Comprehensive Assessment of Land Ecological Risk in Yulin City, 1990-2012: Postprint

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Abstract

Land use/cover change plays a decisive role in regional ecological security and the maintenance of ecosystem service functions, and land ecological risk assessment is an important indicator for measuring the sustainable utilization of land resources. This study takes ecologically fragile Yulin City, Shaanxi Province as the research object. Based on the basic characteristics of Yulin' s land system, four risk indicators were selected: the precipitation anomaly percentage index representing drought risk, land use structure risk representing human activity types and intensity, and soil water erosion and soil wind erosion representing soil erosion. A comprehensive land ecological risk assessment model was constructed to conduct qualitative and quantitative evaluation and analysis of factors affecting land ecological risk in Yulin City from 1990 to 2010. The research results show that: (1) From 1990 to 2012, the mean precipitation anomaly percentage index in Yulin City showed a trend of first decreasing and then increasing, with its low-value areas mainly distributed in the eastern regions; (2) Over the 21-year period, the ecological risk of land use structure overall showed a trend of first increasing and then decreasing, with significant regional differences and obvious changes; (3) Areas with more severe soil water erosion were mainly distributed in the eastern and southern regions, and the mean value showed a trend of first increasing and then decreasing over the 21-year period; (4) Areas with more serious soil wind erosion were mainly distributed in the northern regions, and its mean value showed a continuous decreasing trend over time; (5) The overall land ecological risk showed a decreasing trend over the 21-year period, with significant differences in ecological risk among various districts and counties. Through the comprehensive assessment of land ecological risk in Yulin City, theoretical suggestions can be provided for optimizing land resource allocation and protecting the ecological environment, thereby achieving harmonious development of the regional economy and ecology.

Comprehensive Evaluation of Land Ecological Risk in Yulin City from 1990 to 2012

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Abstract: Land use/cover change plays a decisive role in regional ecological security and the maintenance of ecosystem services, and ecological risk assessment of land serves as a vital indicator for measuring the sustainable utilization of land resources. This study examines Yulin City in Shaanxi Province, an ecologically fragile region, and develops a comprehensive evaluation model for land ecological risk based on the area' s fundamental land system characteristics. Four risk indicators were selected: the precipitation anomaly percentage index to characterize drought risk, land use structure risk to reflect human activity types and intensity, and soil hydraulic erosion and soil wind erosion to represent soil erosion. The model enables qualitative and quantitative evaluation and analysis of factors influencing land ecological risk in Yulin City from 1990 to 2010. The results show that: (1) The mean precipitation anomaly percentage index in Yulin City exhibited a decreasing then increasing trend from 1990 to 2012, with low-value areas primarily distributed in the eastern regions; (2) Land use structure ecological risk generally increased then decreased over the 21-year period, showing substantial regional variation and significant changes; (3) Areas with severe soil hydraulic erosion were mainly distributed in the eastern and southern regions, with mean values increasing then decreasing over the 21-year period; (4) Areas with serious soil wind erosion were primarily located in the northern region, with mean values consistently decreasing over time; and (5) Overall land ecological risk decreased during the 21-year period, though significant differences existed among districts and counties. This comprehensive assessment of land ecological risk in Yulin City provides theoretical recommendations for optimizing land resource allocation and protecting the ecological environment to achieve harmonious regional economic and ecological development.

Keywords: Land; Ecological risk; Fragile ecology; Energy development; Yulin City

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Introduction

In recent years, rapid population growth and socioeconomic development have led to the rapid depletion of natural resources and declining environmental quality, generating a series of ecological and environmental problems that seriously threaten human survival and development. Consequently, how to maintain human security has become a focal concern, and ecological risk assessment has attracted increasing attention both domestically and internationally [1-6]. Some scholars have constructed ecological risk index models based on land use data to conduct comprehensive regional ecological risk assessments [7-10], while others have applied landscape ecology principles to evaluate regional ecological risk [11-13]. Zhang Xiaoyuan et al. [14] built an evaluation index system for risk sources, risk receptors, and risk responses based on the PSR model, using comprehensive fuzzy evaluation to assess land use ecological risk in the Three Gorges Reservoir barrier zone in Chongqing. Zhang Sifeng et al. [15] employed the ecological gradient risk assessment method to evaluate ecological risk in Yulin’ s coal mining areas through qualitative, semi-quantitative, and quantitative approaches.

