

Landscape Ecological Risk and Its Spatiotemporal Differentiation in Yulin City (Postprint)

Authors: Shi Yuqiong, Wang Ninglian, Li Tuansheng, Wang Han, Wang Ninglian

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Abstract

Using ETM remote sensing images from 2000, 2005, 2010, and 2015 as data sources, a comprehensive landscape ecological risk index was constructed based on landscape pattern, ecological sensitivity, and vegetation productivity, and the spatiotemporal differentiation of landscape ecological risk in Yulin City was investigated using ArcGIS 10.2 and GS+9.0 software as the platform. The results indicate that: the overall landscape ecological risk level in Yulin City is relatively high; moderate risk was predominant in 2000, 2005, and 2010, while high risk became predominant in 2015; from 2000 to 2010, the area of moderate-risk zones expanded while that of high-risk zones contracted; from 2010 to 2015, the area of moderate-risk zones rapidly contracted while that of high-risk zones rapidly expanded. The spatial variation of landscape ecological risk in Yulin City is relatively small, with a moderate degree of spatial autocorrelation. In 2000, the influence of natural factors on the spatial variation of landscape ecological risk was slightly greater than that of anthropogenic factors; in 2005 and 2010, the influences of the two were essentially equivalent; in 2015, it was more strongly influenced by natural factors.

Full Text

Landscape Ecological Risk and Its Spatiotemporal Variation in Yulin

SHI Yu-qiong^{1,2,3}, WANG Ning-lian^{2,3}, LI Tuan-sheng¹, WANG Han

¹College of Forestry, Shanxi Agricultural University, Taigu 030800, Shanxi, China

²College of Urban and Environmental Sciences, Xi'an 710124, Shaanxi, China

³Shaanxi Province Key Laboratory of Surface System and Environmental Carrying Capacity, Xi'an 710124, Shaanxi, China

College of Earth and Resources Sciences, Chang'an University, Xi'an 710054, Shaanxi, China

Abstract: ETM remote sensing images from 2000, 2005, 2010, and 2015 were used as data sources to construct the comprehensive landscape ecological risk index for Yulin based on landscape pattern, ecological sensitivity, and vegetation productivity. ArcGIS 10.2 and GS+ 9.0 software platforms were employed to analyze the spatiotemporal differentiation of landscape ecological risk in the study area. The results showed that the landscape ecological risk in Yulin was holistically high. The risk level of the main regional landscape ecological ecosystem was moderate in 2000, 2005, and 2010, but became high in 2015. From 2000 to 2010, the area with moderate risk expanded while the area with high risk decreased. From 2010 to 2015, the area with moderate risk decreased rapidly, while the area with high risk expanded rapidly. The spatial variation of landscape ecological risk in Yulin was low, and the spatial correlation of landscape ecological risk was moderate. The effect of natural factors (such as landform and climate) on the spatial variation of landscape ecological risk was slightly higher than that of human factors in 2000, and they were almost equal in 2005 and 2010. However, in 2015, the effect of natural factors on the spatial variation of landscape ecological risk was high.

Keywords: landscape ecological; risk index; spatiotemporal variation; structural feature; Yulin; Shaanxi Province

1. Introduction

1.1 Study Area

Yulin City is located in northern Shaanxi Province, China (36°57' -39°35' N, 107°15' -111°15' E). The region has a temperate continental monsoon climate with an annual average temperature of approximately 10°C and annual precipitation ranging from 400 mm, concentrated mainly in the June–September period. The topography consists of the Mu Us Sandy Land in the north and the Loess Plateau in the south. Land use types include cultivated land, forest land, grassland, water bodies, built-up land, unused land, and desert.

1.2 Methods

1.2.1 Data Sources The primary data sources included ETM remote sensing images from 2000, 2005, 2010, and 2015, with a spatial resolution of 30 m. MODIS NDVI data with 250 m resolution were obtained for the same years. Meteorological data were collected from local weather stations, and socioeconomic statistics were derived from the Yulin Statistical Yearbook.

1.2.2 Landscape Ecological Risk Index The landscape ecological risk index was calculated based on landscape pattern metrics, ecological sensitivity,

and vegetation productivity. The comprehensive index was constructed as follows:

$$\text{LER} = 1 - \alpha\text{CONNECT} + \beta\text{FRAG} - \phi\text{SHDI} - \chi\text{NDVI}$$

where the coefficients were determined through principal component analysis. All indices were normalized using:

$$X^* = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$$

where X^* represents the normalized value, X is the original value, and X_{\max} and X_{\min} are the maximum and minimum values, respectively.

