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## Dynamic Assessment of Land Ecological Security and Analysis of Influencing Factors in Jiayuguan City (Postprint)

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### Abstract

Land ecological security assessment holds significant importance for managing regional ecological risks and ensuring ecological security. An indicator evaluation system was constructed based on the ‘quantity security-quality security-structure security-safeguard security’ model, combination weighting was performed using the relative entropy method, revealing the dynamic evolution of land ecological security in Jiayuguan City, and factor analysis was utilized to investigate its main influencing factors. The results indicate that: (1) From 2000 to 2017, the comprehensive land ecological security index in Jiayuguan City exhibited an increasing trend, rising from 0.415 in 2000 to 0.644 in 2017, with the security level elevating from relatively unsafe to marginally safe, demonstrating an improvement in overall security level; nevertheless, the current security level remains relatively low, and land ecological security risks still persist. (2) Across the subsystems, the quantity security index exhibited minor fluctuations with limited improvement; the quality security index demonstrated a generally continuous upward trajectory at a comparatively rapid growth rate; the structure security index exhibited relatively pronounced growth from 2000 to 2009, and showed minor fluctuations after 2009; the safeguard security index displayed a marked fluctuating pattern, undergoing a process of initial increase, followed by decrease, and subsequent fluctuating increase, overall assuming an inclined ‘N’ -shaped configuration. (3) The main influencing factors of land ecological security changes can be consolidated into four dimensions: resource and environmental background, industrial structure evolution, environmental pollution control, and effectiveness of ecological construction.

## Full Text

# Dynamic Evaluation and Influencing Factors Analysis of Land Ecological Security in Jiayuguan City

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**Abstract:** Land ecological security evaluation is crucial for managing regional ecological risks and safeguarding ecological security. Based on the “quantity safety-quality safety-structure safety-guarantee safety” model, this study constructs an indicator evaluation system, employs the relative entropy method for combined weighting, reveals the dynamic evolution of land ecological security in Jiayuguan City, and explores its main influencing factors using factor analysis. The results indicate: (1) From 2000 to 2017, the comprehensive land ecological security index in Jiayuguan City showed an upward trend, increasing from 0.415 to 0.644, with the security level rising from “relatively unsafe” to “critically safe.” Although the overall security level has improved, it remains relatively low, and land ecological security risks persist. (2) Among the subsystems, the quantity safety index fluctuated with little improvement; the quality safety index demonstrated a sustained upward trend with relatively rapid growth; the structure safety index showed minor fluctuations; and the guarantee safety index exhibited a distinct fluctuating pattern of first increasing, then decreasing, and then increasing again, roughly forming an “N-shaped” trend. (3) The main influencing factors of land ecological security changes can be integrated into four dimensions: resource-environment background, industrial structure succession, environmental pollution control, and ecological construction effectiveness.

**Keywords:** land ecological security; dynamic evaluation; influencing factors; Jiayuguan City

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## 1 Introduction

Land constitutes the foundation of human survival and development, providing essential conditions for human habitation and daily life. With the acceleration of industrialization and urbanization, human impacts on the ecological environment have intensified, leading to increased demand for construction land and extensive occupation of cultivated land and forestland, exacerbating soil erosion. These changes have caused land ecological security issues to enter public discourse, as scarce land resources and fragile ecological environments severely constrain sustainable land use and socio-economic development.

Land ecological security refers to the capacity of a land system within a certain

region to maintain its structure and functions with minimal threat, thereby providing services for sustainable economic and social development and ensuring the long-term coordinated development of the composite ecosystem. Land ecological security evaluation serves as an effective tool to reveal regional ecological security status and trends, playing a supervisory and early warning role in ecological conditions.

In 1976, the Food and Agriculture Organization (FAO) published the *Outline of Land Evaluation*, which first systematically assessed land suitability for specific uses. In 1991, the United Nations Environment Programme (UNEP) explicitly proposed the concept of ecological security in the *Convention on Environmental Impact Assessment in a Transboundary Context*. In 2000, China's State Council issued the *National Ecological and Environmental Protection Outline*, emphasizing the necessity of ecological security at the national level. Subsequently, the *Comprehensive National Land Use Plan (2016-2030)* proposed control requirements for ecological spaces, significantly promoting land ecological security evaluation research.

