land

MDPI

Article

Research on Land Use Pattern and Ecological Risk of Lanzhou–Xining Urban Agglomeration from the Perspective of Terrain Gradient

Ziyang Wang [1,2], Peiji Shi [1,2,*], Jing Shi [1,2], Xuebin Zhang [1,2] and Litang Yao [1,2]

[1] College of Geographic and Environmental Science, Northwest Normal University, Lanzhou 730070, China; 2019212399@nwnu.edu.cn (Z.W.)
[2] Gansu Engineering Research Center of Land Utilization and Comprehension Consolidation, Lanzhou 730070, China
* Correspondence: shipj@nwnu.edu.com; Tel.: +86-931-138-9366-5158

Abstract: At the intersection of the Qinghai–Tibet Plateau and Loess Plateau, topographic factors often profoundly affect the evolution of the regional land use pattern and ecological risk. This paper takes the Lanzhou–Xining urban agglomeration as the research area, divides the topographic gradient based on the topographic index, analyzes the characteristics of the land use pattern using the land use transfer matrix model, dynamic attitude and state degree model, and analyzes the influence of topographic factors on the land use pattern using the distribution model. At the same time, an ecological risk evaluation index system is constructed, the spatial principal component method is used to evaluate the ecological risk, and the influence of topography on the regional ecological risk is discussed. The results show that from 1990 to 2020, the area of construction land in the study area increased by 1045.807 km^2 and the area of ecological land increased by 587.41 km^2, with the most significant changes occurring in the attitude and state of construction land and unused land. It is found that cultivated land, water area and construction land are dominant in low terrain, while woodland, grassland and unused land are mainly distributed in middle and high terrain. During the study period, the ecological risk in the midwest and southeast of the Lanzhou–Xining urban agglomeration decreased, while the ecological risk in the northeast increased first and then decreased, although generally there was an increasing trend. Moran's I varied from 0.942 to 0.955 from 1990 to 2020, indicating that the ecological risk index in the study area was highly positively correlated in space, while the spatial aggregation effect of the ecological risk was obvious. Low and moderately low risk areas are mainly distributed in high terrain, while high and moderately high risk areas are dominant in low terrain. The research results of this paper can make a lot of sense for ecological protection, land resource utilization and sustainable development of the Lanzhou–Xining urban agglomeration.

Keywords: terrain gradient; land use pattern; ecological risk; Lanzhou–Xining urban agglomeration

check for updates

Citation: Wang, Z.; Shi, P.; Shi, J.; Zhang, X.; Yao, L. Research on Land Use Pattern and Ecological Risk of Lanzhou–Xining Urban Agglomeration from the Perspective of Terrain Gradient. *Land* **2023**, *12*, 996. https://doi.org/10.3390/land12050996

Academic Editor: Xiangzheng Deng

Received: 30 March 2023
Revised: 25 April 2023
Accepted: 28 April 2023
Published: 30 April 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

As the most basic element of the natural environment [1], topography affects the spatial allocation of regional resources; redistributes water, heat and nutrients within the region, which influences the overall layout and utilization mode of the land use types; and also has a certain impact on the degree of regional ecological risk [2]. For a long time, there have been problems in the Lanzhou–Xining urban agglomeration, such as complex terrain, fragile ecological environment and the uneven spatial and temporal distribution of water and soil resources [3]. Moreover, with the cultivation and development of the Lanzhou–Xining urban agglomeration and the implementation of the strategy of western development, the regional economy and the scale of cities and towns continue to expand, forcing the degree of landscape fragmentation and ecological risk to become increasingly

severe, which brings serious profits and losses to the sustainable development of the regional ecosystem and social economy [4]. Therefore, given the complex natural ecological conditions of the Lanzhou–Xining urban agglomeration, analyzing the temporal and spatial distribution and evolutionary trend of the land use pattern and regional ecological risk from the perspective of the topographic gradient can lay a solid foundation for diagnosing and predicting the development of regional ecological environmental quality. It can also provide decision-making bases for formulating differentiated, operable and scientific ecological environmental protection, which is of great significance to regional sustainable and high-quality development.

At present, the academic research on land use patterns is more mature. Non-parametric correlation analysis [5], trend canonical correspondence analysis [6] and multivariate statistics [7] are mainly used to analyze land use patterns in different terrain gradients. The spatial heterogeneity of the Lanzhou–Xining urban agglomeration is pronounced, although the existing achievements are often simply divided based on the altitude gradient, and there are relatively few studies on the fine division at the pixel scale through the topographic position. At the same time, the academic research on ecological risk has been quite abundant, including the heavy metal ecological risk in sediments [8], microbial ecological risk in water [9], carbon emission risk [10], ecological risk after land consolidation [11] and urban and river basin ecological risk [12]. Generally speaking, from the research object, the ecological risk assessment is mainly carried out around river basins [13], cities and industrial and mining areas [14], as well as in ecologically sensitive and fragile wetlands [15,16], arid areas [17], alpine areas [18] and karst areas [19]. Judging from the evaluation unit, most of them take the administrative region as the evaluation unit, which separates the original natural geographical relationship of the surface, resulting in a relative lack of consideration of spatial heterogeneity. Therefore, scholars often choose the best research unit according to the needs of the ecological risk assessments for different purposes and regions to optimize the evaluation effect [20]. From the research content, it mainly includes the analysis of temporal and spatial evolution [21,22], dynamic monitoring [23], the influencing mechanism [24] and the driving factors [25] for ecological risk. In terms of research methods, the analytic hierarchy process [26], fuzzy evaluation method [27], principal component analysis method [28], multi-criteria evaluation method [29] and artificial neural network [30] are generally used for ecological risk assessment, although these methods have some shortcomings, such as the fuzzy evaluation method not being sensitive enough to reflect the ecological risk degreed of indicators, and the comprehensive evaluation method needing many indicators and complicated steps in the evaluation process [31]. The spatial principal component analysis (SPCA) method has a relative advantage in relation to ecological risk assessment [32], which can eliminate the dimensional differences among indicators, screen out key factors and automatically obtain the index weights, and the analysis results can clearly reflect the spatial distribution and evolutionary characteristics of ecological risks in the region [33]. Taken together, domestic and foreign scholars mostly focus on the study of the land use pattern and ecological risk in areas with intense human activities, while study of the Qinghai–Tibet alpine region, loess hilly region and farming–pastoral ecotone, which are ecologically fragile and have a strong response to global changes, is relatively rare. Hence, the terrain conditions in this area are complex, and the stability and resilience of the ecosystem are poor [34], so the study of the land use pattern and ecological risk based on the terrain gradient needs to be further deepened.

The Lanzhou–Xining urban agglomeration, in the transition zone between the Qinghai–Tibet Plateau, Inner Mongolia Plateau and Loess Plateau, is an important strategic support area for safeguarding national ecological security and promoting ecological protection and high-quality development of the Yellow River Basin [35]. It is of far-reaching historical and strategic significance for protecting the ecological environment of the Yellow River Basin and promoting high-quality economic development along the Yellow River. This area represents a vast territory, with various topographies and large surface fluctuations. The overall elevation difference of the area is close to 4000 m, and the land use pattern is

obviously differentiated, and this area is the densest area of human social and economic activities in the Qinghai–Tibet Plateau and the Loess Plateau [36]. Therefore, it is among the vital issues concerning the sustainable and high-quality development of the Lanzhou–Xining urban agglomeration to clarify the land use pattern and ecological risk change characteristics under different terrain gradients, and it is also the crucial precursor for the optimization of the regional land space. Based on these considerations, this paper constructs an analysis framework from the perspective of the terrain gradient to grasp the influence of terrain factors on the land use pattern of the Lanzhou–Xining urban agglomeration, and it uses SPCA to evaluate the ecological risk and analyzes the influence of terrain factors on the ecological risk on the basis of the evaluation results. This is intended to provide a basis for the management and control of the ecological space division of the Lanzhou–Xining urban agglomeration and effectively prevent the deterioration of the ecological environment, and it offers references for the ecological environmental protection of similar regions.

2. Materials and Methods

2.1. Study Area

The Lanzhou–Xining urban agglomeration (Figure 1) is located in the northwest inland area of China (34 51′–37 38′ N, 99 1′–1105 38′ E), with a total land area of 9.75 × 104 km^2, a resident population of 12.19 million in 2020 and a total production value of CNY 613.914 billion. According to the Development Plan of the Lanzhou–Xining Urban Agglomeration, published by the National Development and Reform Commission, its planning scope includes Lanzhou City, Gansu Province, Baiyin District, Pingchuan District, Jingyuan County, Jingtai County, Anding district, Longxi County, Weiyuan County and Lintao County of Dingxi City, Linxia City, Dongxiang Autonomous County, Yongjing County, Jishishan Baoan Dongxiang Salar Autonomous County, Xining City, Haidong City, and Qinghai Province, a total of 39 counties (districts, municipalities). The Lanzhou–Xining urban agglomeration is located in the transition zone of the first and second steps [37], and its geomorphology is complex and diverse, high in the northwest and low in the southeast, with an altitude of 1200 m to 5260 m. Due to the influence of its special geographical location and altitude factors, the average precipitation for many years is 300–500 mm, mainly concentrated in July to September. There are the main streams of the Yellow River, Huangshui River, Datong River and other important tributaries in the Lanzhou–Xining urban agglomeration, with average annual total water resources of about 1.8 × 1010 m^3. The Lanzhou–Xining urban agglomeration is an important growth polarity for supporting the development of northwest China, and it is an important fulcrum for ensuring the ecological security of the upper reaches of the Yellow River. Its ecological and economic status is prominent. However, due to the influence of its natural conditions, development space and development mode, the overall development level needs to be speedily improved.

2.2. Data Source

The data involved in this paper mainly comprise topographic data, meteorological data, land use type data, population and per capita GDP spatial distribution data and other data of the Lanzhou–Xining urban agglomeration in 1990, 2000, 2010 and 2020. The reasonable classification and accuracy of land use data is a necessary prerequisite for the precise analysis of land use spatial patterns [38]. The data concerning land use types used in this paper are selected from the multi-scene remote sensing images of the United States Geological Survey (https://www.usgs.gov accessed on 1 August 2022) in 1990, 2000, 2010 and 2020. Based on the remote sensing analysis software ENVI 4.7, geometric correction, terrain correction, image fusion, enhancement processing and cutting and splicing are carried out. With reference to the Specification for Investigation of Land Use Status and the National System for Monitoring Land Use Coverage by Remote Sensing, the study area is divided into six categories, grassland, cultivated land, construction land, woodland, water area and unused land, by manual interactive interpretation, and the interpretation accuracy of the remote sensing images in the four phases reaches 84.6%, 85.4%, 87.3%

and 88.9%, respectively, as displayed in Figure 2. The digital elevation model (DEM), soil erosion, average annual precipitation, average annual temperature, NDVI, land use data, population density and per capita GDP spatial distribution data are derived all from the Resource and Environment Science Data Center of the China Academy of Sciences (http://www.resdc.cn accessed on 12 September 2022), and the spatial resolution is 1 km.

