Academic Journal of Environment & Earth Science
ISSN 2616-5872 Vol.5, Issue 1: 38-47, DOI: 10.25236/AJEE.2023.050106

Landscape Ecological Risk Assessment during 2000–2020 Based on Land Use and Land Cover Changes in Lanzhou City

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Abstract: *A landscape ecological risk model was constructed to evaluate the landscape ecological risk pertaining to Lanzhou City based on the land use and land cover (LULC) changes obtained using remote sensing data for the years 2000, 2010, and 2020 covering the duration 2010–2020. Results show that during 2010–2020, the LULC types in Lanzhou City mainly comprised of cropland, grassland, and construction land. In terms of LULC changes in Lanzhou City the trend shows a decrease in cropland and increase in construction land with an increase in the fragmentation and separation of cropland, grassland, and shrubland, which is pronounced for cropland and shrubland. The spatial distribution pattern of ecological risk shows very high and very low levels of risk in the main urban area in the south and in the northwest of the city, respectively. From 2010 to 2020, the ecological risk level of the landscape shows a gradual increase with evidence for significant changes. The results of the study provide a scientific basis for the optimization of the landscape pattern, rational utilization and development of land resources in Lanzhou City, and lay a solid foundation for the formulation of ecological risk control measures.*

Keywords: *land use and land cover change; landscape pattern; ecological risk assessment; spatiotemporal differentiation; Lanzhou City*

1. Introduction

Ecological risk assessment has gained serious attention among scholars worldwide because of the continuous changes in the ecological environment due to rapid urban expansion and the growing awareness among urban populations toward ecological issues and environmental protection [1,2]. Ecological risk assessment has become an effective tool and an important basis for regional ecological restoration, natural resource management, sustainable development, other related activities, and for decision making. Compared with traditional ecological risk assessment methods, regional ecological risk assessment pays more attention to the influence of scale, space, and level of ecological risk processes [3]. Regional ecological risk assessment methods involve two aspects: the construction of models for hazard evaluation, exposure to hazards, and characterization of risk with respect to sources and receptors [4–6]. Ecological risk evaluation models combine landscape pattern indicators such as LULC changes and landscape indices to evaluate the comprehensive ecological risk of a region [7, 8].

A symposium on the ecological protection and high-quality development of the Yellow River Basin was hosted in Zhengzhou. It was stressed that the Yellow River Basin is an important ecological region and economic zone, which helps in winning the battle against poverty, and therefore, it is vital for the economic and social development of China and its ecological security. Lanzhou is a major city situated in the upper reaches of the Yellow River. It is the only provincial capital city through which the Yellow River flows, and therefore, it has an important role in protecting and strengthening the ecological security of the Yellow River Basin. Lanzhou is an important transportation hub in the northwest and a key city on the Silk Road Economic Belt. Because of the impetus provided by the Great Western Development Strategy, in which Lanzhou is a part, the city has undergone an exponential increase in the rate of urban expansion and witnessed drastic changes in terms of LULC, and consequently, has undergone intense changes in its ecological environment. We used LULC data on Lanzhou City for the years 2000, 2010, and 2020 to systematically analyze changes during 2000–2020 in terms of the trends in land use transformation and their spatial distribution patterns. We selected the grid as the evaluation unit based on the landscape pattern, constructed an ecological risk evaluation index system, analyzed the spatiotemporal variations of ecological risk, and evaluated the impact of land use change on ecological risk to provide a better understanding. The developed landscape ecological risk assessment system is intended to provide a scientific basis for the optimization of landscape pattern and the rational utilization and development of land resources in Lanzhou City, and lay a solid foundation for the formulation of ecological risk control measures to foster sustainable development.