Existing research primarily focuses on land ecological security evaluation, land suitability assessment, land sensitivity analysis, land carrying capacity evaluation, and land ecological security early warning, predominantly at provincial, municipal, and county scales. Regarding evaluation frameworks, previous studies have mainly employed two approaches: constructing indicator systems based on the Pressure-State-Response (PSR) model or the Driving-Force-Pressure-State-Impact-Response (DPSIR) model. Most subsequent model expansions represent local improvements within these two frameworks. While both models address land resource quantity, quality, structure, and ecological security to varying degrees, they overlook the guarantee functions of both natural and human factors on land ecological security, including direct and indirect guarantees. Drawing on existing research, this study incorporates guarantee safety into the evaluation system and constructs an indicator framework using the "quantity safety-quality safety-structure safety-guarantee safety" model. Additionally, the relative entropy method is employed to calculate combination weight coefficients, eliminating the shortcomings of single weighting methods and improving evaluation accuracy.

As an important node city of the "Belt and Road" initiative and one of China's only five "direct-pipe cities" (prefecture-level cities without districts), Jiayuguan City is undergoing rapid urbanization and advancing toward high industrialization. Urban development and expansion are severely constrained by fragile ecological environments and scarce water and land resources. This study selects Jiayuguan City as the research object, using the beginning of the Western Development Strategy (2000) as the temporal starting point to conduct a dynamic evaluation of land ecological security from 2000 to 2017 and analyze its main influencing factors, aiming to provide references for sustainable land use and territorial spatial planning in Jiayuguan City.

## 1.1 Study Area Overview

Jiayuguan City is located in the central Hexi Corridor, northwestern Gansu Province, between 39°37'58"~39°50'29" N and 97°49'52"~98°31'24" E. It leans against the Qilian Mountains in the south, borders the Heishan Mountains in the north, adjoins Suzhou District of Jiuquan City in the east, connects with Yumen City (an oil industry center) in the west, and borders the Badain Jaran Desert in the northeast. The city covers an area of 2,935 km<sup>2</sup>, with agricultural areas in the east, urban built-up areas in the center, and extensive Gobi desert in the west. It governs Yugu, Wenshu, and Xincheng towns. The permanent population is 249,800, with an urban population of 233,400, yielding an urbanization rate of 93.45%—the highest in Gansu Province. The administrative region is roughly parallelogram-shaped, longer from east to west and narrower from north to south, with terrain sloping from higher in the southwest to lower in the northeast [Figure 1: see original paper]. The climate is temperate continental desert, characterized by long and intense sunshine, scarce precipitation (85.3 mm annually) and strong evaporation (2,149 mm annually), large diurnal temperature variations, and frequent strong winds. Situated in the hinterland of the Gobi, the region suffers from aridity, sparse vegetation, and ecological fragility. Land use patterns are also distinctive: (1) It is a typical mineral resource-based city with large industrial land areas—Jiuquan Iron and Steel Group alone occupies 70% of the built-up area; (2) As one of only five prefecture-level cities in China without districts, it has a small rural population consisting mostly of “amphibious populations” (migrant workers maintaining rural household registration while living in cities), exhibiting “large city, small countryside” characteristics with high urbanization; (3) Unused land accounts for a large proportion, with cultivated land comprising only 2.25% of the municipal area, while land pollution and desertification are prominent, making land ecological security issues particularly concerning.

## 1.2 Data Sources

The study incorporates socio-economic data, environmental data, and remote sensing imagery. Socio-economic data were obtained from the *Jiayuguan Statistical Yearbook*, *Jiayuguan National Economic and Social Development Statistical Bulletin*, and *Jiayuguan Population Census Main Data Bulletin*. Environmental data came from the *Jiayuguan Environmental Status Bulletin*. Remote sensing imagery primarily consisted of Landsat TM/OLI data from 2000 to 2017, sourced from the Geospatial Data Cloud (<http://www.gscloud.cn/>). Data processing, calculation, cropping, and extraction were performed using ArcGIS 10.2 and ENVI 5.2 software.