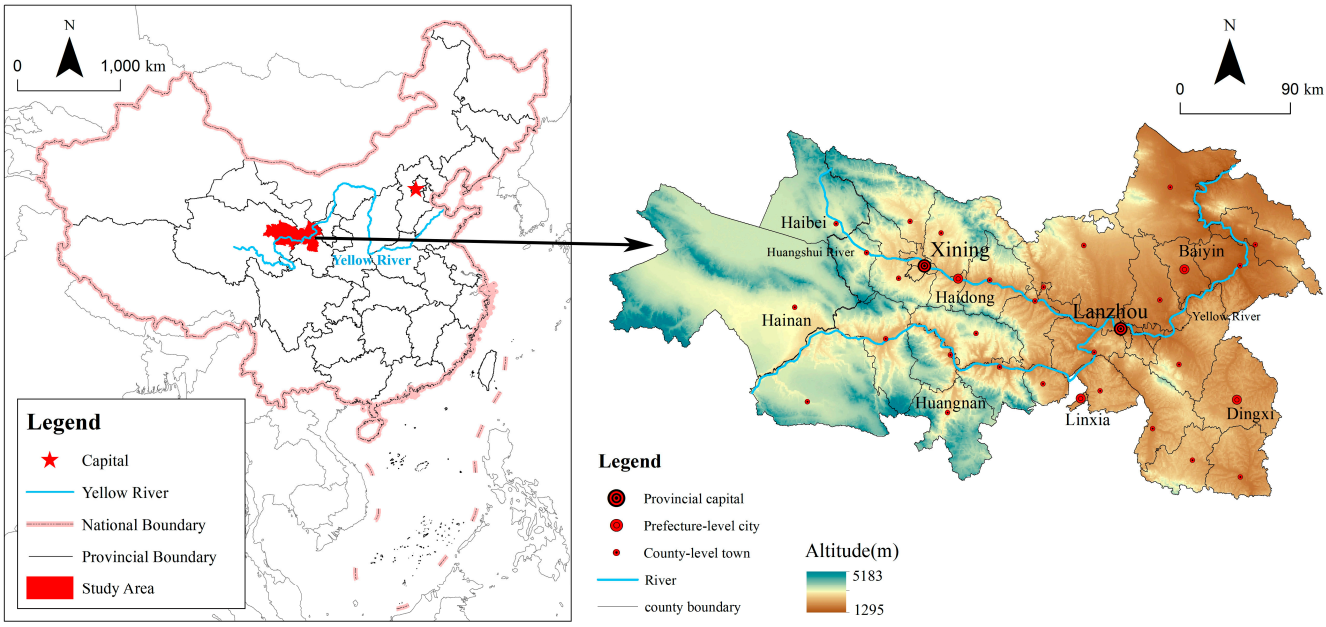

Figure 1. Location of the study area.

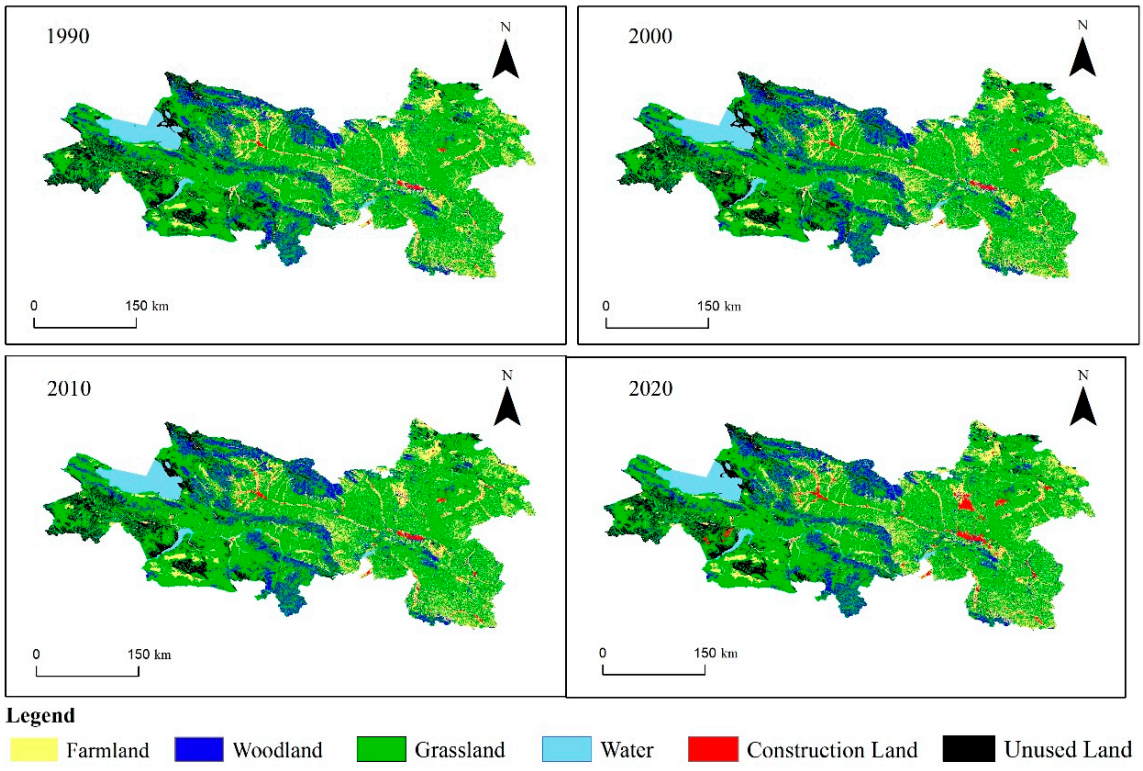

Figure 2. Land use status map of the Lanzhou–Xining urban agglomeration from 1990 to 2020.

2.3. Research Methods

2.3.1. Research Ideas

Considering the complex terrain conditions of the Lanzhou–Xining urban agglomeration, this paper analyzes the land use pattern and ecological risk in this area based on the terrain gradient, and the analysis framework is shown in Figure 3. Firstly, the topographic data were obtained from DEM data using the topographic index model, and all the topographic data were in the WGS_1984 coordinate system. Then, according to the existing research results [39] and the unique natural background conditions of the study area, the topographic data were divided into 0.21–0.43, 0.43–0.56, 0.56–0.68, 0.68–0.84 and 0.84–1.25, representing in turn five topographic gradient classes: low, moderately low, medium, medium–high and high. At the same time, based on the land use data from 1990, 2000, 2010 and 2020, as interpreted by remote sensing images, the land use transfer matrix model, dynamic attitude model and state degree model were used to analyze the characteristics of the regional land use pattern, the ecological risk evaluation index system was constructed, and the spatial distribution of the ecological risk was obtained via spatial principal component analysis. Finally, the distribution index model was used to calculate the distribution index of each land use type and the ecological risk level on different topographic gradient units so as to reflect the influence of topographic factors on the regional land use change and spatial distribution of the ecological risk. In this paper, the gradient division of the topography on the grid scale could probe more deeply the spatial differentiation law of the land use pattern and ecological risk under different terrain gradients. This provided decision-making support for the management measures of the ecological space partition and sustainable development of the urban agglomeration in Lanzhou–Xining.

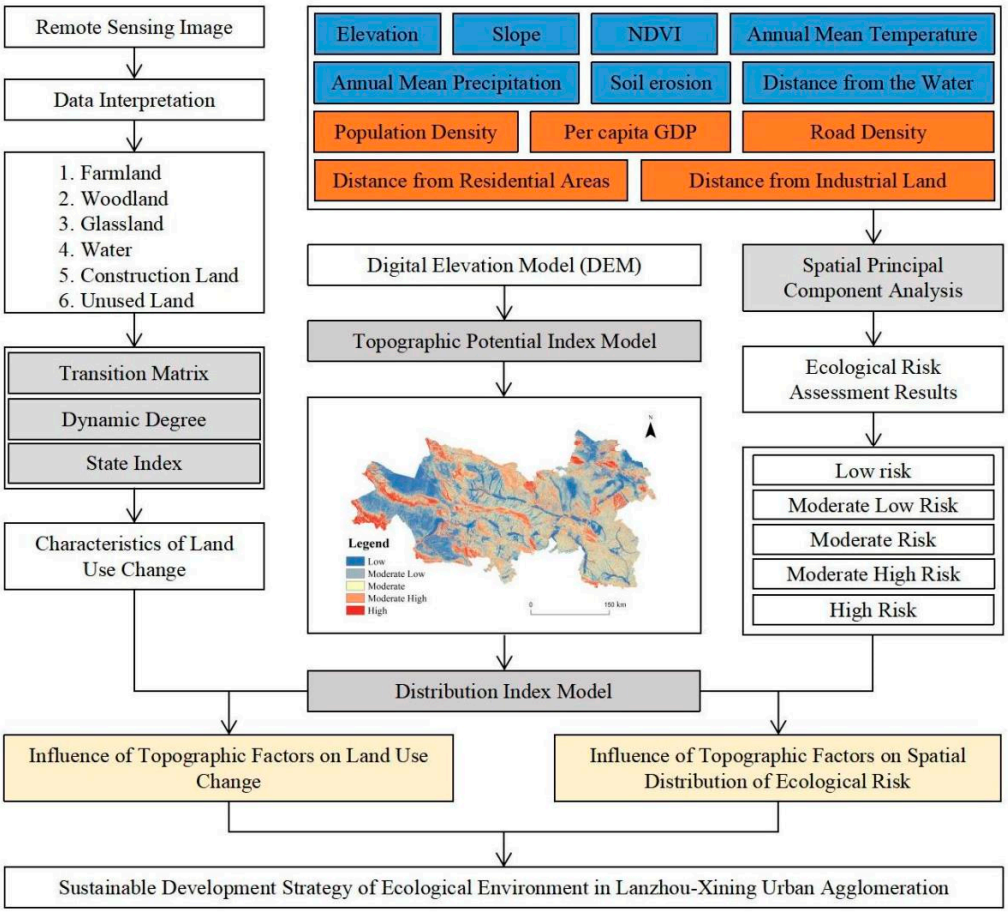

Figure 3. Analysis framework diagram.