The landscape ecological risk levels were classified into four categories using ArcGIS 9.3: low risk ($\text{ILER} < 0.4$), moderate risk ($0.4 \leq \text{ILER} < 0.6$), high risk ($0.6 \leq \text{ILER} < 0.8$), and very high risk ($\text{ILER} \geq 0.8$). The spatial distribution and area proportions of each risk level were then analyzed.

Landscape pattern metrics were calculated using FRAGSTATS software. The fragmentation index (FRAG) was computed as:

$$\text{FRAG} = \frac{\text{NP} \times \text{TE}}{\text{TA} \times 10000}$$

where NP is the number of patches, TE is the total edge length, and TA is the total landscape area.

The connectivity index (CONNECT) and Shannon's diversity index (SHDI) were calculated at the class level. Ecological sensitivity (SENSI) was evaluated based on three factors: soil erosion sensitivity, desertification sensitivity, and biodiversity sensitivity, following established methodologies.

Spatial autocorrelation analysis was performed using Moran's I index to quantify the spatial clustering characteristics of landscape ecological risk. The index was calculated as:

$$\text{Moran's I} = \frac{n \sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i \sum_j w_{ij} \sum_i (x_i - \bar{x})^2}$$

where n is the number of spatial units, x_i and x_j are the risk values at locations i and j , \bar{x} is the mean value, and w_{ij} is the spatial weight matrix.

2. Results

2.1 Temporal Variation Characteristics

2.1.1 Statistical Characteristics of Landscape Ecological Risk presents the statistical characteristics of landscape ecological risk in Yulin from 2000 to 2015. The mean risk values were 0.500, 0.500, 0.464, and 0.691 for 2000, 2005, 2010, and 2015, respectively. The standard deviation remained relatively stable around 0.118–0.142, indicating consistent spatial variability across years. The coefficient of variation ranged from 0.103 to 0.142, suggesting moderate relative dispersion.

The skewness values showed a transition from negative to positive between 2010 and 2015, indicating a shift in the distribution pattern. The kurtosis values were highest in 2010 (5.376), reflecting a more peaked distribution compared to other years.

2.1.2 Area Proportions of Risk Levels The area proportions of different risk levels varied significantly over time. In 2000, 2005, and 2010, moderate risk areas dominated, accounting for 58.760%, 50.248%, and 50.426% of the total area, respectively. However, in 2015, high-risk areas became predominant, covering 65.474% of the region.

Low-risk areas were primarily distributed in the southern mountainous regions with higher vegetation cover, while high-risk areas were concentrated in the northern sandy lands and mining regions. The transition from moderate to high risk between 2010 and 2015 was particularly pronounced, with a 15% increase in high-risk area proportion.

2.2 Spatial Variation Characteristics

The spatial variation of landscape ecological risk in Yulin showed distinct patterns across different periods. From 2000 to 2005, very high-risk areas transitioned to high-risk areas over 80.414% of their extent, while moderate-risk areas showed 100% transition to low-risk areas in some sub-regions.

During 2005–2010, moderate-risk areas exhibited complex transition patterns: 100% transitioned to low-risk areas in some locations, while 38.078% transitioned to high-risk areas in others. This period was characterized by significant landscape transformation due to ecological restoration projects and urban expansion.

From 2010 to 2015, high-risk areas expanded substantially, with 91.512% transitioning from moderate-risk areas. The spatial correlation of risk levels, measured by Moran's I, was moderate (0.2216–0.2716) across all periods, indicating clustered but not highly aggregated patterns.

The influence of natural factors versus human factors on spatial variation evolved over time. In 2000, natural factors (topography, climate) had a slightly stronger

influence than human activities. By 2005 and 2010, their influences were nearly equal. However, in 2015, natural factors became dominant again, likely due to extreme climate events and the inherent vulnerability of the semi-arid ecosystem.

[Figure 1: see original paper] shows the spatial distribution of landscape ecological risk in Yulin for the four study years, illustrating the north-south gradient and the expansion of high-risk areas over time. The southern loess plateau region consistently maintained lower risk levels due to better vegetation cover and soil conditions, while the northern sandy lands showed persistent high risk.

The analysis of industrial output data and land use change reveals that rapid economic development, particularly in coal mining and energy industries, contributed significantly to landscape fragmentation and ecological risk increase, especially during 2010–2015. The conversion of grassland and forest to built-up land and mining areas was the primary driver of risk elevation.

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

Source: ChinaXiv – Machine translation. Verify with original.