A Study on the Spatial Evolution and Evolutionary Models of Rural Settlements in 25 Counties (Cities, Districts) along the Yellow River in Shandong Province

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Abstract: Based on field investigations, text analysis, and remote sensing image interpretation, this study comprehensively constructs models such as land use status and classification index, rural settlement land dynamic degree, landscape pattern index, land use transfer matrix, and principal component analysis to analyze the spatial evolution basis and characteristics of rural settlement land of 25 counties in Shandong Province from 2000 to 2020. The aim is to grasp the basic state of rural settlement spatial evolution in this area and integrate effective paths for optimizing rural settlement space. Research has found that: The rural settlement land of 25 counties in Shandong Province is showing a continuous expansion trend, and the distribution density of rural settlement land patches continues to decrease over time. In recent years, the effectiveness of rural settlement land planning and governance is gradually becoming prominent. From 2000 to 2020, the scale 25 counties along the Yellow River in Shandong Province showed an orderly increase, and the settlement patches showed a spatial layout trend of "relocation integration". From 2000 to 2020, there were differences in the spatial distribution and dynamic trends of rural settlement land within different altitude levels in 25 counties along Shandong Province. The middle and low altitude areas (18-246 meters) were the main distribution areas study area. From 2000 to 2020, there was a clear trend of mutual transformation between space and other land types in 25 counties along the Yellow River in Shandong Province.

Keywords: Rural Settlements; Spatial Evolution; Evolutionary Patterns; Optimize the Path; 25 Counties along the Yellow River in Shandong Province

1. Research Overview

In recent years, research on rural settlements at home and abroad has mainly focused on spatial, cultural, landscape, and ecological aspects. The research content and perspective have gradually expanded from the spatial distribution characteristics of settlements to the spatial evolution laws. Exploring the spatial evolution characteristics and optimization reconstruction paths of settlements from the mechanism of formation in current research. Exploring reconstruction process patterns based on new changes in human land relations and maintenance mechanisms has gradually become a new trend in current settlement research[1]. It is found that current scholars' research on the spatial evolution of rural settlements mainly focuses on spatial patterns and economic and social impacts[2]. Zhu (2011) and Li used spatial rhythm index and interpolation methods to conduct descriptive analysis on the scale, distribution, and shape of rural settlements in northern Jiangsu Province; Based on the analysis of the current situation, Ren and Ma summarized the regular characteristics of the distribution and spatial pattern evolution of rural settlements in Lingnan and Longzhong regions; Based on the analysis of the current situation and characteristics of spatial evolution of rural settlements by Zhou and Qiao, the driving mechanisms of rural settlement transformation were analyzed from different scales; Norris and Karcag respectively analyzed the aging of rural population caused by the farm economic depression in the early 20th century in the Midwest of the United States and the decline and scale of rural settlements caused by the rapid urbanization process in Europe; Based on the analysis of natural villages and shell villages in the mountainous areas of Gannan, Jiang and Peng proposed that small scale, inconvenient

transportation, poor location conditions, and population migration are important reasons for the decline of villages in certain regions of China[3,4]. By comparison, it has been found that foreign scholars mainly rely on the 3S technology platform to construct spatial models using mathematical methods such as transformation matrices to measure and monitor the spatial changes of rural settlement land. However, domestic scholars mostly use maximum likelihood analysis, CA simulation, etc. to analyze the characteristics, patterns, and stages of spatial changes in rural settlement land[5,6]. It can be seen from the integration that scholars' research on the optimization of rural settlement space mainly focuses on the internal mechanisms and model strategies of settlement space optimization. Long believes that the current transformation and development of rural areas are driven by both internal factors and external aid; Li and others believe that the internal mechanism of village development can be summarized as villagers being the main body of village development and capable people being the core element of village development. Optimizing regulation should enhance the internal response mechanism and optimize the external intervention mechanism; Zhang and others pointed out that rural residential areas in different geographical types should adopt different macroeconomic control strategies; Wang et al. constructed four settlement land integration models based on the housing preferences of farmers from different sources of livelihood, including community type, cluster type, block type, and belt type; Tang et al constructed a rural settlement spatial structure optimization model and strategy led by RROD .

In summary, scholars at home and abroad have conducted rich theoretical explorations and case and optimization reconstruction from different perspectives, laying a good foundation for the development of this project. However, it can be concluded that there is still relatively little research on rural settlements in 25 xian in Shandong Province, and spatial evolution and optimization path of rural settlements. There is a need to strengthen the research on the optimization configuration and reconstruction of human land relations, industry land relations, and human industry relations in the spatial distribution of rural areas in 25 xian in Shandong Province. In view of this, this project takes the rural settlement space in 25 counties along the Yellow River in Shandong Province as the research object, analyzes the pattern, process, and mechanism of space in this area, explores the evolutionary trajectory exhibited by its rural settlement space, analyzes the deep settlement space in this area, constructs a systematic adjustment mechanism for optimizing rural settlement space, and provides theoretical basis and policy reference for the optimization and reconstruction of rural settlement space in this area and the orderly promotion of the "rural revitalization" strategy.