2.3.2. Topographic Index Model

In order to quantitatively analyze the relationship between the land use spatial pattern and topographic gradient, this study used the topographic index to measure the topographic gradient. Combining the elevation factor and slope factor into a topographic index could better reflect the spatial differentiation of the topographic conditions [40]. The formula is as follows:

$$T = \lg\left[\left(\frac{E}{E_0} + 1\right)\left(\frac{S}{S_0} + 1\right)\right] \quad (1)$$

where T refers to the topographic index; E and E_0 respectively represent the elevation value of any point in space and the average elevation value (m) in the area where the point is located; and S and S_0 denote the slope value of any point in space and the average slope value of the area in which that point is located, respectively. The terrain is low in areas with small elevations and slopes, and high in the areas between them.

2.3.3. Measurement of Land Use Change

Land Use Transfer Matrix Model

A conversion analysis between the land use types in a certain period of time in the study area can usually be carried out based on the land use change matrix, which can reflect the conversion direction, the source of each land use type at the end of the study and the quantitative characteristics of the conversion, thus reflecting the land use change characteristics in the study area during the study period. Its expression is as in [41]:

$$S = \begin{Bmatrix} s_{11} \cdots s_{1n} \\ s_{21} \cdots s_{2n} \\ s_{n1} \cdots s_{nn} \end{Bmatrix} \quad (2)$$

where n stands for the total number of land use types; i and j are respectively the land use types at the beginning and end of the study (i, j = 1,2, … n); and S_{ij} represents the area converted from the i land type to the j land type during the study period.

Land Use Dynamic Attitude

The dynamic attitude of land use describes the range of the land use change from a quantitative point of view, thus revealing the intensity of some land use changes in the region. The formula is as follows [42]:

$$K = \frac{S_{end} - S_{start}}{S_{start}} \times \frac{1}{T} \times 100\% \quad (3)$$

where K is the dynamic attitude of a certain land use type; and S_{start} and S_{end} respectively reflect the area of a certain land use type at the beginning and the end of the study. The study period is denoted by T.

Land Use Status Index

The land use status index reveals the changing trend and status of a certain land use type, which is of great significance when measuring the degree of regional land use. The formula is as follows [43]:

$$P_i = \frac{\Delta S_{in} - \Delta S_{out}}{\Delta S_{in} + \Delta S_{out}} \quad (4)$$

where P_i represents the state index of a certain land use type, and its range is [−1,1]; ΔS_{in} is the area converted into Class i by other land use types during the study period; and ΔS_{out} is the area where the type i land use type is transformed into other land use types during the study period.

2.3.4. Ecological Risk Assessment Methods

Construction of the Ecological Risk Assessment Index System

An urban agglomeration is the result of a considerable number of cities with different properties, types and grades in a specific range. It is one of the areas with the most intensive human activities and the most sensitive ecological environment, and the ecological environment is strongly disturbed by human activities [44]. In order to objectively and accurately reflect the basic situation of the ecological environment in the region, professors in academia often choose evaluation models and indicators according to the particularity of the region. Referring to previous research results [45–47] and the specific situation of the Lanzhou–Xining urban agglomeration, this paper selects 12 indicators from the natural, social and economic aspects, including the elevation, slope, NDVI, average annual temperature, average annual precipitation, soil erosion, distance from a water body, population density, per capita GDP density, road network density, and distance from industrial points and residential areas, to construct an ecological risk assessment index system (Table 1) and to classify and standardize the risks into five levels: low, moderately low, moderate, moderately high and high risk. The higher the level, the higher the ecological risk.

Table 1. Ecological risk assessment index system of the Lanzhou–Xining urban agglomeration.

Evaluation Indicators	Standardized Value				
	Level 1 (Low)	**Level 2 (Moderately Low)**	**Level 3 (Moderate)**	**Level 4 (Moderately High)**	**Level 5 (High)**
Elevation (m)	<1600	1600~2400	2400~3200	3200~4000	>4000
Slope (°)	<5	5~15	15~25	25~35	>35
NDVI	>0.65	0.65~0.5	0.5~0.35	0.35~0.2	<0.2
Annual mean temperature (°C)	>8	8~6	6~4	4~2	<2
Annual mean precipitation (mm)	>600	600~500	500~400	400~300	<300
Soil erosion	Slight hydraulic, wind, freeze–thaw erosion	Mild hydraulic, wind, freeze–thaw erosion	Moderate hydraulic, wind, freeze–thaw erosion	Intense hydraulic, wind, freeze–thaw erosion	Severe hydraulic, wind, freeze–thaw erosion
Distance from the water (m)	<200	200~1000	1000~2000	2000~3000	>3000
Population density (pop/km^2)	<300	300~600	600~900	900~1200	>1200
Per capita GDP (yuan/km^2)	<7500	7500~8000	8000~8500	8500~9000	>9000
Road density (km/km^2)	<0.1	0.1~0.2	0.2~0.4	0.4~0.6	>0.6
Distance from industrial points (m)	>4000	4000~3000	3000~2000	2000~1000	<1000
Distance from residential areas (m)	>3000	3000~2000	2000~1000	1000~200	<200

Spatial Principal Component Analysis

An SPCA compresses data by eliminating data residuals, aiming at compressing and converting multiple spatial index data into a few irrelevant comprehensive layers. In this paper, the principal component analysis of the 12 selected indicators is carried out by means of SPCA. According to the cumulative contribution rate of 85%, seven spatial principal components are determined, and the ecological risk index of the Lanzhou–Xining

urban agglomeration from 1990 to 2020 is finally calculated. See Equation (5) for the calculation [48]:

$$ERI = r_1Y_1 + r_2Y_2 + r_3Y_3 + \cdots + r_nY_n \quad (5)$$

Among them, *ERI* is the ecological risk index; r_n stands for the nth principal component; and Y_n represents the contribution value corresponding to the nth principal component. According to the grading standard of the ecological risk assessment and the ecological environment of the Lanzhou–Xining urban agglomeration, the *ERI* is divided into low risk (*ERI* < 2.47), moderately low risk (2.47 < *ERI* < 3.29), moderate risk (3.29 < *ERI* < 3.82), moderately high risk (3.82 < *ERI* < 4.50) and high risk (*ERI* > 4.50).

Spatial Autocorrelation

A spatial autocorrelation analysis can reflect the spatial interdependence of the ecological risk degree. It is especially pertinent to identify the spatial correlation degree and high–low value aggregation area of ecological risk when it comes to optimizing the structure of the regional ecosystem and improving the quality of the ecological environment [49]. Global spatial autocorrelation can reflect the similarity in attribute values of spatially adjacent regions. Using GeoDa software, this paper analyzes the spatial correlation between the ecological risk indexes of the Lanzhou–Xining urban agglomeration through Moran's I, and the calculation of the global Moran's I is shown in the following formula:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}(x_i - \bar{x})} \quad (6)$$

Local spatial autocorrelation is an important indicator of whether the attribute values of a single feature are significantly correlated with the attribute values of their adjacent spaces. The local Moran index (Moran's I) is calculated using the following equation [50]:

$$I = \frac{(x_i - \bar{x})}{S^2}\sum_{j} W_{ij}(x_j - \bar{x}) \quad (7)$$

where I is Moran's I; n is the number of grids; x_i and x_j are respectively the mean vulnerability indices for the i_{th} and j_{th} grids; $\bar{x}$ stands for the average value of the ecological risk index of all the grids; and W_{ij} is a spatial weight matrix, which represents the spatial relationship between the spatial units i and j. If the spatial units i and j are adjacent, then $W_{ij} = 1$, and if the spatial units i and j are not adjacent, then $W_{ij} = 0$; S is the sum of the elements of the spatial weight matrix.

A spatial correlation local index (LISA) cluster map is obtained by spatial clustering based on the calculation results of the local Moran's I index, including five spatial clustering modes: "High–High (HH) zone", "Low–Low (LL) zone", "High–Low (HL) zone", "Low–High (LH) zone" and nothing–insignificant. When $I > 0$, it indicates that a high (low) value area is surrounded by a high (low) value area, that is, "High–High" ("Low–Low") aggregation. When $I < 0$, it means that a high (low) value area is surrounded by a low (high) value area, that is, "High–Low" ("Low–High") aggregation. When $I = 0$, it expresses that the observation area has nothing to do with the adjacent area, that is, it is insignificant.

2.4. Distribution Index Model

The distribution index can reflect the distribution characteristics of different landscape ecological risk levels in different regions, and it is used to judge the change in the landscape ecological risk in the temporal and spatial evolution of construction land, and the calculation formula is as follows [51]:

$$P_{ie} = \left(\frac{S_{ie}}{S_i}\right) \times \left(\frac{S}{S_e}\right) \quad (8)$$

where P_{ie} stands for the topographic distribution index; S_{ie} represents the area of type i land use and the ecological risk types in the study area under topographic position e; S_i denotes the total area of type i land use and the ecological risk types in km^2; S_e is the total area of a terrain e; and S represents the total area of the study area. $P_{ie} > 1$, which means that the distribution interval of the i-type on e terrain is the dominant terrain distribution interval. The higher the value of P, the greater the degree of dominance distribution.

3. Results and Analysis

3.1. Analysis of the Land Use Change Characteristics

3.1.1. Analysis of the Land Use Change and Transformation

Through the calculation of the land use change and transfer matrix (Figure 4), it is found that the grassland area in the Lanzhou–Xining urban agglomeration changed the most from 1990 to 2000, with a decrease of 319.5 km^2, which was mainly due to an increase in population, promoting the large-scale reclamation of wasteland into cultivated land and the gradual conversion of grassland into woodland under the implementation of the Three North Shelterbelt Development Program. From 2000 to 2010, the area of unused land and cultivated land in the Lanzhou–Xining urban agglomeration decreased by 1233.5 km^2 and 189.1 km^2, respectively, while the grassland and water area increased by 1001.9 km^2 and 199.7 km^2, respectively, which was primarily fueled by policies such as "return to forests," "return to grasses," and "integrated watershed management," which allow for the adaptation of sloping land and underutilized land prone to soil erosion for planting trees and grasses, thus restoring the vegetation of forested grasslands. From 2010 to 2020, the construction land changed the most, with a total increase of 797.1 km^2. This stage was the climax of urban construction and development in the Lanzhou–Xining City Circle, mainly focusing on the urban expansion of Lanzhou City, Lanzhou New District and Xining City. Generally speaking, the area of unused land in the Lanzhou–Xining urban agglomeration changed the most from 1990 to 2020, with a decrease of 1292.1 km^2. Under the measures for vigorously protecting and restoring the ecological environment, it was mainly converted into grasslands and waters. During the research period, the area of construction land also changed greatly, increasing by 1045.8 km^2, which was caused by the rapid urbanization over the past 30 years, and the areas occupied by cultivated land and grassland reached 728.9 km^2 and 401.2 km^2, respectively, which brought certain risks to the regional ecological security.

