scientifically planning residential communities and their public service facilities; Improve basic supporting facilities, gradually narrow the urban-rural development gap, and form coordinated urban-rural development.

(2) Space structure optimization zone

The Areal feature of spatial structure optimization is that the accessibility of transportation network is good, while the spatial agglomeration of rural settlements is poor, and the accessibility of transportation network between rural settlements is high. Although the best evaluation standard for spatial clustering in rural settlements is not centered around central clustering, there are still other issues with unreasonable spatial structure layout in this type of area, which need further optimization. Rural settlements in hilly areas often need to pass through slow and low-grade hilly area roads first, and then enter the high-grade roads leading to the main urban area. In view of the spatial structure characteristics of such rural settlements, we should actively adjust the distribution pattern of rural residential land in the future, enhance the Radiant intensity intensity of the central settlements of villages and towns to the surrounding rural settlements, appropriately promote the merger and relocation of Human settlement, and strengthen the relevance of population and industry around the township centers.

(3) Traffic structure optimization zone

The Areal feature of traffic network optimization is that the spatial structure of rural settlement land is tight, while the traffic accessibility is low. The main problem in this area is poor transportation convenience, and the transportation network cannot meet production and living needs. Its transportation accessibility still needs to be further improved. For this type of rural settlement land, the government needs to strengthen investment in transportation infrastructure in the future, enhance the transportation convenience between rural settlement land, and promote the optimization of its transportation network structure.

(4) Optimization zone for traffic structure and spatial structure

The optimization of spatial structure and traffic network Areal feature is the basis for the spatial agglomeration of rural settlements and the accessibility of traffic network, but it has developed slowly in the past decade. The advantages of spatial structure and traffic accessibility are not obvious, and there is still room for further optimization. The southern river area has a small topographic relief and dense traffic network, but lacks a strong surrounding urban center as the radiation source. In response to the spatial structure characteristics of rural settlement land in this type of region, the government needs to evaluate the resource advantages of the region in the future, meet the land supply of leading industries, guide them to concentrate appropriately, enhance the driving role of central settlements, and improve the correlation of rural settlement land; Simultaneously improving the transportation network and promoting further optimization of the transportation network.

(5) Restricted Development Zone

The Areal feature of restricted development is that the spatial structure relevance of rural settlement land and the accessibility of transportation network are poor, the spatial structure of rural settlement land is scattered, and the accessibility of transportation network is poor. The main problems in this area are that the natural environment is relatively poor and the level of economic development is relatively slow, and the spatial Ecological niche of rural settlement land is poor. For this type of area, in the future, more rural settlement land should not be arranged, but scattered rural settlement land should be guided to be moderately concentrated, with a focus on strengthening the comprehensive improvement of rural land and the service function of central settlements, moderately developing the ecological tourism industry, and creating ecological and civilized rural settlements relying on green water and green mountains.

4.3 Research Conclusion on the Spatial Form of Rural Settlements

From the perspective of provincial scale, the spatial structure of rural settlement land in various cities in Shandong presents three roughly different patterns in the east, west, and central regions; In the eastern region, there are few hills and rivers, and the terrain is relatively undulating. The spatial correlation between transportation accessibility and rural settlements has shown good performance. The terrain in the central region fluctuates greatly, and the hilly areas of Shandong are mainly distributed here, with poor correlation between settlements; The cities in the southwest and northwest are far from the economic hinterland of Shandong, and their economic interaction with other cities in the province is weak.

From the perspectives of spatial aggregation and transportation accessibility, the spatial structure of rural settlement land in Shandong Province shows an overall trend of improvement, with slight deficiencies at the micro level. In the process of rural land use planning in Shandong Province, the government should fully consider the characteristics of the optimized spatial structure of rural settlement land and the evolution trend of the spatial structure of rural settlement land; The optimization of the spatial structure of settlement land at the regional level should consider the reasonable scale of the settlement to ensure the economy, completeness, and convenience of the allocation of infrastructure and public service facilities, in order to ensure the reasonable allocation of rural settlement spatial elements and achieve the optimization of the spatial structure of rural settlement land in various cities in Shandong.

5. Summary

This article quantitatively analyzes the spatial pattern evolution characteristics of rural settlements in Shandong Province using remote sensing images and geographic information system software, explores the relationship between the spatial pattern of rural settlements and rural revitalization policies, evaluates the degree of coupling and coordination between the spatial pattern of rural settlements and rural revitalization, and proposes strategies and suggestions for optimizing the spatial pattern of rural settlements. The goal of the project is to provide scientific basis and decision-making support for the implementation of the rural revitalization strategy in Shandong Province.

The sustainable development of rural settlements faces severe challenges, and it is necessary to conduct in-depth analysis and thinking on the reconstruction and optimization of rural settlements based on the objective laws of their development and evolution, and provide reasonable guidance and scientific regulation. The National Rural Revitalization Strategic Plan (2018-2022) proposes to promote rural development by classification, and the optimization of rural settlements should also be differentiated. The current classification optimization of rural settlements often only relies on the static status of the settlements, lacking a comprehensive consideration of the development and evolution laws and potential of rural settlements. To this end, it is planned to conduct a systematic study on the evolution, driving factors, and development potential of rural settlement spatial pattern in Shandong, revealing the characteristics and mechanisms of the evolution of rural settlement spatial pattern, and enriching the theoretical research on rural settlement spatial pattern in Shandong. At the same time, studying the evolution characteristics of rural settlement spatial pattern and proposing optimization types and corresponding strategies for rural settlement spatial pattern can make the research on rural settlement spatial pattern optimization more targeted and feasible, and provide guidance for the planning and layout of rural settlements in Shandong Province.

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