## 2 Methods

### 2.1 Indicator System Construction and Weighting

**2.1.1 Indicator Selection** Following principles of scientificity, representativeness, and rationality, and considering Jiayuguan’s urban characteristics, this study selects 35 indicators from four dimensions—quantity safety, quality safety, structure safety, and guarantee safety—to construct the land ecological security evaluation indicator system. Quantity safety indicators reflect per capita land resource utilization and socio-economic status; quality safety indicators characterize land productivity, supply levels, and potential risks; structure safety indicators measure the rationality of land use and socio-economic structures; and guarantee safety indicators reflect government, enterprise, and societal efforts to safeguard land ecological security. This 35-indicator system encompasses land’s production, living, and ecological functions while accommodating Jiayuguan’s “Gobi Steel City” land use characteristics.

**2.1.2 Indicator Standardization** To ensure comparability among indicators, dimensionless processing was performed using range normalization for positive and negative indicators:

**Positive indicators:**

$$S_{ij} = \frac{T_{ij} - T_j^{\min}}{T_j^{\max} - T_j^{\min}}$$

**Negative indicators:**

$$S_{ij} = \frac{T_j^{\max} - T_{ij}}{T_j^{\max} - T_j^{\min}}$$

where  $S_{ij}$  is the standardized value,  $T_{ij}$  is the original value of indicator  $j$  in year  $i$ , and  $T_j^{\max}$  and  $T_j^{\min}$  are the maximum and minimum values of indicator  $j$ , respectively.

**2.1.3 Indicator Weight Determination** Weight reflects the relative importance of an indicator within the entire system. Both entropy weight and coefficient of variation methods have advantages and disadvantages. Therefore, this study first calculates weights using these two methods separately, then employs the relative entropy method to calculate combination weight coefficients, and finally uses the combined weighting method to determine final weights.

First, the optimization model is constructed:

$$\min : \sum_{i=1}^m d_j \log \frac{d_j}{u_{ij}}$$

$$\text{s.t. } \sum_{j=1}^n d_j = 1, \quad d_j > 0, \quad (j = 1, 2, \dots, n)$$

Second, the indicator weight closest to each single weighting method is calculated, i.e., the aggregation weight  $d_j$ :

$$d_j = \frac{\prod_{i=1}^m u_{ij}^{h_i}}{\sum_{j=1}^n \prod_{i=1}^m u_{ij}^{h_i}}, \quad j = 1, 2, \dots, n$$

where  $u_{ij}$  is the weight of indicator  $j$  from the  $i$ -th single weighting method. The closeness  $h_i$  and credibility  $\theta_k$  between each weighting result and the aggregation weight are then calculated:

$$h_i = 1 - \frac{1}{\log n} \sum_{j=1}^n u_{ij} \log \frac{u_{ij}}{d_j}, \quad i = 1, 2, \dots, m$$

Finally, the combination weight  $\omega_j$  is:

$$\omega_j = \sum_{i=1}^m \theta_i u_{ij}, \quad j = 1, 2, \dots, n$$

The indicator system and weight results are shown in .

**2.1.4 Comprehensive Index Calculation** The weighted summation method is used to calculate the land ecological security index:

$$LESI_j = \sum_{j=1}^n T_j \times \omega_j$$

where  $LESI_j$  is the land ecological security index for indicator  $j$  (value range  $[0,1]$ ),  $T_j$  is the standardized value of indicator  $j$ , and  $\omega_j$  is the weight of indicator  $j$ .

## 2.2 Land Ecological Security Grading

Considering Jiayuguan' s land use status and ecological security stability, the land ecological security level is divided into five non-equidistant grades: unsafe, relatively unsafe, critically safe, relatively safe, and safe . The security status is determined based on which grade the comprehensive index falls into.

### 2.3 Factor Analysis Method

Factor analysis is a multivariate statistical method that reduces variables with complex interrelationships into a few comprehensive factors by examining internal dependency relationships. Through factor analysis, information from original variables is transformed to make analysis simpler and more intuitive. The procedure includes: (1) calculating the correlation coefficient matrix (requiring most correlation coefficients  $> 0.3$ ); (2) extracting factors using principal component analysis to form the factor loading matrix; (3) naming and interpreting factors—when factor loadings are ambiguous, factor rotation (orthogonal or oblique) clarifies factor meanings by maximizing high loadings on fewer factors; and (4) calculating factor scores.