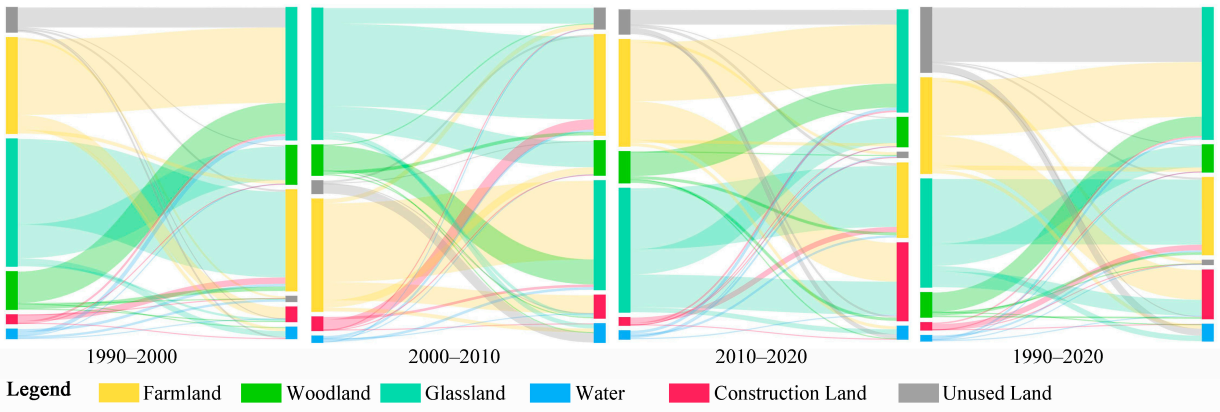

Figure 4. Land use change transfer map.

3.1.2. Analysis of the Dynamic Index and State Degree of Land Use

By calculating the dynamic index and state index of various land use types in different time periods in the study area (Figure 5), it is found that the dynamic index of construction land has the largest change range and is in a gradual upward trend, with the highest dynamic index in 2010–2020, which may be due to the establishment of Lanzhou New

District in 2012 and the large-scale development and construction of the adjacent areas of Yongdeng County and Gaolan County, which has significantly increased the dynamic index of construction land in the Lanzhou–Xining urban agglomeration. The change in the dynamic index of unused land is also prominent, showing a trend of decreasing at first and then increasing. This is mainly because the 1990s represented the peak of land reclamation, while the climax of ecological civilization construction began in 2012, which resulted in a large amount of unused land being transformed into cultivated land and ecological land, which increased the change range of the dynamic index. The change in the state index of cultivated land and construction land is the opposite, which is mainly due to the fact that both cultivated land and construction land are distributed in the valley with relatively flat terrain, and the large-scale development and construction of construction land will inevitably occupy cultivated land on a large scale. The changes in the state index of grassland and water area are similar, both of which show the trend of increasing first and then decreasing, and both of them reach the peak value in 2000–2010, that is, 0.19 and 0.49, respectively. The change in the state index of forest land is relatively stable as a whole, and there is not much fluctuation. The change in the state index of unused land first decreased and then increased, reaching the lowest value in 2000–2010, and then it began to rebound and gradually increase.

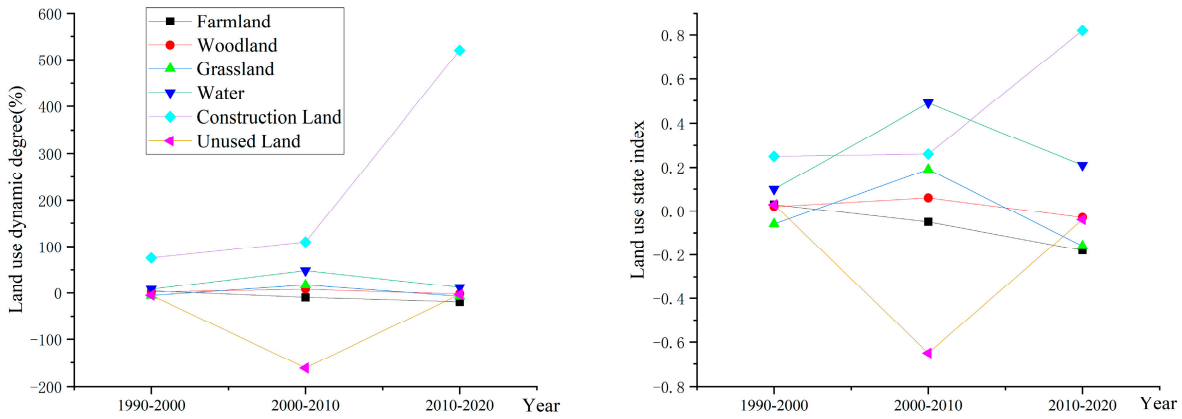

Figure 5. Dynamic index and state index of the land use types in the study area.

3.1.3. Land Use Change Characteristics under Different Topographic Distribution Indexes

As can be seen from Figure 6, during the past 30 years, the change in the cultivated land distribution index tends to be consistent, and all of them show a downward trend with an increase in the topographic position. In the range of less than grade 2 topographic position, the distribution index of cultivated land is greater than 1, indicating that the dominant topographic position of cultivated land is grade 1–2, which is basically consistent with the overall change trend of construction land, and its topographic distribution index shows a downward trend with the increase in topographic position. In 2020, the distribution index of construction land in the grade 1–4 topography is significantly higher than that in other years, indicating that construction land gradually expands to the terraces on both sides of the valley. The distribution index of construction land is greater than 1 in the interval of the less than grade 2 topographic position, which indicates that the dominant topographic position of construction land is grade 1–2. Construction land is greatly influenced by topographic factors, and its high topographic position is not suitable for human production and life, and it is similar to cultivated land and suitable for distribution in valley areas with flat terrain. The topographic distribution index of forest land shows an upward trend with the rise of topographic position. The terrain distribution index is greater than 1 in the 3–5 terrain position, which indicates that the dominant terrain position of woodland is in the 3–5 terrain interval. The grassland distribution index first shows an obvious upward trend with an increase in topographic position at grade 1–3, and it is in a downward trend

at grade 3–5. The distribution index of grassland in the 2–5 terrain position is greater than 1, which indicates that grassland belongs to the dominant interval in the 2–5 terrain position. The topographic distribution index of the water area decreases with the increase in the topographic position index.

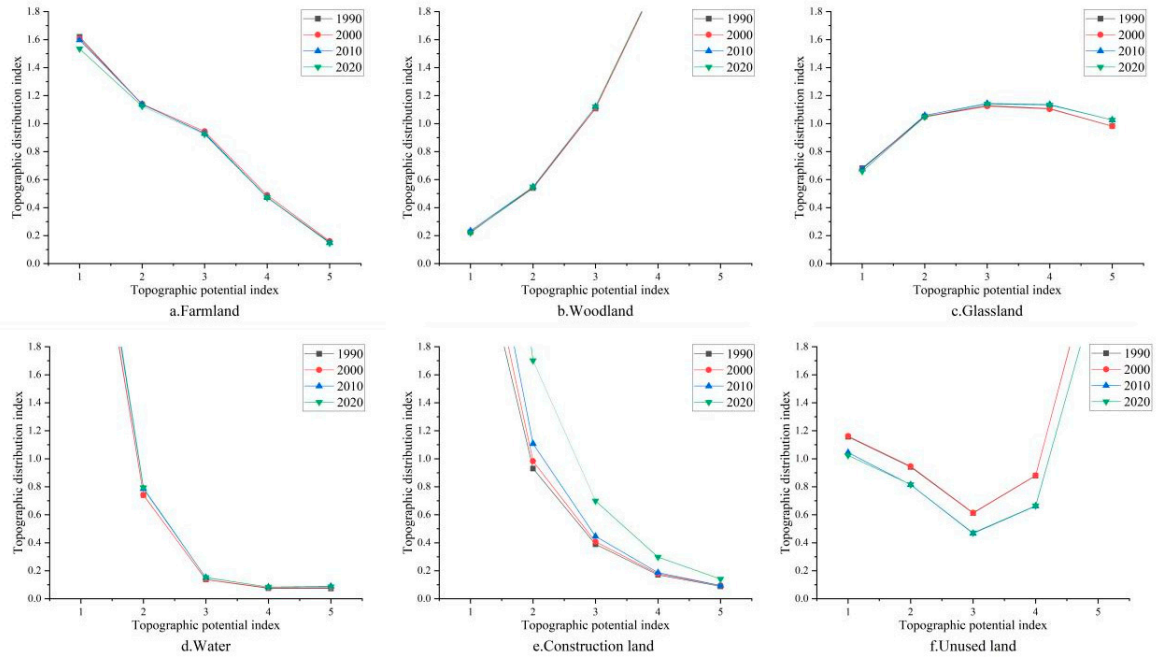

Figure 6. The relationship between the distribution index of each class and the topographic index.

The distribution index of water area is greater than 1 in the topographic position less than level 2, indicating that the 1–2 topographic position is the dominant interval of the water area. The distribution index of unused land has a relatively special change, with the distribution index dropping obviously at the level of 1–3, but then rising at the level of 3–5. With the increase in slope and altitude, the adaptability of human beings to the natural environment decreases and the degree of land development is relatively weakened, so the unused land shows an increasing trend. Moreover, the terrain distribution index is greater than 1 in the 4–5 terrain position, which indicates that this interval is the dominant interval of unused land distribution. The topographic distribution index of unused land in 2010 and 2020 under the same topographic position is lower than that in other years, mainly due to the ecological restoration and soil erosion control in high-altitude and high-slope areas against the background of ecological civilization construction. Overall, cultivated land, water area and construction land are dominant in low terrain, woodland and grassland are dominant in medium and high terrain, and unused land is more distributed in high terrain.