2. Materials and methods

2.1. Overview of the study area

The study area covers the Lanzhou City, the capital of Gansu Province (Figure 1), which is located between 35° 34′ and 37° 08′ N and 102° 35′ and 104° 35′ E with an area of 12958.17 km^2. Lanzhou City has three counties and five districts under its jurisdiction including the fifth national-level new district, the Lanzhou New District, and two national-level development zones such as Lanzhou High-tech Industrial Development Zone and Lanzhou Economic Zone. Lanzhou City is adjacent to Baiyin District and Jingtai and Jingyuan Counties in Baiyin City in the north and northeast, Huining County in Baiyin City in the east and south. To the east and south, it is connected to Huining County of Baiyin City, Dingxi City, Anding County, Lintao County, and Yongjing County of the Linxia Hui Autonomous Prefecture. To the southwest and west, it borders Qinghai Province, and to the northwest, it is adjacent to the Tianzhu Tibetan Autonomous County of Wuwei City. The climate is characterized by low precipitation, abundant sunshine, high evaporation, dryness, and a large temperature difference between day and night. Significant seasonal changes occur with a dry and windy spring, not a scorching summer with concentrated precipitation, a cool and fast cooling autumn, and a cold and dry winter. Lanzhou is located at the intersection of the Loess Plateau and the Qinghai–Tibet Plateau in China, with a high terrain in the west and south and a low terrain in the northeast. Lanzhou consists of four main types of landforms, namely, mesas, hills, mountain basins, and river valleys. With the implementation of the Great Western Development Strategy, Lanzhou has developed rapidly in recent years, and the demand for construction land has increased and resulting in significant increase in pressure on the ecological environment.

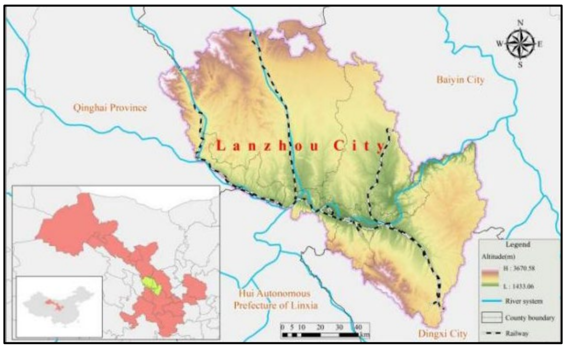

Figure 1: Map of the study area

2.2. Data sources and processing

Data were obtained from the China Land Use Status Remote Sensing Monitoring Database[9,10] for 2000, 2010, and 2020. Data were generated through manual visual interpretation of Landsat Thematic Mapper and Enhanced Thematic Mapper remote sensing images of each phase. The overall identification accuracy is above 95% compared to field survey data. Accuracies of up to 99% for farmland and 98% for grassland, forest, and built-up areas were achieved[9,10].

Based on the classification criteria provided by the Resource and Environment Science Data Centre of the Chinese Academy of Sciences, the LULC types used in the study were classified into six primary types such as arable land, forest land, grassland, waterbodies, urban/rural, industrial and mining, residential land, and unused land to accurately reflect the LULC status of the study area and its spatiotemporal changes comprehensively.

2.3. Research methodology

We applied the principles of landscape ecology, spatial statistical analyses based on LULC change, and landscape pattern and ecological vulnerability indexes to calculate the comprehensive ecological risk index for Lanzhou City. We combined the spatial analysis function of geographic information system (GIS) with the comprehensive ecological risk index to determine the ecological risk distribution and its spatiotemporal changes in the study area considering research outputs from related studies [11–13]. The study area was divided into units of 5 × 5 km for sampling of ecological risk (ecological risk evaluation units), and 604 cells were obtained with equal spacing. The ecological risk index value of the center of each cell was calculated individually to obtain their ecological risk levels. The landscape index method is commonly used in geology to quantify landscape patterns and their changes through the application of various landscape indices. We used landscape disturbance and vulnerability indexes to construct a landscape ecological risk index (ERI) model to characterize the relationship between the LULC type and ecological risk within a sample site.

The landscape disturbance index (I) was used to reflect the degree of disturbance to the ecosystems represented by different landscape types. The landscape disturbance index was constructed using fragmentation, separation, and dominance of landscape, and it was calculated as follows:

$$I_i = aC_i + bF_i + cD_i \qquad (1)$$

where I_i denotes the landscape disturbance index for landscape i. C_i is the landscape fragmentation, which indicates the degree of fragmentation of a fragmented landscape and is often used to describe the degree of fragmentation of an ecosystem following disturbance reflecting reduced biodiversity, and it was calculated as

$$C_i = N_i/A_{ki} \qquad (2)$$

The larger the number of patches of landscape type i, the more fragmented the landscape type i is. F_i is the degree of separation, which refers to the degree of dispersion of patches of landscape types in spatial distribution; the larger the value of F_i, the more dispersed the distribution of landscape types and the more frequent the succession between different landscape types. F_i was calculated as