## 3 Evaluation Results

### 3.1 Overall Land Ecological Security Evaluation

Overall, the comprehensive land ecological security index [Figure 2: see original paper] showed an upward trend from 0.415 in 2000 to 0.644 in 2017, with the security level upgrading from “relatively unsafe” to “critically safe.” This improvement reflects the effectiveness of industrial structure transformation, returning farmland to forest, and comprehensive environmental management since the Western Development Strategy implementation. In 2017, the urbanization rate reached 93.45%, far exceeding Gansu Province and national averages, providing a solid foundation for economic development and intensive land use. Per capita GDP increased from ¥15,337 to ¥69,071, and per capita disposable income reached ¥34,790, both ranking first in the province. However, the security level remains relatively low, and ecological security risks persist.

### 3.2 Subsystem Evaluations

**3.2.1 Quantity Safety Evaluation** As shown in [Figure 3: see original paper], the quantity safety score fluctuated between 0.11 and 0.14, with limited improvement. Cultivated land area increased from 3,037  $\text{hm}^2$  to 6,907  $\text{hm}^2$ , and per capita cultivated land rose from 0.027  $\text{hm}^2$  to 0.035  $\text{hm}^2$ . Despite rapid growth, Jiayuguan still has the smallest per capita cultivated land in the province (less than 0.027  $\text{hm}^2$ ), indicating an arduous task for cultivated land protection. With accelerated industrialization, construction land increased rapidly, with per capita construction land rising from 206.20  $\text{m}^2$  to 289.39  $\text{m}^2$  (far exceeding the national standard of 150  $\text{m}^2$  per capita). Relatively low land use efficiency and development intensity, along with phenomena such as unauthorized construction, land enclosure, and “approved but unconstructed” land, have caused significant land resource loss and idleness. Land expansion primarily occurred through developing unused land, with per capita unused land decreasing from 0.70  $\text{hm}^2$  to 0.35  $\text{hm}^2$ , mostly desert and Gobi with limited usability, indicating severe shortages of reserve land resources. The only surface river (Taolai River) has limited available water resources due to water alloca-

tion systems, and evaporation far exceeds precipitation (85.3 mm vs. 2,149 mm). Per capita water resources dropped to 1,329 m<sup>3</sup>, while industrial and ecological greening water consumption increased, water-saving agriculture remained small-scale, and reclaimed water recycling rates were low, making water scarcity a critical constraint.

**3.2.2 Quality Safety Evaluation** Except for a slight decline in 2004, the quality safety score showed a continuous upward trend with an annual growth rate of 6.89%. Agricultural output value, industrial added value, and unit grain yield increased annually by 11.23% and 13.10%, respectively, with grain yield rising from 8,359 kg · hm<sup>-2</sup> to 11,382 kg · hm<sup>-2</sup>, continuously enhancing land productivity and positively impacting ecological security. Influenced by the regional climate shift from warm-dry to warm-wet, Jiayuguan' s annual rainfall gradually increased while strong winds and sandstorms decreased, alleviating desertification. Urban greening achieved remarkable results, with vegetation coverage increasing from 17.20% to 39.41% and desertified area decreasing, promoting the ecological security index. However, increased cultivated and construction land led to rising fertilizer and plastic film usage, while industrial wastewater, exhaust gas, and solid waste emissions increased, particularly large tailings stored outdoors, which occupy substantial areas and intensify land pollution loads, posing significant environmental and health risks. Consequently, land degradation risk remains a strong constraint on ecological security.

**3.2.3 Structure Safety Evaluation** The structure safety score increased significantly from 2000 to 2009 (from 0.11 to 0.15) with an annual growth rate of 4.49%, then fluctuated between 0.14 and 0.15 thereafter. The proportion of cultivated land in agricultural land showed a trend of first increasing then decreasing, peaking in 2009 (23.67%), indicating that ecological farmland retirement policies significantly impacted Jiayuguan' s land use structure, particularly within agricultural land. Construction land proportion increased from 4.35% to 12.34%, primarily through developing unused land rather than occupying cultivated land, maintaining relatively stable land use structure. However, due to Jiayuguan' s large unused land area, development has somewhat neglected the renovation of already-used land, resulting in low use efficiency and intensive management levels. Unused land proportion decreased from 81.8% to 71.2%, but development intensity after 2009 was insufficient for structural improvement. Continuous afforestation and greening activities gradually increased urban green coverage and forest coverage from 12.14% to 17.20%, playing important roles in air purification, climate regulation, and soil conservation, and enhancing Jiayuguan' s livability.