3.2. Analysis of the Temporal and Spatial Variation Characteristics of Ecological Risk

3.2.1. Ecological Risk Assessment Results

As shown in Figure 7, the moderate, moderately high- and high-risk areas are mainly distributed in the valley basins in the central and western regions and the low-altitude areas in the east, mainly due to the scarcity of vegetation, serious land desertification and soil erosion, and the concentrated distribution of population and industry and strong human interference due to the influence of topography, water resources and traffic conditions, resulting in a high ecological risk in this area. The moderately low-risk and low-risk areas are mainly concentrated in the high-altitude areas in the central and western regions. The main reason is that the land types in this area are mainly grassland and woodland, and the vegetation coverage is high. In addition, the population in this area is sparse, human interference with the ecological environment is low, and the ecological environment

is mainly characterized by natural evolution, so the ecological risk in this area is low. Specifically, from 1990 to 2010, the areas of low risk and moderately low risk in the central and western regions (Haibei Prefecture, Xining City, Hainan Prefecture, Haidong City and Huangnan Prefecture) slightly expanded, while the areas of moderate risk decreased. The southeast region (Dingxi City) was dominated by high risks and gradually changed to moderate risks. The area of highly vulnerable areas in the northeast (Baiyin City and Lanzhou City) has increased. From 2010 to 2020, the areas of low and moderately low risk in the central and western regions will be further expanded, while the areas of moderate risk will be significantly reduced. The areas of moderately high and high risk in the northeast (Baiyin City and Lanzhou City) decreased slightly. Generally speaking, the ecological risks in the central and western regions and the southeastern regions decreased from 1990 to 2020, while the ecological risks in the northeast region increased first and then decreased, although they generally showed an increasing trend.

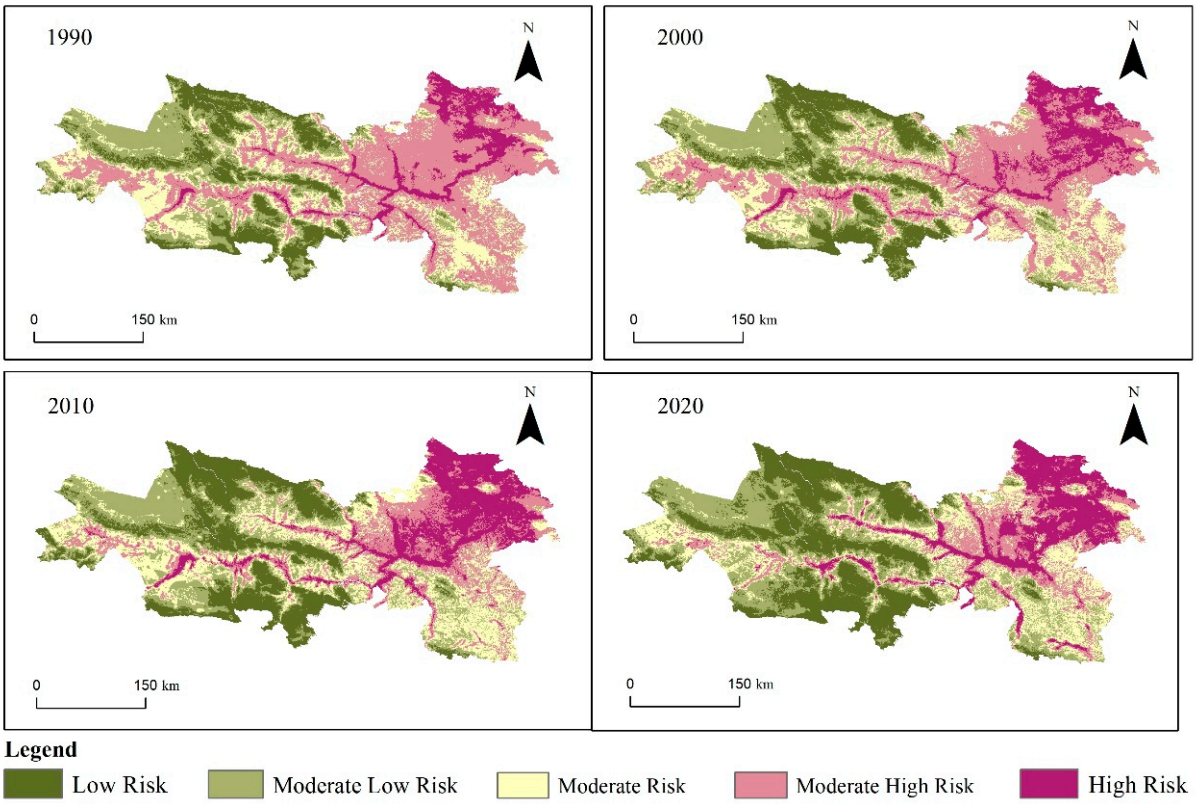

Figure 7. Spatial distribution map of the ecological risk in the Lanzhou–Xining urban agglomeration.

3.2.2. Spatial Correlation of Ecological Risks

Based on the results of the ecological risk assessment of the Lanzhou–Xining urban agglomeration, this paper performs a spatial autocorrelation analysis with the help of GeoDa software. The results show that Moran's I is 0.942, 0.950, 0.952 and 0.955 in 1990, 2000, 2010 and 2020, respectively, and the overall change range is small, indicating that the ecological risk index of the Lanzhou–Xining urban agglomeration is highly positively correlated in space and the spatial aggregation effect of the ecological risk is obvious rather than a random distribution. From 1990 to 2020, the spatial aggregation characteristics of ecological risks in the Lanzhou–Xining urban agglomeration are basically the same, and the HH and LL modes are the main ones (Figure 8). There is a significant HH mode gathering in the valley areas of the central and western regions and the northeast region, among which Linxia City, Lanzhou City and Baiyin City are the most obvious. In the high-altitude areas in the central and western regions and Qinghai Lake region, the LL mode of aggregation is

obvious, among which Haibei Prefecture, Xining City, Haidong City, Huangnan Prefecture and Hainan Prefecture are the most obvious. From 1990 to 2000 and from 2000 to 2010, the change trend of the gathering areas was basically the same, among which the distribution range of the HH mode gathering areas showed a significant decrease trend in Hainan and the valley areas in the central and western regions, and it increased significantly in the northeast. The distribution range of the LL mode cluster is slightly reduced in Guinan county. During 2010–2020, the HH cluster increased in the valley basins and Dingxi City in the central and western regions, and the LL mode cluster showed a slight expansion trend as a whole. Generally speaking, the spatial distribution of the HH cluster in the study area is more obvious than that of the LL mode cluster, and the area of the HH mode cluster is obviously expanding in the valley basin, northeast and southeast of the central and western regions. Except for a slight decrease in Guinan county, the LL mode cluster area has a slight expansion trend in other areas.

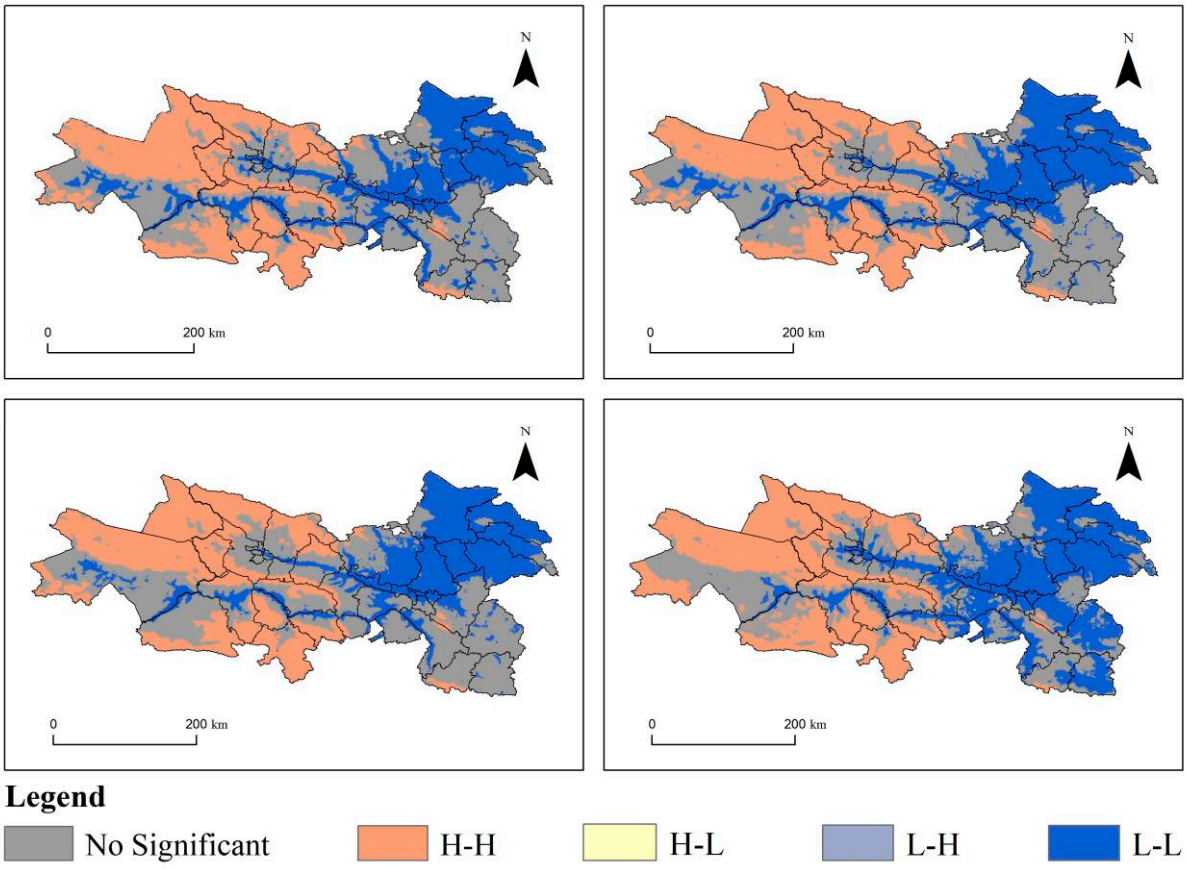

Figure 8. LISA cluster diagram of the ecological risk of the Lanzhou–Xining urban agglomeration from 1990 to 2020.

4. Discussion and Analysis

4.1. Impact of the Topographic Gradient on the Spatial Distribution of the Ecological Risk

As can be seen from Figure 9, the topographic distribution index of the low-risk areas increased with the increase in the topographic position from 1990 to 2020. The terrain distribution index is greater than 1 in the 3–5 terrain, suggesting that areas with higher topographic position indices tend to have lower ecological risk, which may be related to the fact that the areas with high terrain are less disturbed by human activities. With the increase in the topographic index, the distribution index of the low-risk areas is decreasing year by year, which shows that the ecological risk in high-altitude areas is gradually decreasing with the increasing protection of the ecological environment. The change in the distribution index in the moderate-risk areas tends to be consistent. With the

increase in the topographic index, the distribution index first increases and then decreases, and the topographic distribution index is greater than 1 in the 2–4 topographic position, indicating that the dominant topographic position in the moderate-risk areas is in the 2–4 topographic interval. The topographic distribution index of the moderately high-risk areas and high-risk areas decreased with the increase in the topographic position index, and the distribution index of the high-risk areas was greater than 1 in the topographic position less than grade 2, indicating that the 1–2 topographic position was the dominant interval of the high-risk areas. Generally speaking, moderately low-risk areas and low-risk areas are dominant in high terrain, while moderately high-risk areas and high-risk areas are dominant in low terrain. This is mainly due to the fact that human production and life are mainly concentrated in the valley area with low topography, which inevitably damages the ecological environment in that area, while the high topography area is less disturbed by human beings and affected by human ecological environmental protection and ecological protection and restoration measures, which makes the ecological risk degree between low topography areas and high topography areas obviously different.