Early ecological risk research primarily focused on chemical pollutants in specific small areas [16-18]. As economic development intensified and human-land conflicts became prominent, land ecological risk assessment gradually emerged. Domestic scholars have established mathematical evaluation models and landscape-scale ecological risk frameworks integrating land use types and landscape factors. However, current land ecological risk evaluation indicators remain relatively singular, mostly limited to land use changes, with less consideration of regional natural geographical conditions and various natural and social risks related to human activities. While single-factor ecological risk evaluation is relatively mature, there is still a lack of environmental effect characterization based on the interactions among land ecosystem structure, components, and functions. The quantification and spatial representation of comprehensive regional land ecological risk evaluation remain in the exploratory stage.

This study focuses on Yulin City in Shaanxi Province, a typical ecologically fragile area and energy development zone in China. Based on its natural geographical conditions and urban development status, we comprehensively consider Yulin’ s ecological and environmental characteristics, eliminate uncertainty from single-factor evaluation, and establish evaluation indicators for multiple risk sources. We select the precipitation anomaly percentage index to characterize drought conditions, use land use structure risk as an indicator for land ecological security system safety, and choose wind erosion for the northern sandy grassland area and water erosion for the southern Loess Plateau area as ecological risk indicators representing soil erosion. Building upon this, we construct a comprehensive ecological risk evaluation model to quantitatively assess land ecological risk in Yulin City from 1990 to 2012, revealing spatial differences and temporal change processes in land ecological risk across districts and counties.

1. Study Area Overview

Yulin City is located at the northernmost tip of Shaanxi Province, on the western bank of the middle Yellow River, between 107°14 51 E–111°14 31 E and 36°48 58 N–39°35 07 N, with a total land area of 42,920.18 km^2. The terrain is higher in the northwest and lower in the southeast. Geomorphologically, the ancient Great Wall serves as a boundary, with sandy grassland areas to the north and loess hill-gully regions to the south. The region experiences hot, rainy summers and cold, dry winters, with an annual average temperature of 7-13°C, large diurnal temperature variation, and average annual precipitation of approximately 400 mm with significant seasonal differences. Yulin City is a major energy base in China, extremely rich in mineral resources, and known as "China' s Kuwait." In 2013, the city' s total population was 3.7699 million, with a gross domestic product (GDP) of 284.675 billion yuan and total industrial output value of 194.356 billion yuan, accounting for 68.2% of GDP.

2.1 Data Sources

The primary data used in this study include: (1) Land use data for 1990, 2001, and 2012, obtained from the Chinese Academy of Sciences' Resource and Environmental Data Center, Earth System Science Data Sharing Platform, Western China Environment and Ecology Science Data Center, and field land survey data; (2) Meteorological data primarily from the China Meteorological Data Sharing Service Network; (3) DEM data from the Chinese Academy of Sciences' Data Application Environment Center; and (4) Other data including roads, water systems, and administrative boundaries from the National Fundamental Geographic Database.

2.2.1 Evaluation Indicator Selection

Land ecological risk assessment is an important indicator for measuring sustainable land resource utilization. The main factors generating land ecological risk include natural and human factors. In Yulin City, natural disasters mainly comprise drought, frost, heavy rain, strong winds, hail, etc., with drought being the most damaging. Therefore, for natural factors, we selected the precipitation anomaly percentage index to characterize drought risk. Human factors primarily include indirect ecosystem impacts from population urbanization, energy development, land reclamation, deforestation, etc. As land serves as the carrier of human activity, its type and structural changes best reflect human activity types and intensity. Thus, we selected land structure change to characterize ecological risk from human social activities. Additionally, due to Yulin' s fragile natural environment and human activity interference, soil erosion is severe. Since the northern area is sandy grassland (mainly wind erosion) and the southern area is Loess Plateau (mainly water erosion), we selected wind erosion and water erosion as ecological risk indicators representing soil erosion.