**3.2.4 Guarantee Safety Evaluation** The guarantee safety score experienced a process of first increasing, then decreasing, and then fluctuating upward (forming an inclined “N-shaped” pattern). It declined from 2005 to 2010, with 2004 reaching the maximum (0.15) and 2010 the minimum (0.11). Un-

der the principle of “protection during development and development during protection,” Jiayuguan implemented a series of ecological environmental protection policies and measures. Per capita public green space increased from 35.61 m<sup>2</sup> to 56.24 m<sup>2</sup>, and artificial afforestation area expanded from 93 hm<sup>2</sup> to 2,109 hm<sup>2</sup>. With industrial transformation and upgrading, the tertiary industry developed rapidly, with tourism-related income increasing from 0.9×10<sup>8</sup> yuan to 57.21×10<sup>8</sup> yuan, converting tourism resource advantages into economic advantages and rationalizing the industrial structure. Simultaneously, land use structure was continuously adjusted, environmental pollution control investment increased, pollution emissions were strictly controlled, and industrial parks followed circular economy principles, raising enterprise entry thresholds and promoting ecological transformation, thereby strengthening environmental protection awareness.

## 4 Analysis of Main Influencing Factors

Factor analysis was conducted using SPSS 20.0. Based on the correlation matrix of original variables, principal component analysis extracted characteristic factors. Orthogonal rotation via varimax method produced the rotated component loading matrix, extracting four common factors with eigenvalues of 18.766, 7.420, 3.069, and 1.465, respectively. Their variance contribution rates were 56.473%, 21.199%, 8.767%, and 4.185%, with a cumulative contribution of 90.625%, describing most information from original variables.

The first common factor showed high correlations with most indicators (T<sub>4</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>11</sub>, T<sub>18</sub>, T<sub>20</sub>, T<sub>25</sub>), indicating the impact of resource-environment background on land ecological security. The second common factor loaded heavily on T<sub>3</sub>, T<sub>1</sub>, T<sub>31</sub>, T<sub>15</sub>, and T<sub>19</sub>, reflecting industrial structure succession impacts. The third common factor loaded significantly on T<sub>29</sub>, T<sub>16</sub>, and T<sub>33</sub>, indicating environmental pollution control impacts. The fourth common factor loaded substantially on T<sub>26</sub> and T<sub>34</sub>, reflecting ecological construction effectiveness impacts.

### 4.1 Resource-Environment Background

With an eigenvalue of 18.766 and contribution rate of 56.473%, this is the most important factor affecting land ecological security. Jiayuguan is located in an arid region with temperate continental desert climate, experiencing frequent strong winds and sandstorms, scarce precipitation (85.3 mm annually, far below national average), severe spring droughts, and summer dry spells. Per capita water resources are only half the national average, and the fragile environmental background intensifies land ecological security pressure. Since 2000, population size, economic scale, and living standards have improved significantly, increasing cultivated land, forestland, and construction land while decreasing grassland and unused land. Unlike other cities, Jiayuguan primarily expands construction land by occupying unused land, resulting in relatively less land development pressure closely related to its unique resource-environment background. However,

current construction land standards significantly exceed national regulations, with relatively low land intensification levels, insufficient reserve resources suitable for agriculture, forestry, and animal husbandry, and severe water resource shortages. The ecological service system's self-regulation capacity is weak, and projects such as the West-East Gas Pipeline crossing water sources pose potential safety hazards, making land ecological security pressure still considerable.

#### 4.2 Industrial Structure Succession

With an eigenvalue of 7.420 and contribution rate of 21.199%, this factor also significantly influences land ecological security. As a renowned mineral resource-based city, Jiayuguan has long been overly dependent on the large state-owned enterprise Jiuquan Iron and Steel Group, exhibiting a “secondary-primary-tertiary” industrial structure with industry dominating and being difficult to change in the short term. This pattern intensifies ecological environment vulnerability and high environmental costs, constantly affecting urban land ecological security. Since 2011, the government has vigorously advocated “transforming development modes, adjusting structures, and promoting efficiency,” introducing advanced technologies to develop circular economy and supporting high-tech industries, causing the secondary industry proportion to decline. Simultaneously, rich local tourism resources have been exploited to accelerate tertiary industry development, with the three-industry ratio shifting from 3.39:70.76:25.85 to 2.2:51.8:46.0, gradually rationalizing the industrial structure. Adjusting industrial structure through industry-city integration is essential for promoting regional development.