$$F_i = \sqrt{S_i}/2P_i \qquad (3)$$

S_i in equation (3) is the landscape type distance index, and it was calculated as

$$S_i = N_i/A_k \qquad (4)$$

P_i in equation (3) is the relative cover of the landscape type, and it was calculated as

$$P_i = A_{ki}/A_k \qquad (5)$$

D_i in equation (1) represents the landscape type dominance index; the smaller the landscape dominance index the greater the landscape diversity, and it was calculated as

$$D_i = \mathrm{d}\mathrm{L}_i + eP_i \qquad (6)$$

L_i in equation (6) is the relative density of landscape types, and it was calculated as

$$L_i = N_i/N \qquad (7)$$

where N is the total number of patches of all landscape types, d and e are the weights of the relative density of landscape type and the relative cover of landscape type, respectively. In the calculation of landscape dominance the relative cover of landscape type is considered the most important followed by the relative density of landscape type, whose weights are 0.6 and 0.4, respectively. [14]. a, b, and c represent the weights of fragmentation, separation, and dominance of landscape, respectively, and a + b + c = 1. Based on the results of previous studies [15, 16] and combining them with the actual situation of the study area, the size of each landscape index on the ecological environment was analyzed comprehensively. Fragmentation, separation, and dominance were assigned weights of a = 0.5, b = 0.3, and c = 0.2, respectively [17–19].

The landscape vulnerability index (V) was used to characterize the resistances of ecosystem structures to external disturbances within different landscape types; the higher the value, the weaker the resistance of the landscape to external disturbances and the more fragile the ecosystem; conversely, the lower the value, the more stable the landscape. Based on results of relevant studies and the actual conditions in the study area[20–23], the eight considered landscape types were assigned values in the order of vulnerability and normalized to obtain a landscape type vulnerability grading table (Table 1).

Table 1: Classification of vulnerability based on landscape type

Type of land	Assignment	V_i
Arable land	1	0.028
Woodland	2	0.056
Grassland	3	0.083
Shrubland	4	0.111
Wetlands	5	0.139
Waterbodies	6	0.167
Building sites	7	0.194
Bare land	8	0.222

The landscape disturbance index (*I*) and the landscape vulnerability index (*V*) were used to construct a model using the values in Table 1 to calculate the landscape ecological risk index (*ERI*), which was calculated as follows:

$$ERI_k = \sum_{n}^{i=1} \frac{A_{ki} I_i V_i}{A_k}$$

where ERI_k denotes the k ecological risk index of the landscape in the area and n denotes the number of landscape types. A_{ki} denotes the k of the small area of the landscape and i denotes the area of the subdivision. A_k denotes the k of the total area of the subdivision's landscape.

3. Results and Discussion

3.1. Changes in spatiotemporal patterns of land use

LULC data for Lanzhou City from 2000 to 2020 were used to obtain its LULC status in 2000, 2010, and 2020 (Table 2). The LULC change transfer matrix of Lanzhou City from 2000 to 2020 was calculated using ArcMap 10.2 (Table 3).

Table 2: LULC status of Lanzhou City in 2000, 2010, and 2020

Year	2000		2010		2020	
Land Class	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
Arable land	5275.90	40.71%	5228.81	40.35%	4838.17	37.34%
Woodland	110.48	0.85%	77.50	0.60%	232.65	1.80%
Grassland	7083.90	54.67%	7118.82	54.94%	7012.21	54.11%
Shrubland	176.98	1.37%	176.56	1.36%	11.54	0.09%
Wetlands	1.22	0.01%	0.56	0.00%	0.49	0.00%
Waterbodies	40.73	0.31%	35.64	0.28%	39.83	0.31%
Building sites	199.59	1.54%	250.89	1.94%	763.51	5.89%
Bare land	69.37	0.54%	69.38	0.54%	59.76	0.46%