2.2.2 Evaluation Indicator Calculation Methods

1) Precipitation Anomaly Percentage Index

The precipitation anomaly percentage index (Pa) reflects the deviation of precipitation in a certain period from the average precipitation in the same period. Its calculation model [19] is:

$$Pa = \frac{P - \bar{P}}{\bar{P}} \times 100\%$$

where P is precipitation in a certain period and $\bar{P}$ is multi-year average precipitation. In this study, $\bar{P}$ uses the 30-year average from 1980-2010. The precipitation anomaly percentage index characterizes drought conditions; larger values indicate precipitation is higher above the average, while negative anomalies indicate precipitation below the average.

Based on ArcGIS, we used spatial interpolation [20] to obtain continuous precipitation spatial data. To ensure interpolation accuracy, we selected 58 stations in surrounding Ningxia, Shanxi, Shaanxi, Gansu, and Inner Mongolia as interpolation points to generate precipitation data for 1990, 2001, and 2012, as well as multi-year average precipitation data for 1980-2012. The three annual precipitation layers were then raster-calculated with the 1980-2012 multi-year average precipitation layer.

2) Land Use Structure Ecological Risk Intensity Index

Land use structure and its changes can indirectly reflect land ecological risk status. Drawing on existing research results, the land use structure ecological risk model [9] used in this study is:

$$ERI = \sum_{i=1}^{n} \frac{B_i}{B} \times W_i$$

where ERI is the land use structure ecological risk intensity index; B_i is the area of land use type i; B is the total area; and W_i is the ecological risk weight of land use type i.

Drawing on research by Zang Shuying and Ma Caihong et al. [7,10], we used the analytic hierarchy process to assign weights to different land types, with results shown in Table 1. Based on Yulin City’ s land use data, we calculated the land use structure ecological risk index for each district and county according to the land use structure risk model.

Table 1 Weights of different land use types in the evaluation of ecological risk of land use structure

Land use type	Ecological risk weight
Cropland	
Forest land	
Grass land	
Water body	
Construction land	
Unused land	

3) Soil Hydraulic Erosion Amount

Among soil hydraulic erosion estimation models, the two most widely used are the Universal Soil Loss Equation (USLE) and the RUSLE model. The latter is a revised version of the former, with further decomposition of some factors in USLE, making estimation more scientific and accurate. Therefore, this study used the RUSLE model to estimate soil hydraulic erosion amount. Its basic formula is [21]:

$$A_m = R \times K \times LS \times C \times P$$

where A_m is the actual soil erosion amount in the study area ($\mathrm{t \cdot hm^{\ 2} \cdot a^{\ 1}}$); R is the rainfall-runoff factor, expressed as the multi-year average annual rainfall erosivity index ($\mathrm{MJ \cdot mm \cdot hm^{\ 2} \cdot h^{\ 1} \cdot a^{\ 1}}$); K is the soil erodibility factor ($\mathrm{t \cdot h \cdot MJ^{\ 1} \cdot mm^{\ 1}}$); C is the cover-management factor; LS is the slope length-gradient factor; and P is the soil conservation practice factor. Both C and P are dimensionless factors.

4) Soil Wind Erosion Amount

For soil wind erosion under different spatial and temporal scales, various models have emerged, including the WEQ model, WEPS model, and daily wind-sand erosion amount model. However, most models struggle to estimate long-term cumulative erosion amounts. Based on China’ s actual conditions, Dong Zhibao et al. [22-23] established an annual-scale regional soil wind erosion estimation model, expressed as:

$$Q = \int_0^t \int_0^x \int_0^y \frac{V^3 \cdot H \cdot VCR \cdot SDR}{d \cdot F \cdot \tan(\theta)} \, dx \, dy \, dt$$

where Q is soil wind erosion amount (t); V is wind speed ($\mathrm{m \cdot s^{\ 1}}$); H is air relative humidity (%); VCR is vegetation coverage (%); SDR is human-induced surface structure damage rate (%); d is average particle diameter (mm); F is soil hardness ($\mathrm{N \cdot cm^{\ 2}}$); θ is slope angle (°); x, y represent distance from reference points (km); and t is time (s).