#### 4.3 Environmental Pollution Control

With an eigenvalue of 3.069 and contribution rate of 8.767%, this factor is also important for land ecological security. Guided by sustainable development strategy, Jiayuguan has focused on “one control and double compliance” and “strengthening environmental law enforcement supervision and pollution source control,” continuously increasing pollution control investment, accelerating environmental technology innovation, strengthening special pollution remediation, and enforcing total pollutant emission control. Industrial solid waste comprehensive utilization increased from 12.11% to 62.90%, and industrial wastewater compliance discharge rate reached 100%. Adhering to innovative, coordinated, green, open, and shared development concepts, Jiayuguan has seized opportunities from national western development and new energy industry development, strictly implementing the State Council's ten atmospheric pollution prevention measures, gradually eliminating heavily polluting enterprises with low capacity and backward technology, thereby safeguarding land ecological security.

#### 4.4 Ecological Construction Effectiveness

With an eigenvalue of 1.465 and contribution rate of 4.185%, this factor reflects ecological construction impacts. Since 2000, Jiayuguan has continuously

conducted “Greening Year” activities, vigorously implementing afforestation programs, achieving green corridor standards for all built-up area roads. By expanding reservoirs (Dacaotan Reservoir), constructing artificial lakes (East Lake Ecological Tourism Scenic Area), and increasing urban green space, water body and green areas have significantly expanded, greatly improving the urban ecological environment. Leveraging advantages such as abundant sunlight, strong industrial foundation, and robust industrial supporting capacity, Jiayuguan has vigorously developed new and renewable energy, particularly photovoltaic power generation, initially forming an important new energy base in the province. This has reduced fossil fuel dependency and positively impacted climate change mitigation. The city’s average annual precipitation has increased, while occurrences of dry hot winds, strong winds, floating dust, sandstorms, cold waves, high temperatures, and sharp temperature drops have significantly decreased. Sustained ecological construction has enhanced the land ecological security index.

## 5 Conclusions

- (1) From 2000 to 2017, land ecological security in Jiayuguan City showed an upward trend, transitioning from “relatively unsafe” to “critically safe.” The comprehensive index increased from 0.415 to 0.644, with an average annual growth rate of 3.502%. The improvement was particularly evident after 2011, approaching the upper limit of the critically safe level, indicating that industrial structure transformation, farmland retirement, and comprehensive environmental management since the Western Development Strategy have achieved positive results.
- (2) From the subsystem perspective, the quantity safety index fluctuated between 0.11 and 0.14 with limited improvement; the quality safety index showed a continuous upward trend with a relatively high growth rate; the structure safety index increased significantly before 2009 and fluctuated between 0.14 and 0.15 thereafter; the guarantee safety index exhibited a distinct fluctuating pattern of first increasing, then decreasing, and then increasing again, forming an inclined “N-shaped” trend.
- (3) Through factor analysis, the main influencing factors of land ecological security changes can be integrated into four dimensions: resource-environment background, industrial structure succession, environmental pollution control, and ecological construction effectiveness. These factors are crucial for ensuring future sustainable land use and achieving ecological civilization strategy in Jiayuguan City.

## 6 Discussion

Land serves as the carrier for all economic and social activities—urban construction, economic development, and living environment improvement all depend on the resource-environment background. Known as the “Gobi Steel City,” Jiayuguan follows the principle of “one specialty, two improvements, and three

transformations.” On the basis of ensuring stable agricultural development, the city vigorously develops low-carbon and circular economies, expands clean energy industries, builds regional brands, extends industrial chains, accelerates industrial upgrading, guides tertiary industry transformation, and actively constructs a modern service system to continuously optimize industrial structure. Simultaneously, through ecological projects such as farmland retirement, tree planting, grass cultivation, and water diversion for lake creation, the city has continuously expanded urban green and water areas, transforming the original Gobi wasteland into a modern city “not inferior to Jiangnan.” Although its land ecological security level remains relatively low and security risks persist, Jiayuguan has embarked on a unique urbanization path, providing valuable experience for sustainable development of mineral resource-based cities.

However, this study has limitations. Due to data availability constraints, indicators such as soil quality and site conditions were not included, and the indicator system needs further improvement. The analysis was conducted only from a temporal dimension, without spatial differentiation among urban streets (towns) or various land use types. This spatial dimension will be addressed in future research.

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