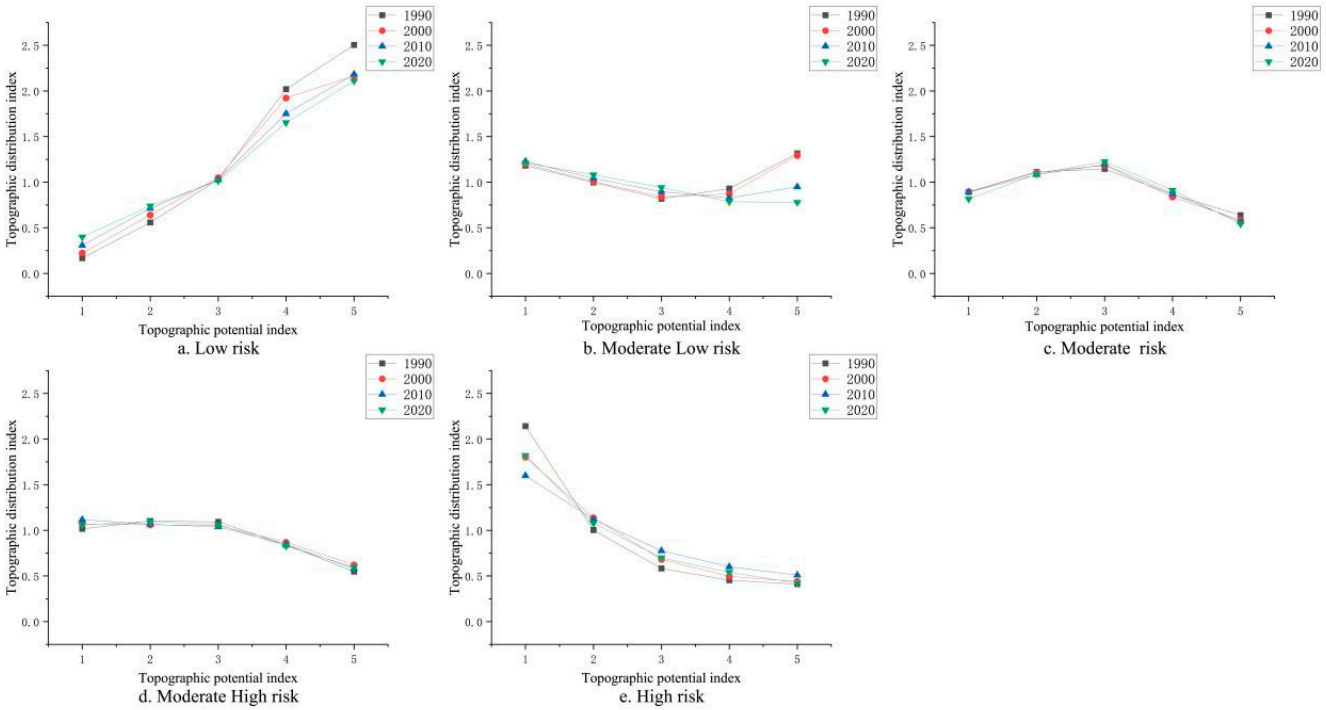

Figure 9. Relationship between the distribution index of the ecological risk types at all levels and the topographic index.

4.2. Response of the Ecological Risk to Human Activities under the Influence of Topographic Factors

Terrain is an important factor affecting human production and life, and it is the decisive factor for human beings choosing settlements, whereas human activities of different natures also profoundly affect the ecological environments of settlements and their surrounding areas [52]. Based on the results of the ecological risk assessment of the Lanzhou–Xining urban agglomeration, the response of the ecological risk to human activities under the influence of topographic factors is discussed. According to the research findings, the ecological risk of the Lanzhou–Xining urban agglomeration is obviously decreasing, and the improvement in the ecological environment in high-altitude areas in the central and western regions is the leading cause of the overall ecological risk reduction in relation to the Lanzhou–Xining urban agglomeration. However, the mountainous areas in the central and western valleys and northeastern regions have complex topographic structures, serious soil erosion (Hehuang Valley) and fragile ecological backgrounds, coupled with the relative

concentration of the population, relatively dense industry, and high intensity and high frequency of human activities caused by the surface disturbance, contributing to the further degradation of the ecological environment in parts of the region [53]. In addition, this region is a high-value gathering area for ecological risks, which has expanded the original ecological risks to some extent and seriously threatened regional ecological security.

In recent years, a series of ecological protection policies successively implemented by the state, such as the comprehensive harnessing of small watersheds, the development of the "Three-North Protection Forest System", returning farmland to forests and grasslands, wetland protection, the ecological conservation and restoration project in the Three-River Source Region, grazing prohibition and different times for rest grazing, and the construction of ecological public welfare forests, are all positive interferences [54]. All these interferences have significantly improved the ecological environment in the Lanzhou–Xining urban agglomeration area and reduced the overall level of ecological risk. Owing to the relative consistency between the negative disturbance of human activity and the spatial distribution of the population, under the influence of topographic factors, the spatial distribution of ecological risks is unbalanced, which leads to obvious differences in the changes in the ecological environment between the valley basins and plateau and mountainous areas. For example, in the plateau and mountainous areas of the central and western regions, the population is relatively sparse and the ecological environment is less negatively disturbed by human activities. On the contrary, on the basis of a series of ecological protection policies implemented by the state, measures such as closing hillsides to facilitate afforestation, reducing livestock and grazing, prohibiting logging and grazing, and reforming pastoral areas have been adopted in various regions to promote the increase in vegetation coverage in this region, thereby reducing ecological risks. The rate of conversion of ecological space into production and living space is accelerating in the relatively flat river valley basin, which raises the overall level of ecological risk in the area. This is due to an increase in the negative disturbance degree and range of human activities in relation to the ecological environment [55]. Given the foregoing, topographic factors have a profound impact on the response of the ecological environment of the Lanzhou–Xining urban agglomeration to human activities. Not only do human activities change the evolutionary speed and development direction of the ecological environment to a certain extent, topography is also one of the important reasons that affect the intensification or weakening of regional ecological risks.

4.3. Zoning Control Strategy for the Ecological Protection and Restoration of National Land and Space

The land desertification, desertification (Gonghe basin and northern Baiyin city) and soil erosion (valley area) are serious in the study area. Although a series of protection measures have been implemented in various areas [56], the ecological environment in some areas is still in a deteriorating trend due to the difficulty of control and the weak implementation. Therefore, we should divide the ecological environmental protection and restoration zones and implement the ecological protection and restoration projects according to local conditions [57]. According to the results of the ecological risk assessment, the study area is divided into five areas: ecological optimization area, ecological promotion area, ecological control area, ecological restoration area and ecological conservation area (Figure 10). The ecological optimization area in the central urban area is mainly intended to renew and repair the urban ecosystem in the urban area, and to renovate the construction land, such as rural residential land, and restore its ecological functions so as to create a green space system with a perfect system structure, diverse functional types and integrated suburban areas, such as forest wetland parks, community gardens, roof greening, etc., to consolidate the functions of the connecting corridors with the urban ecological nodes, enhance the connectivity of the urban green public ecological spaces and the connectivity between the urban areas and suburban green landscapes, form a complete green network structure, and enhance the urban green space ecology.

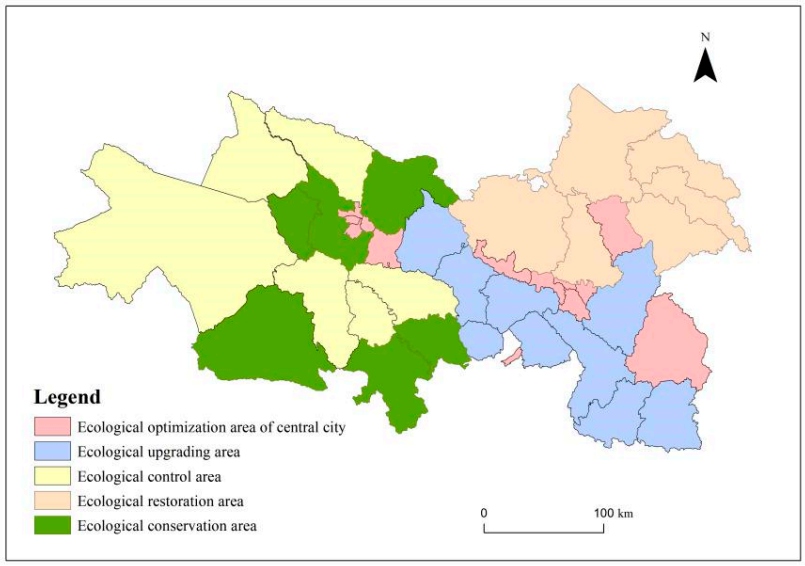

Figure 10. Zoning map of the ecological protection and restoration of the Lanzhou–Xining urban agglomeration.

Most of the ecological upgrading areas have moderate ecological risks. We should gradually improve the implementation standards of ecological protection and restoration projects, such as returning farmland to forests, soil and water conservation, mine restoration, etc., optimize various ecological elements in the region, scientifically add ecological corridors, and build an ecological network pattern with higher quality and stronger resilience to improve the stability of the ecosystem in this region. The ecological protection and restoration of the ecological control area are mandatory for government decision-making, and the development of the area is mainly prohibited. The construction of buffer zones between production, living space and ecological space should be strengthened to reduce the negative impact of human activities on the ecosystem, and construction projects such as closed protection, natural forest protection and natural forest restoration should be implemented. The ecological restoration area has the highest degree of ecological risk, mainly Gobi Desert grassland, and the natural ecological base is poor. The ecological restoration activities are oriented toward tapping the ecological potential, preventing wind and sand fixation and curbing ecological degradation, increasing investment in ecological remediation projects, and improving the fineness of ecological restoration work, such as mine restoration, comprehensive land improvement, and pollution and disaster control. The ecological conservation area has the lowest ecological risk and an excellent ecological base. Therefore, it is necessary to implement projects such as the precise improvement of forest quality and the prevention and control of forest diseases and insect pests to improve the stand structure and improve the stability of the mountain evergreen coniferous forest ecosystem. At the same time, it is necessary to strengthen the protection and restoration of wildlife habitats [58], repair damaged ecological corridors, and alleviate the problems of habitat loss and habitat fragmentation.