5) Comprehensive Land Ecological Risk Index

Based on extensive literature review and Yulin City’ s actual conditions [24-26], we constructed an ecological risk comprehensive index to evaluate Yulin’ s ecological risk. The model is:

$$E = \sum_{i=1}^{n} W_i \times P_i$$

where E is the comprehensive land ecological risk index; W_i is the weight of individual risk; and P_i is the individual ecological risk evaluation value. The weight values W_i for each evaluation indicator were determined using a combination of qualitative and quantitative analytic hierarchy process methods with Yaahp software (Table 2). Based on the land ecological risk comprehensive index model, we calculated the regional land ecological risk comprehensive index. Drawing on existing research, we classified land ecological risk into five levels, with classification standards shown in Table 3 .

Table 2 Weights of different kinds of ecological risks in the comprehensive evaluation of land ecological risk

Ecological risk	Weight
Drought risk	
Land use structure risk	
Water erosion risk	
Wind erosion risk	

Table 3 Classification standards of land ecological risk

Class	Ecological risk index	Risk state
I	0.25	Tiny
II	0.25~0.35	Less
III	0.35~0.45	Small
IV	0.45~0.55	Larger
V	>0.55	Great

3.1 Drought Risk Assessment

Through calculation, we obtained precipitation anomaly percentage index distribution maps for 1990, 2001, and 2012 (Figure 1 [Figure 1: see original paper]). For further quantitative analysis, we conducted zonal statistics using counties as administrative units to obtain the precipitation anomaly percentage index for each district and county (Table 4). Table 4 and Figure 1 reveal that in 1990, low-value areas of the precipitation anomaly percentage index were mainly distributed in the northeastern part of Yulin City, while high-value areas were primarily in the south. The low-value center reached -0.15%, and the high-value center was 29.52%, showing a general increasing trend from north to south. Among all districts and counties, Fugu County and Shenmu County had lower anomaly values, while Qingjian County had the highest. Most areas showed positive values, indicating precipitation above the mean, though large differences between high and low values demonstrated uneven precipitation distribution across Yulin’ s districts and counties, characterized by more precipitation in the south and less in the north.

In 2001, low-value areas of the precipitation anomaly percentage index were mainly distributed in the east, while high-value areas were in the central and western regions, showing an approximate increasing trend from east to west. Fugu County had the lowest anomaly index, while Yuyang District had the highest. The low-value center reached -16.96%, significantly lower than in 1990, indicating reduced precipitation and intensified drought. However, the high-value center reached 48.31%, with an increased gap between high and low values, suggesting exacerbated uneven precipitation distribution and possible simultaneous drought and flood conditions. In 2012, low-value areas were mainly in the southeast, while high-value areas were in the northeast, showing an approximate increasing trend from south to north. Qingjian County had relatively low anomaly values, while Fugu County had higher values. Compared with 1990 and 2001, the overall precipitation anomaly index values increased, indicating significantly higher precipitation in 2012, though differences between high and low values remained obvious and precipitation distribution continued to be uneven.

Table 4 Precipitation anomaly percentage index of each county (district) of Yulin City in 1990, 2001 and 2012 (%)

County (district)	1990	2001	2012
Mizhi County			
Suide County			
Jingbian County			
Yuyang District			
Jiaxian County			
Fugu County			
Shenmu County			
Dingbian County			
Zizhou County			
Qingjian County			
Wubao County			
Hengshan County			
Mean	-8.24		

3.2 Land Use Structure Risk Assessment

Table 5 shows that in 1990, Fugu County had the highest land use structure risk index, while Suide County had the lowest. Counties with relatively high land use ecological risk were mainly distributed in the north, including Fugu County, Shenmu County, and Yuyang District, whereas Jiaxian County, Mizhi County, Wubao County, Suide County, and Zizhou County in the southeast had relatively low land use structure ecological risk. This distribution primarily resulted from larger proportions of cropland and unused land combined with smaller proportions of ecological land (forest, grassland, water areas) in northern counties.