According to Table 2, the dominant types of LULC in Lanzhou in 2020 are arable land, grassland, and construction land, accounting for 37.34, 54.11, and 5.89%, respectively. Since 2000, the largest changes in area have occurred in construction land and arable land. The total increase in construction land is 563.92 km^2, with the proportion increasing from 1.54% in 2000 to 5.89% in 2020. This is related to the rapid urbanization process in Lanzhou over the past 20 years. Under the Great Western Development Strategy, the Lanzhou New Area and the New Silk Road Economic Belt were established, and Lanzhou has become an important transportation hub and it is the central city in the northwest inland, therefore, significant acceleration in urbanization has occurred[24]. In contrast, arable land shows a decreasing trend year-on-year, with a total decrease of 437.73 km^2, and its proportion decreased from 40.71% in 2000 to 37.34% in 2020. Combining with information provided in Table 3, it can be seen that most of the reduced arable land has been transferred to construction land. [25] This change is related to the unique geographical characteristics of Lanzhou, which is located in the upper reaches of the Yellow River, and the urban area is narrow from north to south and long from east to west, depicting "two mountains sandwiched by a river." The expansion of construction land has inevitably taken up some of the arable land, resulting in an overall trend of LULC change from arable land to construction land over the last 20 years.

Table 3: Land use and land cover change transfer matrix in Lanzhou City during 2000–2020

(km^2)	2020							
2000	Arable land	Woodland	Grassland	Shrubland	Wetlands	Waterbodies	Building sites	Bare land
Arable land	4444.71	22.17	338.40	0.08	0.18	10.14	424.11	4.34
Woodland	0.88	65.27	43.61	0.44		0.18	0.06	
Grassland	353.60	129.11	6453.89	3.60	0.01	2.08	120.25	20.89
Shrubland	8.28	15.96	143.98	7.42		0.77	0.51	0.00
Wetlands	0.76		0.01			0.22	0.23	
Waterbodies	8.99	0.05	1.13		0.31	26.07	4.17	0.00
Building sites	16.29	0.00	2.14			0.34	212.06	0.02
Bare land	4.06		28.58			0.01	2.22	34.49

3.2. Changes in landscape pattern

The relevant landscape indices for each landscape type for 2000, 2010, and 2020 were calculated using FRAGSTATS 4.2 software for both class and landscape levels (Table 4).

Table 4: Landscape indices related to each landscape type during 2000–2020

Type of landscape	Year	CA	NP	C_i	F_i	L_i	D_i	U_i	R_i
Arable land	2000	524285.34	3066	0.0058	0.0601	0.0613	0.2674	0.0744	0.0021
	2010	527835.11	2868	0.0054	0.0577	0.0581	0.2677	0.0736	0.0020
	2020	483656.06	7871	0.0163	0.1044	0.1595	0.2878	0.0970	0.0027
Wood land	2000	11044.54	2629	0.2380	2.6419	0.0526	0.0261	0.9168	0.0509
	2010	7747.50	2627	0.3391	3.7648	0.0532	0.0249	1.3039	0.0724
	2020	23257.52	2627	0.1130	1.2541	0.0532	0.0321	0.4391	0.0244
Grass land	2000	708153.62	14083	0.0199	0.0954	0.2817	0.4407	0.1267	0.0106
	2010	711645.09	14059	0.0198	0.0948	0.2850	0.4436	0.1270	0.0106
	2020	700987.42	14059	0.0201	0.0963	0.2850	0.4387	0.1266	0.0106
Shrub land	2000	17691.61	21197	1.1981	4.6832	0.4240	0.1778	2.0396	0.2266
	2010	17650.23	21204	1.2013	4.6949	0.4298	0.1801	2.0452	0.2272
	2020	1153.69	21204	18.3794	71.8275	0.4298	0.1724	30.7724	3.4192
Wet lands	2000	122.27	19	0.1554	20.2875	0.0004	0.0002	6.1640	0.8561
	2010	55.96	8	0.1430	28.7625	0.0002	0.0001	8.7002	1.2084
	2020	49.30	8	0.1623	32.6464	0.0002	0.0001	9.8751	1.3715
Water bodies	2000	4071.50	518	0.1272	3.1811	0.0104	0.0060	1.0192	0.1699
	2010	3562.45	152	0.0427	1.9694	0.0031	0.0029	0.6127	0.1021
	2020	3981.53	152	0.0382	1.7621	0.0031	0.0031	0.5483	0.0914
Building sites	2000	23081.26	622	0.0269	0.6149	0.0124	0.0157	0.2011	0.0391
	2010	19952.56	548	0.0275	0.6677	0.0111	0.0137	0.2168	0.0421
	2020	76325.24	2868	0.0376	0.3993	0.0581	0.0586	0.1503	0.0292
Bare land	2000	6934.80	7864	1.1340	7.2771	0.1573	0.0661	2.7633	0.6141
	2010	6936.06	7871	1.1348	7.2790	0.1595	0.0670	2.7645	0.6143
	2020	5974.19	548	0.0917	2.2299	0.0111	0.0072	0.7163	0.1592

