

Study on the Measurement and Spatio Temporal Evolution of Land Spatial Efficiency Level in Huaihai Economic Zone

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Abstract

This study takes 10 cities in Huaihai economic zone from 2014 to 2023 as the research object, and reveals the internal mechanism and dynamic process of land spatial efficiency by quantitatively analyzing the spatial evolution characteristics of land spatial efficiency. The study uses a multi-dimensional index system and entropy method to measure the level of land spatial efficiency in Huaihai Economic Zone, and analyzes the development differences and evolution paths among cities. The results show that the land spatial efficiency of Huaihai Economic Zone presents the obvious spatial distribution characteristics of "low in the middle and high around", and shows a fluctuating upward trend in time. Through spatial analysis and efficiency measurement, the study puts forward policy suggestions such as optimizing regional coordinated development, promoting ecological civilization construction, optimizing land use structure and spatial layout, which provides a theoretical basis and policy suggestions for the sustainable development of Huaihai economic zone.

Keywords

Land space efficiency, Spatial evolution, Huaihai Economic Zone.

1. Introduction

The efficiency of land space utilization is an important parameter to measure the quality of social and economic system. The sustainable use of land space has always been the core issue in the process of regional sustainable development. At the present stage of significant regional development differences and tight resource and energy constraints, taking multiple measures to improve the efficiency of land space utilization has become the internal requirement of regional sustainable development. As the main criterion to optimize the land spatial pattern, the efficiency of land spatial use will not only affect the development process of economic vitality, but also significantly affect the stability of ecosystem functions and the sustainable and healthy development of economy and society. Huaihai economic zone is located at the junction of Jiangsu, Shandong, Henan and Anhui provinces. It is not only an important grain production base and energy resource rich area in China, but also a hub for the transition from the eastern coast to the inland. In this context, the report of the 19th CPC National Congress formally put forward the concept of high-quality development, emphasizing that high-quality development should pay more attention to the development quality and economic benefits of land and space. However, there are great differences in the resource background and economic base of different regions. If we do not consider the actual development of the region and implement the policy of "one size fits all", it is difficult to regulate and control by regions and give full play to the importance of adjusting measures to local conditions. Therefore, it is of great significance to study the coupling relationship and mechanism between land spatial utilization efficiency and high-quality development, to meet the needs of zoning regulation and control, and to realize

regional coordinated development and promote high-quality transformation, so as to optimize the evolution of land spatial layout and promote the high-quality development of social economy.

The efficiency of land and space utilization is the ability level of providing products and services for human beings in the process of land and space resources utilization, which is the result of the comprehensive effect of natural, economic and social systems. As a major national strategy, improving the efficiency of urban land use has become a key research field in academia in recent years[1]. Scholars have studied the development level, quality and impact mechanism of urban land use efficiency from multiple perspectives, and the research methods are increasingly rich and refined. In terms of research methods, scholars generally use multi-dimensional index system, and use quantitative tools such as SBM model and entropy weight TOPSIS method to scientifically measure the level of urban land spatial use efficiency[2-3]. Different from traditional studies, these studies focus not only on quantitative indicators, but also on quality connotation, such as vegetation index, carbon emission data and net primary productivity of vegetation [4]. In the area of regional research, scholars selected different provinces as the research object to reveal the regional differences of urban land use efficiency. For example, Deng Z (2025) and others took Jinzhong municipal Party committee as the research object to explore the layout optimization path under the difference of land and space utilization efficiency[5]; Ding Y (2022) evaluated the quality of land and space utilization in Hunan Province[6]. Wu J (2021) et al. constructed the evaluation index system of land and space utilization quality in Hefei metropolitan area and studied the land and space efficiency of Hefei metropolitan area[7]. These studies enrich the regional development theory and provide an important reference for the formulation of differentiated development strategy. In the field of coupling coordination, scholars further explore the interaction between new urbanization and other systems. Li Y et al. (2024) studied the coupling coordination between land spatial efficiency and water ecological toughness under the land spatial planning system[8], and Li Q (2022) paid attention to the spatio-temporal coupling between land spatial efficiency and high-quality development in the Wanjiang urban belt [9]. These studies expand the research vision of land spatial efficiency and reveal the complex interaction mechanism between urbanization and ecological, economic and other fields.

