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Spatio-temporal dynamic evaluation of land use benefit and its coupling coordination in Gansu Province

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Abstract: Based on the model of "economic benefit-social benefit-ecological benefit", the evaluation index system of land use benefit was constructed, revealing the dynamic changes of the spatial and temporal pattern of land use benefit in Gansu Province. Combining the coupling coordination degree model, it analyzes the coupling coordination degree of economic, social and ecological benefits, and quantitatively analyzes its main limiting factors. The results show that: (1) The comprehensive benefits of land use in Gansu Province from 2000 to 2017 showed an upward trend. The spatial pattern of "high in the north and low in the south" was obvious, and a "dual core" structure with Lanzhou and Jiayuguan as the main cities was formed.(2) From the perspective of sub-systems, economic benefits show a trend of "rising first and then falling", and the spatial pattern is still "high in the north and low in the south"; the social benefits basically show an upward trend. The northwest is characterized by "first decline and then rise", and the southeast is characterized by "continuous rise". The spatial pattern is "high in the middle, followed by the northwest, and lower in the southeast". The ecological benefits are mainly present the trend of "rising first and then falling" markedly changed the spatial pattern.(3) From the perspective of the coupling coordination relationship, all cities in Gansu Province are in a state of imbalance, mainly with moderate imbalance, and the coupling coordination needs to be improved.

1. Introduction

Land is the cornerstone of human survival and development. With the rapid advancement of urbanization and industrialization in China, the contradiction between the protection of mountains, rivers, forests, fields, lakes and grasses and the construction and development of cities has become increasingly prominent. In the context of limited land resources and non-renewable in the short term, efficient use of land resources is the key to maximizing regional land use benefits and sustainable development. Therefore, scientifically evaluating the benefits of land use and realizing efficient and intensive use of land have become a hot issue in academic research.

Domestic scholars have gradually deepened their research in this area, and the results have become increasingly abundant: the relevant research perspective has expanded from single benefit evaluation^[1] to comprehensive benefit evaluation^[2]; from pure land use benefit research^[3] to the coordinated relationship research between land use benefit and urbanization^[4], the coupling and coordinated relationship research of land use benefit^[5] and the research on land intensive use benefit^[6], etc. However, there are relatively few studies on the coupling and coordination relationship among the comprehensive benefits of land use and economic, social and ecological benefits.

Gansu Province is located in the transitional zone of China's three natural geographic regions. The natural conditions of dislocation of water and land resources, urbanization and industrialization, economic and social development, and land use efficiency are all lower than coastal open cities. The regional development gap in Gansu Province is relatively large. Therefore, this paper selects Gansu Province as the research object, and constructs an index system from three aspects: economic benefit-social benefit-ecological benefit to study the comprehensive benefit level of land use in Gansu Province and its temporal and spatial pattern. The coupling coordination degree model is used to analyze the temporal and spatial differentiation of the coupling degree and coordination degree of the economic, social and ecological benefits of land use in 14 cities in Gansu Province.

2. Evaluation system and research methods

2.1. Land use benefit evaluation system

On the basis of scientificity, comprehensiveness, and data availability, drawing on existing research results and combining with the actual situation of Gansu Province, 18 indicators were selected to construct a land use benefit evaluation index system (table 1), including economic, social and ecological benefits. These data come from the "Gansu Development Yearbook", "China City Statistical Yearbook" and the statistical yearbooks and statistical bulletins of various cities in Gansu Province.

Criterion	Index layer	Units	Attribut
layer			es
Economic	GDP per land (T_1)	$10 k/hm^2$	positive
Benefits	Fiscal revenue per unit area (T_2)	$10 k/hm^2$	positive
A_1	The added value of the secondary and tertiary industries (T_3)	$10 k/km^2$	positive
	Fixed asset investment per land (T_4)	$10 k/hm^2$	positive
	Retail sales of consumer goods per land (T_5)	$10 k/km^2$	positive
	Net income of farmers (T_6)	CNY	positive
Social	The population density (T_7)	person/km ²	positive
Benefits	Engel coefficient (T_8)	%	negative
A_2	Number of hospital beds per 10,000 people (T_9)	bed	positive
	Urbanization level (T_{10})	%	positive
	Total power of agricultural machinery per unit area (T_{11})	kw/hm ²	positive
	Urban road area per capita (T_{12})	m^2	positive
Ecological	Per capita garden area (T_{13})	m^2	positive
Benefits	Green coverage rate of built-up area (T_{14})	%	positive
A_3	Amount of agricultural chemical fertilizer applied per unit	t/hm ²	negative
	planting area (T_{15})		
	Industrial wastewater discharge (T_{16})	10kt	negative
	Comprehensive utilization rate of industrial solid waste (T_{17})	%	positive
	Domestic waste treatment rate (T_{18})	%	positive

Table 1 Land use benefit evaluation system and weight

2.2. Research methods

2.2.1. Evaluation index calculation

The weighted summation method is used to calculate the evaluation index of land use benefits of various cities in Gansu Province. According to the natural break point method, it is divided into five categories: low-efficiency area, low-efficiency area, medium-efficiency area, higher-efficiency area