2. Research Methods

2.1 Dynamic Degree of Rural Settlement Land Use

The dynamic degree index can reflect the average proportion of new settlement land to its own land area every year unit.

$$I = \frac{U_{ij}}{T_j \cdot TLA_i} \quad (1)$$

From among, I is the intensity index of settlement land change, U_{ij} is the change area of settlement land i in the period j .

2.2 Landscape Pattern Analysis

Referring to the research of scholars, combined with the development status of 25 xian in Shandong Province, from the scale and distribution other aspects, selected the total number of plaques (NP), the total area of plaques (CA),the density of plaques (PD) and other indicators, the landscape pattern of rural settlement land of 25 xian in Shandong Province from 2000 to 2020 was analyzed.

2.3 Land Use Transfer Matrix

In this study, the conversion was extracted to analyze the conversion types in different periods in 25 counties along the Yellow River in Shandong Province. The formula is:

$$C_{ij} = \begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1n} \\ C_{21} & C_{22} & \cdots & C_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ C_{n1} & C_{n2} & \cdots & C_{nn} \end{bmatrix} \quad (2)$$

3. Results and Analysis

3.1 Analysis of Spatial Evolution

Characteristics of Rural Settlements in 25 Counties along the Yellow River in Shandong Province

The rural settlement land of 25 xian in Shandong Province is showing a continuous expansion trend, and the distribution density of rural settlement land patches continues to decrease over time; Over time, the scale in 25 counties along the Yellow River in Shandong Province has shown an orderly increase, while settlement patches have shown a spatial layout trend of "relocation integration". The spatial and temporal distribution and regional differences of rural settlement land have gradually become prominent, and the orderliness and rationality of the layout have been enhanced.

Based on the remote sensing image interpretation results of 25 counties in Shandong Province from 2000 to 2020, a dynamic measurement model for rural settlement land was constructed. Using GIS technology and referring to landscape pattern index, characteristics of rural settlement land of 25 xian in Shandong Province were comprehensively analyzed (Figure 1). Discovery: Over time, the land use of rural settlements of 25 xian in Shandong Province has been continuously expanding. From 1845.85km to 1845.85km^2 between 2000 and 2020, respectively, 2130.65 km^2 and 2176.11km^2. Over the past 20 years, rural settlement land has expanded by 18%, with an average annual growth rate of 16.51km^2. Based on the Feature To Point module in ArcGIS 10.3 software, various rural settlement land patches were transformed into vector points. Shandong Province from 2000 to 2020 was analyzed. It was found that over time, the patches of 25 xian in Shandong Province continued to decrease, from 6.07 patches/km^2 in 2000 Reduced to 5.43/km^2 in 2020, the decline was mainly concentrated between 2000 and 2010, which indirectly reflects the gradual effectiveness of rural settlement land planning and governance of 25 xian in Shandong Province in recent years.

Through comparison, it was found that over time, the spatial differentiation of rural settlement land within each constituent unit of 25 xian in Shandong Province has gradually become prominent. Based on the spatial overlay analysis of ArcGIS 10.3, spatial data of rural settlement land of 25 xian in Shandong Province from 2000 to 2020 were extracted. It was found that:

①land use scale, the overall scale counties and urban areas along the Yellow River in Shandong Province has increased from 2000 to 2020. However, temporal and spatial differences in distribution and changes. During the research period, Jinan and Tai'an sections in the central part of the 25 xian, as well as in the Liaocheng and Jining sections in the western part, was significantly higher, while the land use scale of rural settlements in the Binzhou and Dongying sections in the eastern part was significantly lower.