In 2001, the overall distribution of land use structure ecological risk changed significantly, with Mizhi County showing the highest risk index and Shenmu County the lowest. Ecological risk increased markedly compared with 1990, mainly due to rapid urban expansion and increased construction land proportion. Zizhou County, Mizhi County, Suide County, Jiaxian County, and Wubao County showed significantly intensified ecological risk, primarily related to land type conversion and notably increased cropland area proportion.

In 2012, counties with relatively high land use structure ecological risk were mainly distributed in the south, with Wubao County showing the highest index and Yuyang District the lowest. Examining changes in land use structure risk index: from 1990-2001, Fugu County, Jingbian County, Shenmu County, and Yuyang District showed decreased risk indices, while all other counties showed increased risk indices. From 2001-2012, Fugu County, Mizhi County, Suide County, Qingjian County, and Wubao County showed increased risk indices, while all other counties showed decreased risk indices. Overall, from 1990-2012, Yuyang District, Shenmu County, and Jingbian County consistently showed decreasing land use structure risk indices, while Mizhi County, Qingjian County, Suide County, and Wubao County consistently showed increasing trends.

Table 5 Risk indexes and changes of land use structure in different counties (district) in Yulin City in 1990, 2001 and 2012

County (district)	1990	2001	2012	1990-2001 change	2001-2012 change
Dingbian County				-0.0416	
Fugu County				-0.0048	
Hengshan County				-0.0319	
Jiaxian County				-0.0177	
Jingbian County				-0.0079	
Mizhi County				-0.0302	
Qingjian County				-0.0038	
Shenmu County				-0.0167	

County (district)	1990	2001	2012	1990–2001 change	2001–2012 change
Suide County				-0.0220	
Wubao County				-0.0374	
Yuyang District				-0.0125	
Zizhou County				-0.0374	

3.3 Soil Hydraulic Erosion Assessment

Based on the soil hydraulic erosion model, we overlaid various factor layers through raster calculation to obtain soil hydraulic erosion intensity maps for Yulin City in 1990, 2001, and 2012 (Figure 2 [Figure 2: see original paper]). Figure 2 shows that severely eroded areas were mainly distributed in the northeastern and central-southern parts of Yulin City. The northeast lies in a water-wind erosion interlaced zone, while the central-southern area has complex topography with steep slopes, resulting in severe soil erosion.

Temporally, in 1990, soil hydraulic erosion in southeastern Yulin was relatively severe, with maximum erosion reaching 1,692.49 t · hm^{2} · a^{1} and average erosion of approximately 147.06 t · hm^{2} · a^{1}. Qingjian County had the highest erosion amount, while Dingbian County had the lowest. In 2001, soil hydraulic erosion in eastern and southern Yulin was severe, with maximum erosion reaching 3,711.99 t · hm^{2} · a^{1} and average erosion of approximately 296.65 t · hm^{2} · a^{1}. Fugu County had the highest erosion intensity, while Yuyang District had the lowest. In 2012, soil hydraulic erosion in southern Yulin was relatively severe, with maximum erosion reaching 3,076.8 t · hm^{2} · a^{1} and average erosion of approximately 181.10 t · hm^{2} · a^{1}. Qingjian County had the highest erosion intensity, while Yuyang District had the lowest.