Although the research on land spatial efficiency has made significant progress, there are still obvious deficiencies in research methods, scales and contents. The academic community's understanding of land spatial efficiency is still deepening, and it is urgent to build a more scientific and comprehensive evaluation index system and theoretical framework. In view of this, taking 10 cities in the Huaihai Economic Zone as the research object, this paper uses the entropy weight method to measure the level of land spatial efficiency and study the spatio-temporal evolution, which not only helps to deepen the theoretical cognition of the development law of land spatial efficiency, but also provides scientific methodological guidance for narrowing the development gap between cities in the Huaihai economic zone.

2. Research Methods and Data Sources

2.1. Research area

As China's first inter provincial collaborative development pilot zone, Huaihai Economic Zone covers 10 prefecture level cities, including Xuzhou, Lianyungang, Suqian, Huaibei, Suzhou, Shangqiu, Zaozhuang, Jining, Linyi and Heze, at the junction of Jiangsu, Shandong, Henan and Anhui provinces. The region is located at the intersection of the "belt and road" and the economic corridor in the north wing of the Yangtze River Delta, with dual regional characteristics of coastal opening and inland hinterland. The 10 cities selected in the study show typical gradient characteristics in the allocation of elements of spatial efficiency. This

imbalance in regional development not only reflects the complexity of the development of land spatial efficiency in the Huaihai Economic Zone, but also highlights the necessity of building a scientific, dynamic and multi-dimensional measurement index system. Through in-depth analysis of the development characteristics of the land spatial efficiency of these 10 cities, it provides decision-making basis for breaking the barriers of "administrative region economy" and realizing the cross domain optimal allocation of factors.

2.2. Research Methods

In order to overcome the interference caused by subjective factors, this paper calculates the land spatial efficiency level of Huaihai Economic Zone Based on the entropy method of objective weighting method, so as to determine the comprehensive weight of each index. Combined with reference [10-12], the specific calculation format is as follows:

Firstly, standardize the positive and negative indicators.

$$x'_{ij} = \left[\frac{x_{ij} - \min(x_{1j}, x_{2j}, \dots, x_{nj})}{\max(x_{1j}, x_{2j}, \dots, x_{nj}) - \min(x_{1j}, x_{2j}, \dots, x_{nj})} \right] \quad (1)$$

$$x'_{ij} = \left[\frac{\max(x_{1j}, x_{2j}, \dots, x_{nj}) - x_{ij}}{\max(x_{1j}, x_{2j}, \dots, x_{nj}) - \min(x_{1j}, x_{2j}, \dots, x_{nj})} \right] \quad (2)$$

Secondly, calculate the proportion p_{ij} , entropy e_j , coefficient of difference g_j , and weight value w of the indicators.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad (3)$$

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (4)$$

$$g_j = \frac{1 - e_j}{m - \sum_{j=1}^m e_j} \quad (5)$$

$$w = \frac{g_j}{\sum_{j=1}^m g_j} \quad (1 \leq j \leq m) \quad (6)$$

Finally, calculate the comprehensive score.

$$U = \sum_{j=1}^n (w_j \times x_{ij}) \quad (7)$$

Among them, x_{ij} is the standardized value of the j th indicator of the i -th city ($i=1, 2, \dots, n$; $j=1, 2, \dots, m$), σ_j and $\bar{x}$ are the standard deviation and mean of the j th indicator, w is the weight, U is the score of land spatial efficiency.

2.3. Data sources

This study focuses on 10 cities in Huaihai economic zone from 2014 to 2023, based on panel data. Data sources include the official statistical yearbook, which mainly covers authoritative statistical data such as the statistical yearbook of China's cities and the statistical yearbook of China's urban construction. Aiming at the problem of missing data in some years in the research process, the scientific interpolation method is used to supplement the data to ensure the overall integrity and academic reliability of the data set. Referring to relevant literature, the index system of land spatial efficiency is designed from the three levels of town, agriculture and ecology[13-15]. See Table 1 for the specific evaluation index system.

