Temporal and Spatial Pattern Evolution Analysis of Ecological Environment Vulnerability in Panzhihua

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Abstract. In this study, the evaluation factors of Panzhihua City from 2005 to 2015 were selected from the three aspects of “ecological sensitivity-ecological resilience-ecological stress” to construct an evaluation system suitable for the ecological environment vulnerability of Panzhihua City, and explore the ecological vulnerability of each period. The law of spatial and temporal differentiation is different. The results show that: (1) The overall vulnerability of Panzhihua City from 2005 to 2015 is gradually increasing in the northwest to the southeast, and the overall ecological quality is moderate; (2) The overall ecological vulnerability index of Panzhihua City is decreasing from 2005 to 2015. It shows that the fragile situation of the ecological environment in the study area is developing in a direction of gradual recovery.

Introduction

Analyzing the fragility characteristics and causes of ecological environment is an important index to measure the economic development of a region. The academic term "ecological vulnerability" was first proposed by Albinet and Margat in their research in the 1960s. Eco-environmental vulnerability is an irreversible variability in the structure and function of an ecosystem in response to natural and external factors in its own internal and external environment. At present, the more comprehensive ecological environment vulnerability assessment index system established at home and abroad mainly includes PSR model, VSD model and SRP model and so forth; the evaluation methods include principal component, Bayesian network, and support vector machine, projection tracking and other methods. By establishing a comprehensive evaluation system of ecological environment vulnerability, this study quantitatively analyzed the spatial and temporal patterns of ecological environment vulnerability in Panzhihua City from 2005 to 2015 by using spatial principal component analysis, so as to provide scientific support in response to the sustainable development path of national ecological civilization construction.

Study Area and Data Acquisition and Preprocessing

The location of the study area is shown in Figure 1. The data used in this study mainly used Landsat TM/ETM/OLI series image data and related text data. For the remote sensing images of each year,
atmospheric correction, geometric correction, enhancement and other pre-processing, according to the classification standard (GBT 21010-2007) based on the support vector machine model combined with the visual interpretation classification method to obtain the three land use data from 2005 to 2015, with an interpretation accuracy of more than 85%.

**Indicator System and Research Method**

**Evaluation Model Construction**

In this study, the SRP conceptual model was constructed from the "Ecological Sensitivity-Ecological Recovery-Ecological Pressure Model" to measure the ecological vulnerability of the study area. On the basis of reference to a large number of scholars' research [6-7], the evaluation indicators selected by each factor layer of this study are divided into positive and negative.

**Standardization of Evaluation Indicators**

In order to realize the unified quantization spatial superposition operation for each evaluation index, the calculation formula of the index based on the standardization method of the range is as follows:

\[ Y_i = \frac{X_i - X_{i,\text{min}}}{X_{i,\text{max}} - X_{i,\text{min}}} \]  

(1)

\[ Y_i = \frac{X_{i,\text{max}} - X_i}{X_{i,\text{max}} - X_{i,\text{min}}} \]  

(2)

Where: \( Y_i \) indicates the normalized value of the \( i \)-th indicator, \( X_i \) indicates the \( i \)-th index initialization value, \( X_{i,\text{max}} \), \( X_{i,\text{min}} \) - indicates represents the initial maximum and minimum values of the index \( i \) within the study area of each study period. Among them, the positive index is calculated by formula (1), and the negative index is calculated by formula (2).

**Determination of Index Weight**

Through the analysis and calculation of SPCA- Spatial Principal Component Analysis, the eigenvalues, contribution rates and cumulative contribution rates of principal components in each period are obtained, and the first five indicators of factors with cumulative contribution rate greater than 85% are selected. As the principal component factor, the ecological environment vulnerability index of Panzhihua City from 2005 to 2015 was calculated according to formula (3) to formula (5). The various ecological vulnerability index (-Ecological Vulnerability Index) expressions are as follows:

\[ EVI_{2005} = 0.3993y_1 + 0.2278y_2 + 0.1053y_3 + 0.0802y_4 + 0.0731y_5 \]  

(3)

\[ EVI_{2010} = 0.3757y_1 + 0.2521y_2 + 0.1094y_3 + 0.0869y_4 + 0.0669y_5 \]  

(4)

\[ EVI_{2015} = 0.3671y_1 + 0.2472y_2 + 0.1139y_3 + 0.0949y_4 + 0.0680y_5 \]  

(5)

Formula: \( y_1 \sim y_5 \) respectively represents five composite principal components with contribution rate of more than 85% from 14 initial variables in each period.