Notes: CA: patch area, NP: number of patches, C_i: fragmentation of landscape type, F_i: separation of landscape type, L_i: relative density of landscape type, D_i: dominance of landscape type, U_i: landscape disturbance index, R_i: landscape loss index

From Table 4, we can see that the areas of patches of four landscape types such as arable land, woodland, shrubland, and construction land have changed significantly. Arable land and shrubland show a decreasing trend and woodland and construction land show an increasing trend. From 2010 to 2020, shrubland decreased sharply and construction land increased rapidly. Arable land, construction land, and bare land show significant changes in the number of patches. The combined changes in the area of patches show that the construction and development of urban ecological land has become more systematic from 2000 to 2020 because of the accelerated urbanization of Lanzhou City. However, due to the implementation of green development and natural factors such as climate and topography, the decrease in the area of woodland and wetland remains relatively small. With urban expansion, some arable land is inevitably occupied, and arable land shows a gradual trend of fragmentation from 2000 to 2020. However, shrubland shows significant increase in the fragmentation level from 2010 to 2020, which may be related to the overall greening of Lanzhou City in the last decade and the policy of ‘efficient use appropriate to the location,’ wherein human interventions have changed traditional low shrubs into public welfare and protective forests with higher ecological and economic values. The disturbance of shrubs and wetlands showed a significant upward trend from 2010 to 2020. In summary, the changes in the above landscape types from 2000 to 2020 are closely related to human activities.

3.3. Spatiotemporal variation of landscape ecological risk

3.3.1. Temporal changes of landscape ecological risk

The temporal changes of landscape ecological risk in Lanzhou City were estimated according to the landscape ecological risk index model. First, the *ERI* index of each sample plot of landscape ecological risk was calculated. Second, data were imported into ArcMap as *ERI* index centroids based on the fishnet coordinate points and interpolated. Finally, according to the range of ERI index values, the landscape ecological risk levels in Lanzhou City were classified into five risk levels in ArcMap in combination with results of related research [26-27] as follows: very low ($ERI \leq 0.01$), low ($0.01 < ERI \leq 0.15$), medium ($0.15 < ERI \leq 0.25$), high ($0.25 < ERI \leq 0.35$), and very high ($ERI > 0.35$). A line graph of the changes in the annual average ecological risk index of Lanzhou City is shown in Figure 2. The distribution of the area of ecological risk zones and their percentages for each considered year were calculated (Figure 3 and Table 5).

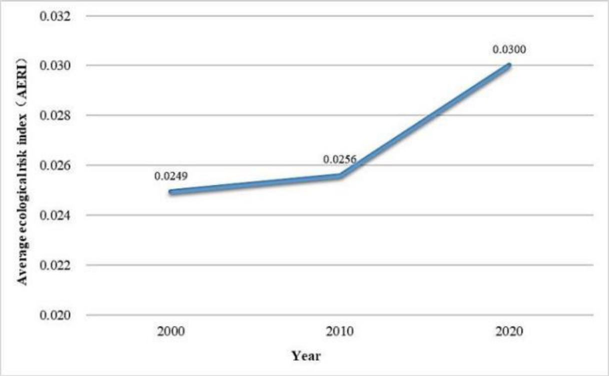

Figure 2: Changes in the average ecological risk index during 2000–2020

Figure 2 shows that the ecological risk index for Lanzhou City during 2000–2020 is on an upward trend, with a small change of only 0.0007 from 2000 to 2010; however, from 2010 to 2020, the index increases from 0.0256 to 0.0300, an increase of 0.0044 corresponding to 6.3 times compared to the previous decade. Table 4 shows that from 2000 to 2010, low and very low ecological risk areas had the highest proportion in Lanzhou City; however, by 2020, the medium ecological risk areas had the largest proportion with a significant increase in the proportion of very high ecological risk areas. Although the proportion of high ecological risk in 2010 decreased, the proportion in 2020 increased instead of decreasing, from 7.95 to 16.76%, an increase of 10.25% compared to 2000.