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and high-efficiency area. Calculated as follows:

$$P(j) = \sum_{i=1}^{n} S_{ij} * \omega_i \tag{1}$$

2.2.2. Coupling coordination degree model

The degree of coupling (C) and the degree of coupling coordination (D) are used to reflect the relationship between the benefits and the degree of coupling and coordination. The formula is as follows:

$$C = \left[\frac{f(j)*g(j)*h(j)}{\left(\frac{P(j)}{3}\right)^3}\right]^{\frac{1}{3}}$$
(2)

$$D = \sqrt{C * T} \tag{3}$$

$$T = \alpha f(j) + \beta g(j) + \gamma h(j) \tag{4}$$

The value ranges of C and D are both [0, 1]. The larger the value, the better the coupling relationship and the coupling coordination relationship. The T represents the comprehensive benefit index of the level of coupled and coordinated development; f(j), g(j), h(j) and P(j) represent the economic, social, ecological and comprehensive benefits of land use in the j city; α , β , and γ represent the weight of the economic, social, and ecological benefit system, and the value is 1/3.

3. Temporal and spatial dynamic evaluation of land use benefits in Gansu Province

3.1. The comprehensive benefits

The comprehensive benefits of land use in Gansu Province showed an upward trend in time series. There is still a big gap in the benefit value of the 14 cities, but the gap is gradually narrowing. From the perspective of each value, the spatial pattern of "high in the north and low in the south" is obvious: the high comprehensive benefit value is distributed in a dot pattern, forming a "dual core" structure dominated by Lanzhou City and Jiayuguan City; the medium and higher comprehensive benefit value is mainly distributed in Hexi area, including Jiuquan City, Zhangye City, Jinchang City and other places; the low and lower comprehensive benefits are mainly distributed in the southern ethnic regions, including Longnan City and Gannan Prefecture.



Figure 1 Distribution map of comprehensive benefits of land use in Gansu Province

3.2. Economic benefits

The main body and average economic benefits of the cities in Gansu Province mainly show a time-series characteristic of "rising first and then falling", and the gap in economic benefits between cities has increased. From the distribution point of view, the spatial pattern is "high in the north and low in the south". The cities with high and higher economic benefits are distributed in scattered spots, efficiency; areas with lower and medium economic benefits include most cities in Gansu Province,

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which are mainly distributed in Hexi, Central Gansu and Southeast Gansu; low economic benefit areas are mainly distributed in southern ethnic areas, including Longnan City and Gannan Prefecture.



Figure 2 Distribution Map of Economic Benefits of Land Use in Gansu Province

3.3 Social benefits

The social benefit value of land use in the cities of Gansu Province is on the rise. The northwestern part is characterized by a "first decline and then rise", and the southeast part is a dynamic characteristic of "continuous rise". From the distribution point of view, the spatial pattern is "high in the middle, second in the northwest, and lower in the southeast". Cities with high social benefits are also distributed in dots, gradually forming high-value areas consisting of Lanzhou, Jiayuguan and Jinchang; cities with higher social benefits are mainly distributed in the Hexi region, mainly including Jiuquan and Zhangye; cities with medium social benefits Gathered in Hexi and Southeastern Gansu from 2000 to 2009. In 2017, they were scattered in various places, mainly including Wuwei and Tianshui; low and lower social benefits were mainly concentrated in the southern ethnic areas, mainly including Longnan, Linxia Prefecture, Gannan Prefecture, etc.



Figure 3 Distribution of social benefits of land use in Gansu Province

3.4 Ecological benefits

The ecological benefits of land use in cities in Gansu Province also showed a time-series characteristic of "rising first and then falling". From a spatial point of view, the number of high ecological benefit areas increased first and then decreased, from dual cores (Jiayuguan and Tianshui City) to three cores (Jiayuguan, Tianshui and Qingyang City), and then to single core (Jiayuguan City); high and medium ecological benefit areas are mainly located in Hexi and Longzhong areas, with little change in number; low and lower ecological benefit areas are mainly distributed in southern ethnic areas and Longzhong areas from 2000 to 2009, and gradually expanded to the northwest from 2009 to 2017, making some cities in the Hexi region also turn into low-efficiency areas.



Figure 4 Distribution of ecological benefits of land use in Gansu Province

4. Coupling relationship among land use benefits in Gansu Province

After calculation, it is found that the degree of coupling between the various subsystems is relatively high (C> 0.85), but the coupling coordination relationship is in an unbalanced state (D <0.5), and most of them are moderately out of adjustment.

On the whole, the degree of coupling and coordination in Gansu Province is increasing. From a regional perspective, the degree of coupling and coordination in central Gansu is relatively high, and most of them have mild and moderate imbalances. The Hexi and Southeastern regions of Gansu are mainly moderately unbalanced. The degree of coupling in the southern ethnic regions is relatively low, and most of them are seriously unbalanced. In general, there are obvious spatial differences in the coupling and coordination of land use benefits in Gansu Province. The degree of coupling and coordination in northwestern cities is higher than that in southeast cities, and regional central cities such as Lanzhou and Jiayuguan have better coordination.



Figure 5 Distribution map of land use benefit coupling coordination degree in Gansu Province

5. Conclusions

The comprehensive benefits of land use in Gansu Province showed a continuous increase; the economic benefits and ecological benefits of land use showed a "rising first and then falling" characteristics; the social benefits of land use "decline first and then rise" in the northwest and "continuously rise" in the southeast.

The economic, social and ecological benefits of land use in various cities in Gansu Province are all in a state of imbalance, with obvious differences between regions.

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