Table 1. Evaluation index system of land spatial efficiency

Level	Indicators	Unit	Weight
Urban spatial efficiency	Urbanization rate of permanent residents	%	0.07
	Construction land area	Square meter	0.18
Agricultural spatial efficiency	Urban Road area per capita	M2/person	0.09
	Number of agricultural employees	Person	0.13
	Annual output value of Agriculture	Yuan	0.14
	Cultivated land area	Square meter	0.16
Ecological space efficiency	Ecological land area	Square meter	0.04
		Tons of standard coal	
	Total energy consumption		0.07
	Total energy consumption	Million yuan	0.12

3. Result Analysis

3.1. Temporal variation characteristics of land spatial efficiency

The measurement results of land spatial efficiency level in Huaihai economic zone are shown in Figure 1. On the whole, the level of land spatial efficiency in Huaihai Economic Zone showed a fluctuating upward trend from 2014 to 2023, and maintained in the range of 0.4-0.5, indicating that the construction of land spatial efficiency in Huaihai economic zone still has great potential for improvement. The level of land spatial efficiency rose from 0.4254 in 2014 to 0.5332 in 2023, a relative increase of 25.34%, with an average annual growth rate of 2.57%, indicating that Huaihai Economic Zone has achieved remarkable results in the process of improving land spatial efficiency. This growth not only reflects the continuous efforts of Huaihai Economic Zone in optimizing land use efficiency, but also reflects the positive results of the coordinated development of regional economy and the transformation and upgrading of industrial structure. With the improvement of the level of land spatial efficiency, the urban function and service capacity of Huaihai economic zone are continuously enhanced, and the quality of life and economic vitality of residents are also improved accordingly. Specifically, the construction of land spatial efficiency in the Huaihai Economic Zone will develop rapidly before 2019, and the construction speed will slow down after 2019. By 2019, the urbanization level in the Huaihai Economic Zone has reached 0.5148, which may be due to the fact that some cities in the region have entered the middle and late stages of urbanization development, the intensity of land resource development tends to be saturated, and the marginal effect decreases; At the same time, the ecological environment constraints and resource carrying pressure have increased, and the use of space resources has paid more attention to quality and intensification, resulting in a relative slowdown in the improvement of land spatial efficiency. In addition, after 2019, affected by the global economic downturn and the new crown epidemic, the pace of regional economic development has been adjusted, which also restricts the rapid growth of land spatial efficiency to a certain extent.

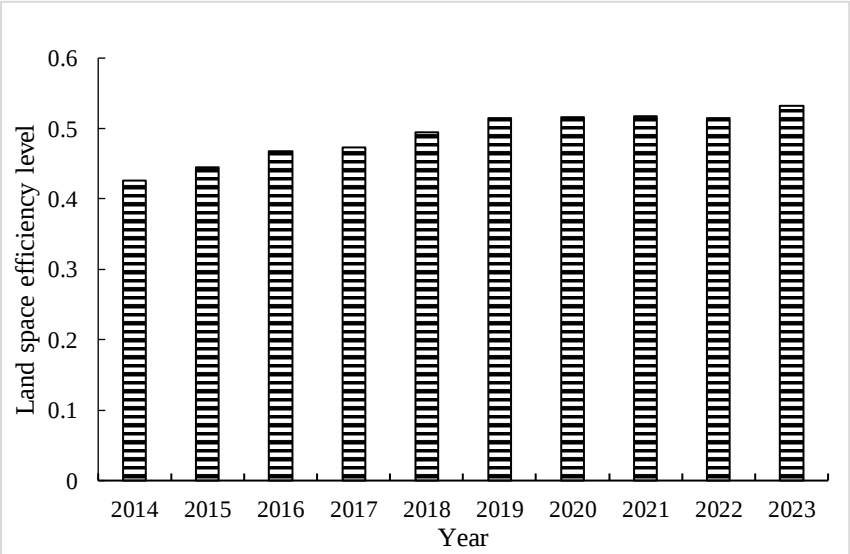


Figure 1. Development level of the land spatial efficiency in Huaihai economic zone

3.2. Spatial evolution characteristics of the land spatial efficiency

According to the evaluation results of urban ecological resilience, the spatial efficiency level of each city is divided into low level [0.2073, 0.3154], low level [0.3154, 0.4234], medium level [0.4234, 0.5314]), high level (0.5314, 0.6394], and high level [0.6394, 0.7475] using ArcGIS software to map the spatial distribution of urbanization grades of cities. The final results are shown in Table 2.