Table 5: Area and proportion of different ecological risk areas from 2000 to 2020

Ecological risk level	Year	Area (km²)	Percentage (%)
Very low ecological risk area	2000	3211.5213	24.79%
	2010	3649.0365	28.17%
	2020	2856.645	22.05%
Low ecological risk area	2000	3584.6127	27.67%
	2010	3634.5735	28.05%
	2020	2855.2329	22.04%
Medium ecological risk area	2000	2822.0832	21.78%
	2010	2669.274	20.60%
	2020	2963.7234	22.88%
High ecological risk area	2000	1327.4091	10.25%
	2010	1029.6126	7.95%
	2020	2171.5695	16.76%
Very high ecological risk area	2000	2009.5614	15.51%
	2010	1972.6911	15.23%
	2020	2108.0169	16.27%

The above results show that the impact of human activities on the natural environment in Lanzhou

City was more significant from 2000 to 2010. Anthropogenic activities such as urban expansion, mountain cutting and land reclamation, and artificial alteration of surface vegetation gradually increased the ecological risk of the urban landscape from a medium risk level in 2000 to a high risk level in 2020. The increase in ecological risk level continues to remain a serious issue. (Figure 3)

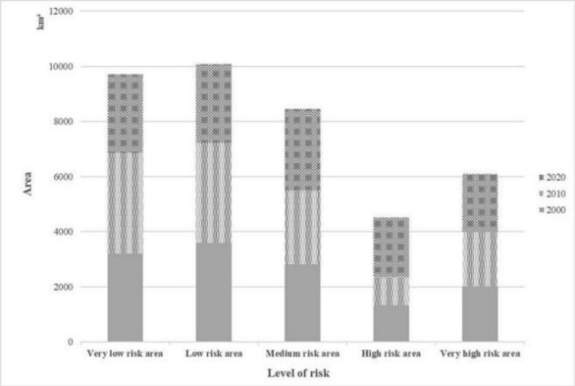

Figure 3: Histogram of the proportion of areas of different ecological risk levels in 2000, 2010, and 2020

3.3.2. Spatial changes of landscape ecological risk

The spatial distributions of ecological risks in Lanzhou City for 2000, 2010, and 2020 were analyzed using interpolation in ArcMap (Figure 4) and the spatial area transfer matrixes of ecological risks for each year were obtained (Tables 6 and 7).

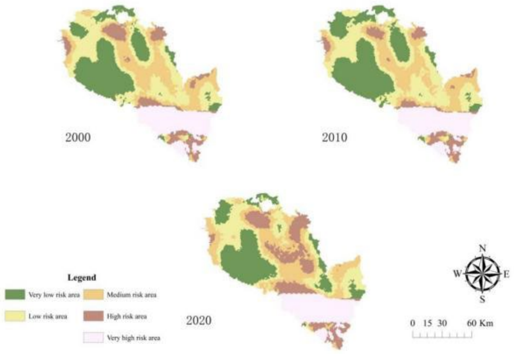

Figure 4: Spatial distribution of different ecological risk levels in Lanzhou during 2000–2020

Figure 4 shows that in 2000 the very low and low risk areas in Lanzhou were mainly located in the area west of the Zhuanglang River in Yongdeng County, the northern part of Wushengyi and Pingcheng Township areas, and the Qinwangchuan Basin area in Gaolan County. High risk areas were mainly located in the western and central parts of Yongdeng County, the northern part of Gaolan County, and the areas north and south of the main urban area in Qilihe District and most of Yuzhezhong County. Very high risk areas were concentrated in the urban areas, including Chengguan, Anning, Xigu, and Qilihe Districts. The distribution of high and very high risk areas in Lanzhou City is consistent with the distribution of construction land within the city.

Table 6: Area transfer matrix of different ecological risk levels in Lanzhou City from 2000 to 2010

Area/km^2			2010		
2000	Very low ecological risk area	Low ecological risk areas	Medium ecological risk area	High ecological risk area	Very high ecological risk area
Very low ecological risk area	3206	5	0	0	
Low ecological risk area	434	3142	7	0	0
Medium ecological risk area	8	485	2308	20	0
High ecological risk area	0	2	353	971	1
Very high ecological risk area	0	0	0	38	1971

In 2010, the spatial distribution of various levels of ecological risk areas in Lanzhou City did not change much compared to 2000. The main changes were in the very low and low ecological risk areas.