Comparing soil hydraulic erosion intensity across 1990, 2001, and 2012, the intensity ranking was 2001 > 2012 > 1990. From 1990-2001, soil erosion intensity increased significantly, most notably in Fugu County, Jingbian County, and Dingbian County. By 2012, soil hydraulic erosion intensity in all counties had somewhat decreased, with the most significant changes in Fugu County, Shenmu County, and Dingbian County. Overall, from 1990–2012, soil hydraulic erosion intensity in Shenmu County, Fugu County, Wubao County, and Jiaxian County moderated, while all other counties showed varying degrees of intensification, most significantly in Qingjian County, Jingbian County, and Zizhou County.

3.4 Soil Wind Erosion Assessment

Based on the soil wind erosion model, we overlaid various factor layers through raster calculation to obtain soil wind erosion intensity maps for Yulin City in

1990, 2001, and 2012 (Figure 3 [Figure 3: see original paper]). As shown in Figure 3, in 1990, wind erosion in western and northern Yulin was relatively severe, with maximum erosion reaching 128.83 $\text{t} \cdot \text{km}^{2}$ and average erosion of approximately 22.91 $\text{t} \cdot \text{km}^{2}$. Yuyang District and Dingbian County had the highest erosion amounts, while Suide County and Qingjian County had the lowest. In 2001, wind erosion in northern Yulin remained severe, with maximum erosion reaching 130.398 $\text{t} \cdot \text{km}^{2}$ and average erosion of approximately 2.82 $\text{t} \cdot \text{km}^{2}$. Yuyang District and Shenmu County had the highest erosion amounts, while Suide County and Mizhi County had the lowest. In 2012, wind erosion in northern Yulin was relatively severe, with maximum erosion reaching 52.12 $\text{t} \cdot \text{km}^{2}$ and average erosion of approximately 0.70 $\text{t} \cdot \text{km}^{2}$. Yuyang District had the highest erosion amount, followed by Shenmu County, while Mizhi County and Suide County had the lowest.

Comparing soil wind erosion intensity across 1990, 2001, and 2012, the intensity ranking was 1990 > 2001 > 2012. The erosion intensity distribution map shows that severely eroded areas were mainly distributed in northern Yulin, primarily due to low vegetation coverage in the sandy grassland area. In terms of erosion amount changes, the overall trend from 1990-2012 was decreasing, with the largest reduction in Yuyang District, followed by Dingbian County and Hengshan County. The change rate from 1990-2001 was approximately 1.2 times that of 2001-2012.

3.5 Comprehensive Land Ecological Risk Assessment

Table 6 shows that in 1990, Fugu County had the highest comprehensive land ecological risk index, while Suide County had the lowest, with the maximum value approximately 2.8 times the minimum. In 2001, Jiaxian County had the highest index and Shenmu County the lowest, with the maximum about 2 times the minimum, showing a reduced difference. In 2012, Qingjian County had the highest index and Shenmu County the lowest, with the maximum about 1.9 times the minimum, indicating a further reduced difference compared with 1990 and 2001.

Examining changes across districts and counties: from 1990-2001, Jingbian County, Yuyang District, Fugu County, Shenmu County, and Qingjian County showed decreased comprehensive land ecological risk indices, indicating improved ecological risk, with Fugu County showing the largest decrease at approximately 4.48% annual decline rate. All other counties showed increased indices, indicating intensified ecological risk, with Mizhi County showing the largest increase at approximately 11.99% annual growth rate. From 2001-2012, Fugu County, Qingjian County, and Wubao County showed increased indices, with Qingjian County showing the largest increase at approximately 3.73% annual growth rate. All other counties showed decreased indices, with Hengshan County showing the largest decrease at approximately 3.74% annual decline rate.

Overall, from 1990-2012, Mizhi County, Suide County, Jiaxian County, Zizhou County, and Wubao County showed increased comprehensive land ecological risk indices, with Suide County showing the largest increase at approximately 4.78% annual growth rate. All other counties showed decreased indices, with Shenmu County showing the largest decrease at approximately 2.50% annual decline rate.