Table 2. Spatial distribution of the land spatial efficiency in Huaihai economic zone

Year	High	Higher	Moderate	Lower	Low
2014		Xuzhou,Linyi	Lianyungang, Jining	Suqian, Suzhou, Shangqiu, Heze	Huaibei,Zaozhuang
2017	Xuzhou	Jining,Linyi	Lianyungang, Suqian, Suzhou, Shangqiu, Heze	Zaozhuang	Huaibei
2020	Xuzhou	Linyi,Shangqiu	Lianyungang, Suqian, Suzhou, Heze	Zaozhuang	Huaibei
2023	Xuzhou	Linyi,Heze,Lianyungang,Shangqiu	Suqian, Suzhou	Zaozhuang	Huaibei

From 2013 to 2022, the spatial evolution of new urbanization in Huaihai Economic Zone showed a development trend of "high around and low in the middle", which generally showed the distinctive characteristics of urban gradient differentiation and unbalanced regional coordinated development. Specifically, Xuzhou and Linyi, as transportation hubs, have always maintained a high level of momentum and driven the coordinated development of surrounding cities. Jining, Shangqiu and other cities have performed prominently in optimizing land construction, steadily rising from a moderate level to a high level. In contrast, the development of Zaozhuang, Huaibei and other cities is relatively lagging behind, and the land use efficiency has not been effectively optimized. In 2014, the difference in construction level between cities was relatively small, but by 2024, the development gap between high-level and low-level cities will be significantly expanded. This spatial pattern reflects the complexity and imbalance of regional development in Huaihai economic zone. It is not only the result of optimizing land use efficiency, but also the product of multiple factors such as location, industry and infrastructure. In the future, Huaihai economic zone needs to further promote regional coordinated

development, optimize land use efficiency, narrow the development gap between cities, and achieve a more balanced and high-quality urbanization process.

4. Conclusion and Suggestions

4.1. Conclusion

(1) From 2014 to 2023, the level of land spatial efficiency in Huaihai Economic Zone showed a fluctuating upward trend, rising from 0.4254 to 0.5332, a relative increase of 25.34%, with an average annual growth rate of 2.57%, indicating that the construction of regional land spatial efficiency has achieved remarkable results.

(2) The spatial evolution of new urbanization in Huaihai economic zone shows a development trend of "high around and low in the middle", and the characteristics of "urban gradient differentiation and unbalanced regional coordinated development" are distinct. Xuzhou and Linyi have always maintained a high level of momentum.

(3) Before 2019, the construction of land spatial efficiency developed rapidly, and the growth rate slowed down after 2019. The main reasons include: the city has entered the middle and late stage of development, the intensity of land resource development tends to be saturated, the ecological environment constraints have increased, and the impact of the global economic downturn and the new crown epidemic.

4.2. Suggestions

According to the results of in-depth and systematic research, combined with the theoretical and practical needs of land spatial efficiency, the following suggestions are put forward:

(1) Strengthen coordinated regional development and promote the formation of a multi center interactive urbanization pattern led by core cities. In terms of public transport, we should strengthen the construction of urban public transport system, improve the degree of urban and rural transport interconnection, and combine the improvement of infrastructure and the rational sharing of resources, which can not only improve the overall land and space utilization efficiency, but also effectively alleviate the pressure of slow development and busy resources in some cities.

(2) Promote ecological civilization and strengthen land resources and environmental protection. In areas with fragile ecology or low ecological resilience, ecological restoration and protection should be strengthened, its ecological carrying capacity should be improved, and the ecological security pattern should be improved to prevent environmental degradation. optimize the land development structure, promote green utilization, and enhance the overall sustainable development ability of the region.

(3) Optimize the land use structure and spatial layout, and promote the integrated development of urban and rural areas. The inefficient land use areas should be transformed and upgraded to promote the intensive use of land resources. Strengthen the consolidation and reuse of inefficient land, and improve the efficiency and quality of space utilization. By strengthening the connection between urban and rural infrastructure and public services, we will lay the foundation for the sustainable and healthy development of the regional economy.

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