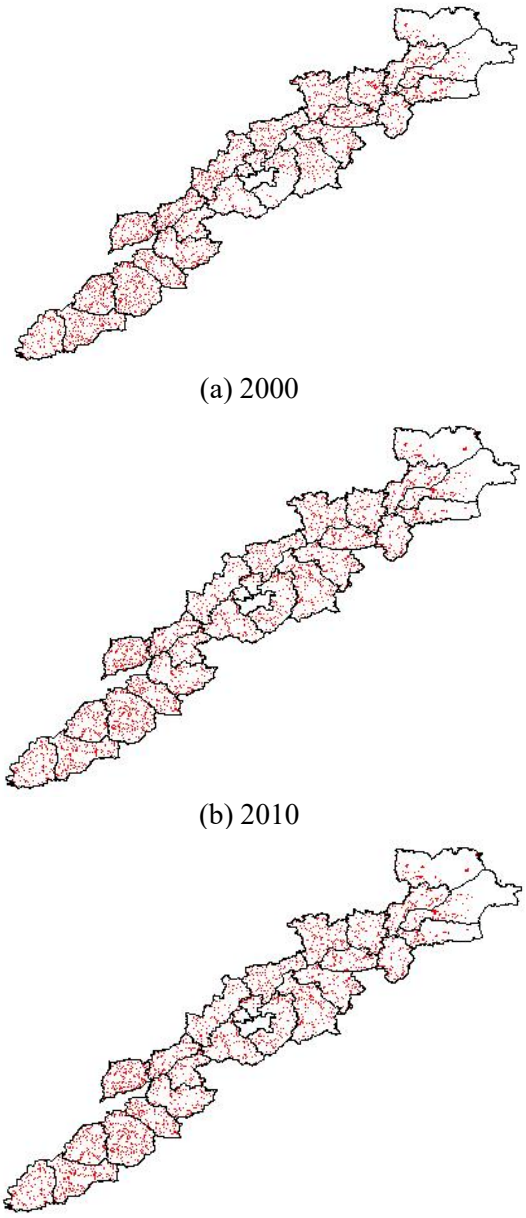
②From the perspective of distribution density, during the research period, density of rural settlements 25 xian in Shandong Province, Jinan and Dezhou, was consistently higher than that of other counties. This also indirectly reflects the high degree of fragmentation in Linyi section of the 25 xian.

③Above analysis, it is found that from 2000 to 2020, with the development of "rural revitalization" and urban-rural coordination and integration, the scale of rural settlement land in 25 xian in Shandong Province showed an orderly increase, and the spatial layout of settlement patches showed a "relocation integration" trend. Distribution differences gradually became prominent, and the orderliness and rationality of the layout also gradually strengthened.

3.2 Spatial Altitude Distribution Characteristics of Rural Settlements in 25 Counties along the Yellow River in Shandong Province

From 2000 to 2020, there were differences in the spatial distribution and dynamic trends of rural settlement land within different altitude levels in 25 counties along Shandong Province. Low altitude areas (18-246 meters) were the main distribution areas. Over time, the altitude level 25 counties along the Yellow River in Shandong Province has slightly increased.

As a typical mountainous area, terrain factors have distribution and changes land in the study area. Based on the 30m resolution DEM data (digital elevation image data) of Shandong Province, the elevation of Shandong Province was divided into four categories using ArcGIS 10.1 natural discontinuity analysis, and overlaid with rural settlement land patches from 2000 to 2020. The distribution and changes of rural settlement land at different elevation levels can be calculated (Table 1).



(a) 2000

(b) 2010

(c) 2020

Figure 1. Distribution of Rural Settlement Land in 25 xian in Shandong Province from 2000 to 2020

From Table 1, it can be seen that there are differences in the spatial distribution and dynamic trend of rural settlement land within different altitude levels in Shandong Province from 2000 to 2020. The middle and low altitude areas (18-246 meters) are the main distribution areas of rural settlement land, and over time, the altitude spatial distribution has slightly increased; Except for the area with an altitude level of 18-146 meters, the fragmentation of rural settlement land patches within each altitude level range is gradually increasing.

In 2000, rural settlement land in Shandong Province was mainly distributed in the middle and low altitude range of 18-246 meters, accounting 85% rural settlement land area. Compared to this, the distribution scale middle and high altitude range of 246-551 meters was relatively small, accounting for 14.7%. During this period, rural settlements distributed in high-altitude areas above 551 meters were relatively rare, accounting for only 0.1% in Shandong Province. In 2010, the distribution and scale of rural settlement land in Shandong Province changed, and the altitude range of 18-246 meters remained the main distribution area (81.9%); Compared to 2000, within the altitude range of 18-146 meters, the area number of patches have both increased, but their proportion in the study area has decreased; The elevation range of 146-246 meters is the primary expansion area of rural settlement land area from 2000 to 2010, indicating an overall increase in the spatial distribution and elevation of rural settlement land area from 2000 to 2010; Compared to other areas, the area within the altitude range of 246-371 meters showed the most significant increase in the proportion of rural settlement land area and patch number between 2000 and 2010. It is worth noting that high-altitude areas is still significantly less. Similar to 2010, there were significant topographic differences in the scale and distribution 2020. The 18-246 meter altitude range was the main distribution area of rural settlement land, and more than 75% of the newly added rural settlement land was the low altitude range of 18-146 meters. This indirectly reflects that the impact of ecological protection and planning in mountainous areas on the spatial distribution and location selection of rural settlements is gradually becoming prominent during this period.