4.4. Sustainable Development Strategy for the Regional Ecological Environment

On the basis of studying the characteristics of the land use change and the dynamic evolution of the ecological risk, this paper analyzes the influence of topographic factors on land use types and the spatial distribution of ecological risks. Based on this, the following suggestions are put forward for the ecological environmental protection of the Lanzhou–Xining urban agglomeration: strictly implement the relevant policies of land space planning and strengthen the division and management of towns, agriculture, ecological space, urban development boundaries, permanent basic farmland and ecological protection red lines. Cultivated land is widely distributed in the moderate-risk and above areas of the Lanzhou–

Xining urban agglomeration. Over the years, due to the policy of returning farmland to forests and grasslands and urban expansion, the cultivated land area has generally decreased, and there are certain contradictions in the spatial distribution of the ecological, urban and agricultural land, and obvious urban land encroachments on ecological and agricultural land. From the perspective of sustainable development, we should strictly define the "three areas" and "three lines", resolutely protect the ecological and agricultural space, and avoid excessive expansion of urban land.

On this basis, we should actively guide the population and industries to gather in central cities, appropriately expand the scale of central cities, and improve the driving role of regional economic development so as to adjust and optimize the spatial structure of land, strengthen the regional zoning management, and reduce the environmental pressure in surrounding areas. It is also necessary to optimize the industrial structure, reduce resource consumption, and build a green and ecological urban agglomeration development system. Moreover, we should give full play to the resource advantages of the Lanzhou–Xining urban agglomeration, focus on petrochemical and non-ferrous metallurgical industries, promote the transformation of traditional pillar industries into green, low-carbon, clean and safe industries, and stimulate the new vitality of the green development of the traditional pillar industries [59]. The Lanzhou–Xining urban agglomeration is rich in wind, light and heat resources, and it actively develops new energy industries around superior resources such as wind and light, thus reducing environmental pressure and promoting environmentally sustainable development [60]. At the same time, we should actively change the development mode of agriculture and animal husbandry, focus on developing modern ecological agriculture, improve the farming level and land use efficiency, and prevent the degradation of cultivated land.

4.5. Enlightenment

The Lanzhou–Xining urban agglomeration is located in the intersection of the Qinghai–Tibet Plateau, Loess Hilly and Inner Mongolia Plateau, and it is the most concentrated area of human activities in the upper reaches of the Yellow River. The landform in the territory is mainly mountainous and hilly, and its land use mode is more obviously affected by topographic factors than that in the plain area [38]. Topographic factors play an important role in the formation of and change in the land use pattern. As an important spatial limiting factor, topographic factors play a certain spatial limiting role in human development and utilization of land resources, optimal allocation of land structure and other activities. Through on-the-spot investigation and quantitative analysis, this study reveals the spatial hierarchy and structural multilevel and functional pluralism of the land use pattern in the Lanzhou–Xining urban agglomeration, and it discusses the influence of topographic factors on regional ecological risks. Under the influence of topographic factors, the ecological risk has a strong response to human activities. Unreasonable development and utilization activities can easily cause local environmental damage and aggravate the island effect in terms of ecological degradation and poverty. Therefore, to adjust the land use structure and optimize the allocation of land resources, we should fully consider the importance of topographic factors, focus on the regionality, particularity and dynamics of land use in the Lanzhou–Xining urban agglomeration, follow the principles of landscape ecology and sustainable development, and make reasonable arrangements and coordination with regard to the distribution laws of various land types under different topographic conditions so as to realize the sustainable development of the social economy and national space.

5. Conclusions

This paper takes the Lanzhou–Xining urban agglomeration as the research area, divides the topographic gradient based on the topographic index, analyzes the characteristics of the regional land use pattern using the land use transfer matrix model, dynamic attitude and state degree model, and analyzes the influence of topographic factors on the land use change using the distribution model. At the same time, an ecological risk evaluation index

system is constructed, and the spatial principal component method is used to evaluate the ecological risk. The spatial correlation of the ecological risk is analyzed, and the influence of topographic factors on the regional ecological risk is discussed on the basis of the evaluation results. The results show that from 1990 to 2020, the area of unused land and cultivated land in the Lanzhou–Xining urban agglomeration decreased, while the area of woodland, grassland, water and construction land increased, of which the area of construction land increased by 1045.807 km^2 and the area of ecological land increased by 587.41 km^2, which was related to the rapid urbanization and construction and ecological environment protection and restoration in the Lanzhou–Xining urban agglomeration over the past 30 years. From 1990 to 2020, the dynamic attitude and state of construction land and unused land changed most significantly, which was caused by human construction and development and vegetation restoration activities. It is found that cultivated land, water area and construction land are dominant in low terrain, woodland and grassland are dominant in medium and high terrain, and unused land is more distributed in high terrain. From 1990 to 2020, the ecological risk in the central, western and southeastern parts of the Lanzhou–Xining urban agglomeration decreased, while the ecological risk in the northeast increased first and then decreased, although overall there was an increasing trend. The Moran's I changed from 0.942 to 0.955 during the study period, which indicated that the ecological risk index of the Lanzhou–Xining urban agglomeration was highly positively correlated in space, and the spatial aggregation effect of the ecological risk was obvious. From 1990 to 2020, the spatial distribution of the HH mode cluster in the study area changed more obviously than that of the LL mode cluster, and the area of the HH cluster was obviously expanding in the valley basin and northeast and southeast of the central and western regions. Except for a slight decrease in Guinan county, the LL mode cluster area had a slight expansion trend in other areas. At the same time, moderately low-risk areas and low-risk areas are dominant in high terrain, while moderately high-risk areas and high-risk areas are dominant in low terrain.

Author Contributions: All the authors Z.W., P.S., J.S., X.Z. and L.Y. contributed to designing the research, writing and revising the manuscript, as well as analyzing the date. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the National Natural Science Foundation of China (41771130, 42101276, 42161043); the Natural Science Foundation of Gansu Province (22JR5RA851); and the Major Project of Key Research Bases for Humanities and Social Sciences Funded by the Ministry of Education of China (22JJD790015).

Data Availability Statement: Unable to share data publicly.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Song, G.; Wang, P.; Wang, Y. Land-Use Types Change Characteristics and Spatial Heterogeneity in Bayan of Heilongjiang Province. *Econ. Geogr.* **2015**, *35*, 163–170.
2. Zheng, K.; Li, C.; Wu, Y. Temporal and spatial variation of landscape ecological risk and influential factors in Yunnan mountainous area. *Acta Ecol. Sin.* **2022**, *42*, 7458–7469.
3. Zhang, W.; Shi, P.; Tong, H. Research on Construction Land Use Benefit and the Coupling Coordination Relationship Based on a Three-Dimensional Frame Model—A Case Study in the Lanzhou-Xining Urban Agglomeration. *Land* **2022**, *11*, 460. [CrossRef]
4. Li, Z.; Shi, P. Spatial Pattern Changes and Influencing Factors of Urban-Rural Construction Land Development Intensity in the Lanzhou—Xining Urban Agglomeration. *J. Ecol. Rural. Environ.* **2020**, *36*, 450–458.
5. Pamela, T.; Christopher, H.; Amon, M. Changes in landuse/landcover patterns and human population growth in the Lake Chivero catchment, Zimbabwe. *Geocarto Int.* **2016**, *32*, 797–811.
6. Zhao, Z.; Zhang, B.; Jin, X. Spatial gradients pattern of landscapes and their relations with environmental factors in Haihe River basin. *Acta Ecol. Sin.* **2011**, *31*, 1925–1935.
7. Ma, S.; An, Y.; Yang, G. The analysis of distribution characteristics and reasons of NDVI change trends along the terrain gradient. *Ecol. Environ. Sci.* **2019**, *28*, 857–864.
8. Pandey, P.; Soupir, M.; Haddad, M.; Rothwell, J. Assessing the impacts of watershed indexes and precipitation on spatial in-stream E. coli concentrations. *Ecol. Indic.* **2012**, *23*, 641–652. [CrossRef]