Figure 4 [Figure 4: see original paper] reveals significant changes in Yulin City' s land ecological risk levels from 1990-2012. In 1990, five counties (approximately 42%) fell into the top three risk classes, mainly located in the southeastern region with relatively low land ecological risk and relatively safe ecological environments. Areas with greater ecological risk in the western Mu Us Sandy Land suffered severe soil erosion, low vegetation coverage, and serious ecological environmental damage. In 2001, no counties belonged to Class I ecological risk, while seven counties (approximately 58%) fell into Classes IV and V, mainly located in southeastern Yulin and Dingbian County in the northwest, with the ecological environment remaining in an unsafe state. In 2012, no counties belonged to Class I or V ecological risk. Eight counties (approximately 67%) fell into the top three risk classes, representing an increase compared with 1990 and 2001 and indicating reduced ecological risk. However, four counties still showed relatively high ecological risk, leaving the ecological security situation severe.

Discussion and Conclusions

This study selected four risk indicators—drought, land use structure, soil hydraulic erosion, and wind erosion—to construct a regional comprehensive ecological risk evaluation model for an exploratory assessment of land ecological risk in Yulin City from 1990-2012. The main findings are as follows:

First, significant spatiotemporal differences exist among various ecological risk elements in Yulin City. From 1990-2012, the mean precipitation anomaly percentage index first decreased then increased, generally showing an increasing trend from south to north, with low-value areas mainly in the eastern region and obvious differences between high and low values, indicating uneven precipitation distribution. Land use structure ecological risk showed large regional differences and significant changes, following an increasing then decreasing trend. The land use structure risk indices of Mizhi County, Qingjian County, Suide County, and Wubao County consistently increased, requiring attention, while Yuyang District consistently decreased, showing improvement. Areas with severe soil hydraulic erosion were mainly distributed in the eastern and southern regions, primarily related to topographic factors in these areas, with mean values increasing then decreasing. Soil hydraulic erosion intensity in Shenmu County, Fugu County, Jiaxian County, and Wubao County moderated, while Qingjian County, Jingbian County, and Zizhou County showed significant intensification. Wind erosion was more severe in northern areas, with Yuyang District showing the largest erosion amount and Suide County and Mizhi County the smallest, following a consistently decreasing trend with Yuyang District showing the largest reduction, followed by Dingbian County and Hengshan County.

Second, Yulin City' s land ecological risk levels changed substantially with obvious regional differences. In 1990, seven counties fell into Class IV and V ecological risk levels, with relatively high ecological risk, with Fugu County showing the highest risk. In 2001, seven counties still belonged to Class IV and V, with relatively high ecological risk and the ecological environment in an unsafe state, with Jiaxian County showing the highest risk. In 2012, ecological risk somewhat abated, but four counties still belonged to Class IV and V, leaving the ecological security situation severe. Regionally, areas with higher ecological risk were mainly in the northwest in 1990, in central Yulin and western Dingbian County in 2001, and mainly in the southeast in 2012. The overall ecological security status improved, but the situation remains severe and requires attention.

Yulin City belongs to arid and semi-arid regions, represents a typical farming-pastoral ecotone, and serves as an energy development base. Its ecological environment is fragile, with prominent human-land contradictions. Under the dual influence of energy industry development and ecological restoration, land ecological security issues have become increasingly prominent. This study constructed a regional-scale comprehensive ecological risk evaluation index system and estimation model from the perspectives of natural disasters, human activities, and ecological background, quantitatively evaluating spatiotemporal variation differences in Yulin City' s land ecological risk from 1990-2012 and analyzing its dynamic change trends. The results indicate that with large-scale energy exploitation and booming coal industry development, Yulin' s ecological environment has suffered severe damage, making it crucial to raise ecological awareness and strengthen ecological civilization construction. Future research will focus on establishing a reasonable land ecological risk evaluation index system based on land ecological risk mechanisms, refining regional research scales, improving spatial expression precision, using combined subjective and objective weighting methods to reasonably determine indicator weights, and enhancing the scientific rigor of comprehensive land ecological risk evaluation from the perspectives of index system construction and regional scale refinement to provide decision-making support for rational land resource management and planning.

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