3.3 Analysis of the Spatial Transformation Trend of Rural Settlements in 25 Counties along the Yellow River in Shandong Province

Over time, there has been a clear trend of mutual transformation between along the Yellow River in Shandong Province. Over the 20, the transfer area higher than that of transfer out. The newly added rural settlement land is mainly transferred from flat farmland and is widely central counties. Driven by rural hollowing and urbanization, farmland and urban land are the main and secondary sources of transfer.

Table 1. Spatial distribution and changes of rural settlement land under different altitude conditions in 25 counties along the Yellow River in Shandong Province from 2000 to 2020

	Year 2000		Year 2010		Year 2020		Year 2000-2010		Year2010-2020	
Elevation	Area /Km²	Number	Area /Km²	Number	Area /Km²	Number	Area /Km²	Number	Area /Km²	Number
18-146 m	869.89	4243	932.85	3956	968.34	3939	62.96	-287	35.49	-17
146-246 m	702.88	5618	812.73	5732	818.76	5742	109.85	114	6.03	10
246-371 m	220.61	2342	296.84	3030	299.35	3042	76.23	688	2.51	12
371-551 m	51.44	630	83.15	1096	84.59	1110	31.71	466	1.44	14
551-1406 m	0.99	25	5.05	84	5.04	83	4.06	59	-0.01	-1

Changes in it is inevitable that it will encroach or transform into other types of land, thereby causing changes in the overall. In view of this, based on software such as ENVI5.2 and ArcGIS10.1, the land change information of 25 xian in Shandong Province from 2000 to 2020 was extracted, and a land use transfer matrix and land use conversion contribution rate model were constructed for the research period (Table 2), and then the conversion trend of rural settlement land area and structure in 25 counties along the Yellow River in Shandong Province was analyzed.

From Table 2, it can be seen that there is a significant trend of mutual transformation between space types 25 along the Yellow River in Shandong. Over the past 20 years, the area in rural settlements in 25 counties along the Yellow River in Shandong Province has reached 1649.43km². The stable land area of rural settlements is 1186.2km², this changes the study area were relatively active during this period. Among them, the newly added rural settlement land is mainly transferred from flat farmland, with an area and contribution rate of 826.91km, respectively² 83.54% and widely distributed in various counties and districts western regions; Guided by rural planning and sustainable utilization, 86.12km² the conversion of grassland into rural settlement land is particularly significant in Dongying section; By comparison, it can be seen that in the process of rural planning regulation and reconstruction, a small amount of urban land and forest land have been converted into rural settlement land, and their contribution rates to the newly added rural settlement land are basically the same, both of which are about 3%. Concentrated in the Jinan and Tai'an sections research area; Compared to others, the contribution rate of water bodies and other land to the newly added rural settlement land is relatively low, both less than 1%.

By comparison, it is found that from 2000 to 2020, the transfer area 25 counties along the Yellow River in Shandong Province is lower than that newly added. In the past 20 years, 659.62km² has been transferred to other land types, of which cultivated land is the primary transfer source (69.3%) and mainly distributed in remote villages far away from urban areas, which shows that a series of problems caused by "hollowing out" and "centrifugation" of rural development in this area are gradually emerging. Urban land is the secondary transfer source (23.2%), which shows that the development of urban-rural coordination and integration is gradually changing the form and scale, and a considerable number of suburban villages are gradually turning into towns; Comparatively speaking, the scale woodland, grassland, water body and other land, and the sum of the four accounts for less than 10% of the rural settlement land transfer.

Based on the above analysis, it can be seen that under the joint drive of rural revitalization, new rural construction, the changes in rural settlement land in 25 xian in Shandong Province from 2000 to 2020 have shown a relatively active trend, which has also had a certain impact on the structural characteristics and form combination.

Table 2. Transformation trend between rural settlement land and other land types in 25 counties along the Yellow River in Shandong Province from 2000 to 2020

Changes in land use types	from 2000 to 2020 (km) ²
Grassland - rural settlement land	86.12
Urban land - rural settlement land	31.70
Farmland - rural settlement land	826.91
Forest land - rural settlement land	30.90
Other land use - rural settlement land	5.56
Water bodies - rural settlement land	8.62
Rural settlement land - grassland	20.33
Rural settlement land - urban land	152.77
Rural settlement land - cultivated land	456.90
Rural settlement land - forest land	6.14

Rural settlement land - other land	16.72
Rural settlement land water body	6.76
Rural settlement land remains unchanged	1186.20

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