**Eco-vulnerability Assessment Model**

The multi-factor weighted superposition model was used to calculate the ecological vulnerability index (-Ecological Vulnerability Index) of each period, and the normalization method was used to quantitatively analyze the current situation of ecological environment vulnerability in Panzhihua City. The calculation formula of the ecological environment vulnerability index is as follows:
\[ \text{EVI} = r_1y_1 + r_2y_2 + r_3y_3 + \cdots + r_ny_n \]  

(6)

\[ r_{i,n} = \frac{\lambda_{i,n}}{\sum_{k=1}^{n} \lambda_{i,k}} \]  

(7)

\[ \text{EEVI}_i = \frac{(\text{EVI}_i - \text{EVI}_{i, \text{min}})}{(\text{EVI}_{i, \text{max}} - \text{EVI}_{i, \text{min}})} \]  

(8)

Where: \( \text{EVI}_i \) indicates the value of the vulnerability index for the \( i \)-th year; \( y_{i,n} \) - Indicates the \( n \)-th principal component indicator in the \( i \)-th year; \( r_{i,n} \) - indicates the contribution rate of the \( n \)-th principal component of the \( i \)-th year; \( \lambda_{i,n} \) - indicates the eigenvalue of the \( n \)-th principal component of the \( i \)-th year; \( \text{EEVI}_i \) - indicates the standardized value of the ecological environment vulnerability in the \( i \)-th year, ranging from 0-1; \( \text{EVI}_{i, \text{max}}, \text{EVI}_{i, \text{min}} \) - indicates the maximum and minimum values of the eco-environment vulnerability index for the \( i \)-th year, respectively.

In view of the existing ecological vulnerability evaluation grading standards \(^{[8-9]}\), and considering the natural environment and vulnerability characteristics of Panzhihua City, the evaluation results are more intuitive through classification.

**Result and Analysis**

**Fragile Ecological Environment as a Whole Spatial Pattern Distribution**

The eco-environment vulnerability index of Panzhihua City from 2005 to 2015 is between 0.30-1.31, and the multi-year average is 0.45 (see Figure 3). The overall ecological environment quality of the study area is in a state of mild vulnerability; according to the ecological environment vulnerability level in Panzhihua area the spatial distribution characteristic map (see Figure 2) shows that the research area is generally more vulnerable to the southeastern part than the northwestern region, with different distribution characteristics.

The analysis shows that the overall eco-environmental vulnerability level ratio in Panzhihua area from 2005 to 2015 is: mildly vulnerable > slightly fragile > moderately fragile > potential fragile > severely fragile, and the overall vulnerability is between slightly fragile and moderately fragile. The overall ecological environment vulnerability of Panzhihua City is decreasing from the southeast to the northwest, and the overall level is at a mildly fragile level.

![Figure 2. Classification and grading results of ecological environment vulnerability assessment in Panzhihua City.](image)

![Figure 3. Histogram of minimum, maximum and mean of eco-environmental vulnerability in Panzhihua City.](image)

**The Change Speed of Eco-environmental Vulnerability**

Combined with the CA-Markov model and the dynamic degree model, the comprehensive dynamics of the single dynamic degree and the overall vulnerability level of each level of vulnerability in Panzhihua City are calculated (see Table 1). From a single dynamic point of view, during the whole research period from 2005 to 2015, due to the construction of ecological
environment and the implementation of protection measures, the severely vulnerable area of Panzhihua City decreased at an average annual rate of 0.35%, the potential vulnerable area increased at an average annual rate of 0.21%, and the moderately vulnerable area decreased at an average annual rate of 0.15%. From the comprehensive dynamic analysis, the overall change range in 2010-2015 is greater than that in 2005-2010; the change rate of the overall ecological environment vulnerability level in Panzhihua City from 2005 to 2015 is 0.38%, and the annual average change is 0.04%. It is characterized by severe vulnerability reduction and potential fragile increase, while other vulnerability levels were developing towards the trend of good ecological environment quality to a small extent.

Table 1. Dynamic environmental vulnerability of Panzhihua City (%).

| Time classification | 2005-2010 | Annual average | 2010-2015 | Annual average | 2005-2015 | Annual average |
|---------------------|-----------|----------------|-----------|----------------|-----------|----------------|
| Potential           | 1.54      | 0.31           | 2.66      | 0.53           | 2.10      | 0.21           |
| Microscopic         | 0.36      | 0.07           | 0.75      | 0.15           | 0.55      | 0.06           |
| Mild                | -0.19     | -0.04          | -0.30     | -0.06          | -0.25     | -0.02          |
| Moderate            | -0.82     | -0.16          | -2.08     | -0.42          | -1.45     | -0.15          |
| Severe              | -2.59     | -0.52          | -4.42     | -0.88          | -3.51     | -0.35          |
| Comprehensive rate of change | 0.25 | 0.05 | 0.51 | 0.10 | 0.38 | 0.04 |

Summary and Conclusions
(1) Based on the special natural geographical features of Panzhihua City. Besides, based on remote sensing images, meteorological data and humanistic data, this paper adopts the framework of “ecological sensitivity-ecological resilience-ecological stress” evaluation system, and selects the index factors reasonably. To establish a comprehensive evaluation index system, and based on spatial principal component analysis, CA-Markov model and dynamic degree model to explore the spatial and temporal pattern differentiation of ecological vulnerability in Panzhihua City from 2005 to 2015. It provides a new idea for the study of ecological vulnerability in Panzhihua City.

(2) The comprehensive index of ecological environment vulnerability of Panzhihua City gradually decreased from 2005 to 2015, and the level of each vulnerable type was transformed into a main trend in two directions. It verified that Panzhihua City removed the natural restorative power of the ecosystem itself. The implementation of the “Tianbao Project” policy and the construction of the garden city are important for the ecological restoration of the study area.

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