9. Yin, D.; Qi, X.; Wang, Y.; Xu, R.; An, Y.; Wang, X.; Geng, H. Geochemical characteristics and ecological risk assessment of heavy metals in surface sediments of Baiyangdian Lake, Xiong'an New Area. *Geol. China* **2022**, *49*, 979–992.
10. Zhang, C.; Zhao, L.; Zhang, H.; Chen, M.; Fang, R.; Yao, Y.; Zhang, Q.; Wang, Q. Spatial-temporal characteristics of carbon emissions from land use change in Yellow River Delta region, China. *Ecol. Indic.* **2022**, *136*, 108623. [CrossRef]
11. Dong, Y.; Liu, S.; Wang, J.; Hou, X. Assessment of risk and carbon sequestration function of land consolidation based on landscape pattern. *Trans. Chin. Soc. Agric. Eng.* **2017**, *33*, 246–253.
12. Wang, S.; Zhang, Q.; Wang, Z.; Yu, L.; Xiang, S.; Gao, M. GIS-based ecological risk assessment and ecological zoning in the Three Gorges Reservoir area. *Acta Ecol. Sin.* **2022**, *42*, 4654–4664.
13. Wang, K.; Zheng, H.; Zhao, X.; Sang, Z.; Yan, W.; Cai, Z. Landscape ecological risk assessment of the Hailar River basin based on ecosystem services in China. *Ecol. Indic.* **2023**, *147*, 109795. [CrossRef]
14. Chen, J.; Yang, Y.; Feng, Z.; Huang, R.; Zhou, G.; You, H. Ecological Risk Assessment and Prediction Based on Scale Optimization—A Case Study of Nanning, a Landscape Garden City in China. *Remote Sens.* **2023**, *15*, 1304. [CrossRef]
15. Malekmohammsdi, B.; Jahanishakib, F. Vulnerability assessment of wetland landscape ecosystem services using driver-pressure-state-impact-response (DPSIR) model. *Ecol. Indic.* **2017**, *82*, 293–303. [CrossRef]
16. Chen, H.; Li, D.; Chen, Y.; Zhao, Z. Spatial–Temporal Evolution Monitoring and Ecological Risk Assessment of Coastal Wetlands on Hainan Island, China. *Remote Sens.* **2023**, *15*, 1035. [CrossRef]
17. Yan, J.; Li, G.; Qi, G.; Yao, X.; Qiao, H.; Song, M. Dynamic prediction and impact factors analysis of ecological risk in Chinese farming-pastoral ecotone. *Hum. Ecol. Risk Assess. Int. J.* **2023**, *29*, 123–143. [CrossRef]
18. Cui, B.; Zhang, Y.; Wang, Z.; Gu, C.; Liu, L.; Wei, B. Ecological Risk Assessment of Transboundary Region Based on Land-Cover Change: A Case Study of Gandaki River Basin, Himalayas. *Land* **2022**, *11*, 638. [CrossRef]
19. Wang, Q.; Zhao, X.; Pu, J. Spatial-temporal variations and influencing factors of eco-environment vulnerability in the karst region of Southeast Yunnan, China. *Chin. J. Appl. Ecol.* **2021**, *32*, 2180–2190.
20. Chen, C.; Lv, Y.; Wang, T. Emerging issues and prospects for regionalecological risk assessment. *Acta Ecol. Sin.* **2010**, *30*, 808–816.
21. Wolf, D.; Sobhani, P.; Esmaeilzadeh, H. Assessing Changes in Land Use/Land Cover and Ecological Risk to Conserve Protected Areas in Urban–Rural Contexts. *Land* **2023**, *12*, 231. [CrossRef]
22. Liu, H.; Wang, R.; Sun, H.; Cao, W.; Song, J.; Zhang, X. Spatiotemporal evolution and driving forces of ecosystem service value and ecological risk in the Ulan Buh Desert. *Front. Environ. Sci.* **2022**, *10*, 1053797. [CrossRef]
23. Gao, B.; Wu, Y.; Li, C.; Zheng, K.; Wu, Y.; Wang, M. Multi-Scenario Prediction of Landscape Ecological Risk in the Sichuan-Yunnan Ecological Barrier Based on Terrain Gradients. *Land* **2022**, *11*, 2079. [CrossRef]
24. Li, H.; Su, F.; Guo, C.; Dong, L.; Song, F.; Wei, C. Landscape ecological risk assessment and driving mechanism of coastal estuarine tidal flats—A case study of the liaohe estuary wetlands. *Front. Environ. Sci.* **2022**, *10*, 1070009. [CrossRef]
25. Lin, X.; Wang, Z. Landscape ecological risk assessment and its driving factors of multi-mountainous city. *Ecol. Indic.* **2023**, *146*, 109823. [CrossRef]
26. Tang, C.; Wu, X.; Zhang, Q. Ecological security evaluations of the tourism industry in Ecological Conservation Development Areas: A case study of Beijing's ECDA. *J. Clean. Prod.* **2018**, *197*, 999–1010. [CrossRef]
27. Zhang, X.; Zhou, Q.; Zhang, J. Land UseEcological Risk Evaluation of the Barrier Area of Three Gorges Reservoir Area in Chongging Based on Comprehensive Fuzzy Evaluation. *Res. Soil Water Conserv.* **2013**, *20*, 262–266+301.
28. Pereira, J.; Vásquez, Ó.C. The single machine weighted mean squared deviation problem. *Eur. J. Oper. Res.* **2017**, *261*, 515–529. [CrossRef]
29. Li, H.; Jing, S.; Yang, Z. Ecological vulnerability assessment for ecological conservation and environmental management. *J. Environ. Manag.* **2018**, *206*, 1115–1125.
30. Dzeroski, S. Applications of symbolic machine learning to ecological modelling. *Ecol. Model.* **2001**, *146*, 263–273. [CrossRef]
31. Wang, Y.; Yang, Z.; Yu, M.; Lin, R.; Zhu, L.; Bai, F. Integrating Ecosystem Health and Services for Assessing Ecological Risk and its Response to Typical Land-Use Patterns in the Eco-fragile Region, North China. *Environ. Manag.* **2022**, *71*, 867–884. [CrossRef] [PubMed]
32. Guo, Z.; Wei, W.; Pang, S.; Li, Z.; Zhou, J.; Xie, B. Spatio-Temporal evolution and motivation analysis of ecological vulnerability in Arid Inland River Basin based on SPCA and remote sensing index: A case study on the Shiyang River Basin. *Acta Ecol. Sin.* **2019**, *39*, 2558–2572.
33. Pan, J.; Liu, X. Assessment of landscape ecological security and optimization of landscape pattern based on spatial principal component analysis and resistance model in arid inland area: A case study of Ganzhou District, Zhangye City, Northwest China. *Chin. J. Appl. Ecol.* **2015**, *26*, 3126–3136.
34. Liu, D.; Chen, H.; Geng, T. Spatiotemporal changes of regional ecological risks in Shaanxi Province based on geomorphologic regionalization. *Prog. Geogr.* **2020**, *39*, 243–254. [CrossRef]
35. Zhang, Q.; Ye, P.; Wang, J. Scientific discussion and ponder on the coordination of natural environmental in the upper Yellow River Basin. *Adv. Earth Sci.* **2023**, *38*, 320.
36. Luo, J.; Zhang, X.; Shi, P. Land Use Multi-Functionality and Zoning Governance Strategy of Densely Populated Areas in the Upper Reaches of the Yellow River: A Case Study of the Lanzhou–Xining Region, China. *Land* **2022**, *11*, 897. [CrossRef]
37. Tong, H.; Shi, P.; Luo, J.; Liu, X. The Structure and Pattern of Urban Network in the Lanzhou-Xining Urban Agglomeration. *Chin. Geogr. Sci.* **2020**, *30*, 59–74. [CrossRef]

38. Ha, K.; Ding, Q.; Men, M. Spatial distribution of land use and its relationship with terrain factors in hilly area. *Geogr. Res.* **2015**, *34*, 909–921.
39. Tang, G.; Song, J. Comparison of Slope Classification Methods in Slope Mapping from DEMs. *J. Soil Water Conserv.* **2006**, *2*, 157–160.
40. Gong, W.; Wang, H.; Wang, X.; Fan, W.; Stott, P. Effect of terrain on landscape patterns and ecological effects by a gradient-based RS and GIS analysis. *J. For. Res.* **2017**, *28*, 1061–1072. [CrossRef]
41. Wang, X.; Liu, G.; Xiang, A.; Xiao, S.; Lin, D. Terrain gradient response of landscape ecological environment to land use and land use pattern in the hilly watershed in South China. *Ecol. Indic.* **2023**, *146*, 109797. [CrossRef]
42. Zhang, X.; Shen, J.; Sun, F.; Wang, S. Spatial-Temporal Evolution and Influencing Factors Analysis of Ecosystem Services Value: A Case Study in Sunan Canal Basin of Jiangsu Province, Eastern China. *Remote Sens.* **2022**, *15*, 112. [CrossRef]
43. Tong, W.; Lang, F. Remote Sensing Monitoring and Analysis of LUCC of Wuhan in Recent 20 Years. *J. Geomat.* **2021**, *46*, 83–87.
44. Fang, C. Progress and the future direction of research into urban agglomeration in China. *Acta Geogr. Sin.* **2014**, *69*, 1130–1144.
45. Wei, S.; Pan, J.; Liu, X. Landscape ecological safety assessment and landscape pattern optimization in arid inland river basin: Take Ganzhou district as an example. *Hum. Ecol. Risk Assess. Int. J.* **2020**, *26*, 782–806. [CrossRef]
46. Li, Q.; Zhang, Z.; Wan, L. Landscape pattern optimization in Ningjiang River Basin based on landscape ecological risk assessment. *Acta Geogr. Sin.* **2019**, *74*, 1420–1437.
47. Li, H.; Ma, T.; Wang, K. Construction of ecological security pattern in Northern Peixian based on MCR and SPCA. *J. Ecol. Rural. Environ.* **2020**, *36*, 1036–1045.
48. Zou, T.; Kunihiko, Y. Environmental vulnerability evaluation using a spatial principal components approach in the Daxing'anling region, China. *Ecol. Indic.* **2017**, *78*, 405–415. [CrossRef]
49. Lu, Y.; Yan, L.; Xu, X. Ecological Vulnerability Assessment and Spatial Auto-Correlation Analysis over the Bohai Rim Region. *Resour. Sci.* **2010**, *32*, 303–308.
50. Xu, Y.; Zhong, Y.; Feng, X.; Hu, L.; Zheng, L. Ecological risk pattern of Poyang Lake basin based on land use. *Acta Ecol. Sin.* **2016**, *36*, 7850–7857.
51. Shi, Z.; Ma, L.; Zhang, W.; Gong, M. Differentiation and correlation of spatial pattern and multifunction in rural settlements considering topographic gradients: Evidence from Loess Hilly Region, China. *J. Environ. Manag.* **2022**, *315*, 115127. [CrossRef] [PubMed]
52. Li, G.; Fang, C. Quantitative function identification and analysis of urban ecological production living spaces. *Acta Geogr. Sin.* **2016**, *71*, 49–65.
53. Liao, J.; Jia, Y.; Tang, L.; Huang, Q.; Wang, Y.; Huang, N. Assessment of urbanization-induced ecological risks in an area with significant ecosystem services based on land use/cover change scenarios. *Int. J. Sustain. Dev. World Ecol.* **2018**, *25*, 448–457. [CrossRef]
54. Feng, Y.; Li, G. Interaction between urbanization and eco-environment in Tibetan Plateau. *Acta Geogr. Sin.* **2020**, *75*, 1386–1405. [CrossRef]
55. Liang, X.; Li, Y.; Zhao, Y. Coupling Land Use Analysis and Ecological Risk Assessment. *Mt. Res. Dev.* **2020**, *40*, R1–R10. [CrossRef]
56. Wu, T.; Sun, P. Study on Import Trade Potential and Influencing Factors of National Woody Forest Products along "Silk Road Economic Belt". *Areal Res. Dev.* **2021**, *40*, 32–38.
57. Li, Q.; Shi, X.; Wu, Q. Exploring suitable topographical factor conditions for vegetation growth in Wanhuigou catchment on the Loess Plateau, China: A new perspective for ecological protection and restoration. *Ecol. Eng.* **2020**, *158*, 106053. [CrossRef]
58. Amin, R.; Meghann, J.; Morgan, C. Incorporating social values and wildlife habitats for biodiversity conservation modeling in landscapes of the Great Plains. *Landsc. Ecol.* **2021**, *36*, 1137–1160.
59. Guo, A.; Zhang, Y.; Yang, C. The Impact of Spatial Structure of Strategic Emerging Industries on Urban Carbon Emission Intensity—Based on the Investigation of Big Data of Enterprises in Lanzhou-Xining Urban Agglomeration. *Urban Probl.* **2022**, *322*, 4–16.
60. Wang, G.; Dang, P.; Li, Y. Research on the evaluation system of new energy development decision in Dunhuang city based on analytic hierarchy process. *Energy Rep.* **2022**, *8*, 129–135. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.