Time-series Evaluation and Forecasting Analysis of Urban Land Ecological Security in Harbin (Postprint)

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Abstract

From a time series perspective and based on a humanistic and social science viewpoint, this study constructs an evaluation system for land ecological security grounded in the "nature—society—economy" synergy model. The entropy weight method and comprehensive index method are applied to calculate the comprehensive value of urban land ecological security in Harbin. The results indicate that the comprehensive value of land ecological security in the study area increased year by year from 0.7599 in 2004 to 0.8904 in 2016, and is expected to maintain a favorable development trend in the coming years. Overall, the region exhibits a dynamic evolution process characterized as "sensitive—good—secure" . The primary driving factors influencing land ecological security in the study area are land use structure, urbanization rate, population density, and agricultural fertilizer application amount.

Full Text

Preamble

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1 Introduction

1.1 Study Area Overview

The total area of the study region is 5310×10 hm², with cultivated land accounting for 45.3% of the total land area. By 2016, the cultivated land area reached 197.74×10 hm², representing 46.0% of the total, demonstrating a stable trend in agricultural land use.

The region' s socio-economic development has been rapid, with urbanization accelerating in recent years. This has led to increasing pressure on land resources and prominent ecological security issues. The evaluation of urban land ecological security has become a critical research focus. Based on the "Nature-Economy-Society" synergistic model, this study constructs an evaluation index system incorporating multiple dimensions including land resource status, ecological environment quality, and socio-economic development. The time series spans from 2004 to 2016, with data derived from statistical yearbooks, land use survey data, and relevant government reports.

1.2 Evaluation Framework

The evaluation framework adopts the entropy weight method to determine objective weights for each index, avoiding subjective bias in weight assignment. The comprehensive index method is then applied to calculate the overall land ecological security value. This approach ensures both scientific rigor and practical applicability in assessing the dynamic changes in urban land ecological security.

2 Materials and Methods

2.1 Data Collection

The research data primarily includes: (1) Land use data from 2004-2016, obtained from the Land and Resources Bureau; (2) Socio-economic statistical data from the Statistical Yearbook; (3) Ecological environment monitoring data from the Environmental Protection Agency. All data underwent standardization preprocessing to ensure comparability across different dimensions.

Table 1 presents the urban land ecological security evaluation index system and actual values for each index from 2004 to 2016. The system comprises multiple indicators including cultivated land area, land use intensity, ecological service value, and environmental quality indices.

Table 1. Index System of Urban Land Ecological Security Evaluation and Actual Values

Index	Unit	2004	2007	2010	2013	2016
Cultivated land area	10 hm²	36.10	37.00	35.50	37.90	197.74
Land use intensity	%	67.91	67.89	70.36	68.87	46.0
Ecological service value	10 yuan/km²	10.50	10.00	10.00	10.40	1083.09
Environmental quality index	-	0.1983	0.1980	0.1976	0.2004	0.2057
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Population density	persons/hm²	298.56	323.76	321.53	326.69	342.50
Urbanization rate	%	48.75	48.21	47.97	51.38	35.40

Data sources: Statistical Yearbook (2005–2017), Land Use Survey Data (2015), and relevant planning documents.

2.2 Evaluation Methodology

The entropy weight method calculates weights based on the degree of variation in each index. Higher information entropy indicates smaller variation and lower

weight, while lower entropy suggests greater variation and higher weight. The comprehensive evaluation model is constructed as follows:

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where T represents the comprehensive land ecological security index, w_i denotes the weight of index i, and x_i is the standardized value of index i.

The evaluation period covers 2004–2013 for model construction and validation, with 2014–2016 data used for accuracy verification. The grey prediction model is employed for forecasting future trends, providing a scientific basis for land use planning and decision-making.

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3 Results and Analysis

3.2.2 Comprehensive Evaluation Results

The comprehensive evaluation reveals that Harbin City's land ecological security index increased from 0.7599 in 2004 to 0.8904 in 2016, following a "Sensitive-Good-Safe" evolutionary pattern. The temporal variation shows distinct phases: 2004–2007 (sensitive stage), 2008–2010 (transition stage), and 2011–2016 (improvement stage).

Table 5. Grading Standard of Urban Land Ecological Security

Security Level	Index Range (T)
Unsafe	$T \leq 0.4$
Sensitive	$0.4 < T \leq 0.6$
Good	$0.6 < T \leq 0.8$
Safe	$0.8 < T \leq 0.9$
Very Safe	$0.9 < T$

Figure 3 illustrates the predicted trend of Harbin' s land ecological security index. The forecast indicates that the city will maintain a "Good" security level in the coming years, with continued improvement expected.

The main driving factors influencing land ecological security include: (1) Land use structure and intensity, (2) Urbanization rate and population density, (3) Agricultural fertilizer application amount, and (4) Ecological protection policies. Among these, land use structure and urbanization rate demonstrate the most significant correlation with security level changes.

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Abstract: In recent years, research on urban land ecological security problems has become an important topic in land ecological research. The evaluation and prediction of regional land ecological security of a city is a prerequisite to solve the land ecological security issues of the city. From the perspective of human society, this paper embarked on time series analysis and the land ecological security evaluation system was constructed based on the "nature-society-economy synergistic model" , using the entropy weight method and comprehensive index method. The weight of each evaluation index was obtained and the comprehensive value of land ecological security was calculated to evaluate and forecast the status of urban land ecological security and the driving factors of land ecological security in Harbin City, Heilongjiang Province, China. The countermeasures to strengthen the land ecological security of the city were proposed. The research results show as follows: (1) The land ecological security value of Harbin City was increased from 0.7599 in 2004 to 0.8904 in 2016, which indicated the dynamic change process following a pattern of "Sensitive level-Good level-Safe" . (2) The land ecological security of Harbin City will be in the Good level in the next few years and maintain a good development trend. (3) The main influence factors of land ecological security in Harbin City include the land use structure, urbanization rate, population density and the amount of fertilizer applied to agriculture.

Keywords: land ecological security; time series evolution prediction; comprehensive index method; Harbin City

Note: Figure translations are in progress. See original paper for figures.