A total of 485 km^2 of medium risk areas were transformed into low risk areas and 434 km^2 of low risk areas were transformed into very low risk areas. The spatial changes mainly occurred in the northern part of Yongdeng County, which shows an increasing trend of very low ecological risk areas during 2000–2020, extending along the northeast direction.

Table 7: Area transfer matrix of different ecological risk levels in Lanzhou City from 2010 to 2020

Area/km^2			2020		
2010	Very low ecological risk area	Low ecological risk area	Medium ecological risk area	High ecological risk area	Very high ecological risk area
Very low ecological risk area	2529	843	233	43	0
Low ecological risk area	325	1709	1289	311	0
Medium ecological risk area	2	302	1317	1038	9
High ecological risk area	0	0	124	743	161
Very high ecological risk area	0	0	0	36	1937

The spatial distribution of ecological risk areas in Lanzhou City in 2020 changed significantly compared to that in 2010. From 2010 to 2020, the overall trend shows a decrease in very low and low risk areas and an increase in medium and high risk areas. The highest transformation of area was in the conversion of low risk areas into medium risk areas, with a total of 1289 km^2, followed by the transformation of medium risk areas to high risk areas, with a total of 1038 km^2. Although there is an increase in very low risk areas, it was mainly because of the transfer of low risk areas with a total of 325 km^2, which is far less than the transfer of high and very high risk areas. In the Qinwangchuan Basin of Gaolan County, most of the very low risk areas were transformed into medium and high risk areas. In addition, the high and very high risk areas expanded further in the north-south direction in the main urban area. Most of the low risk areas in the southern part of Gaolan and Yongdeng counties were transformed into medium risk areas. The reasons for such changes are twofold. First, from 2010 to 2020, the rapid increase in the urbanization level of Lanzhou City was in the east-west direction influenced by topography, and then, it expanded in the north-south direction, resulting in mountain transformation caused by land cutting projects in the northern mountains. Second, the Lanzhou New Area, a national-level new area approved by the State Council in August 2012, is located in the Qinwangchuan Basin. The establishment of the Lanzhou New Area brought economic growth, industrial transformation, and capital investment to Lanzhou City, but it also led to a huge change in the natural ecological environment of the area because of the construction of many enterprises and factories and residential areas, which further increased human activities. A large area of original ground cover was modified and destroyed, resulting in an increase in human interference causing changes to different types of local landscapes and a rapid rise in ecological risk levels.

4. Conclusions

We constructed a model for landscape ecological risk assessment in Lanzhou City based on remote sensing data on LULC in Lanzhou City for the years 2000, 2010, and 2020 using a combination of relevant landscape indicators, and evaluated the landscape ecological risk. The conclusions of our study are as follows:

(1) During 2000–2020, the types of LULC in Lanzhou City were mainly arable land, grassland, and construction land. The changes in LULC mainly showed a trend of decreasing arable land and increasing construction land. Arable land was mainly converted to construction land during 2010–2020 because of the high rate of urbanization in Lanzhou from north to south, especially in areas such as Yongdeng, Gaolan, and Yuzhong counties.

(2) During 2000–2020, the changes in landscape pattern in Lanzhou showed an increase in the fragmentation and separation of landscape types such as arable land, grassland, and shrubland, with the trend of fragmentation prominent in arable land and shrubland. The decrease in landscape fragmentation and disturbance indices of forest land and waterbodies was because of the increase in awareness on ecological protection among the city’s population and the government’s policy of

"protecting forests and water," resulting in the effective protection and restoration of forests and waterbodies to improve the ecological environment.

(3) During 2000–2020, Lanzhou showed spatial distribution patterns of very high ecological risk in the main urban areas in the south-central part of the city and very low ecological risk in the north-western part. The very high risk areas were Chengguan, Anning, Qilihe, and Xigu Districts, while the very low and low risk areas were in the western and northern parts of Yongdeng County, north-central part of Gaolan County, and the eastern part of Yuzhong County, where human activities were relatively less. A gradual increase and significant change in ecological risk areas were observed from 2010 to 2020, with the low ecological risk areas shifting to middle ecological risk areas and middle ecological risk areas shifting to high ecological risk areas.

(4) The urban expansion of Lanzhou City during 2000–2020 led to a trend of decreasing patch size and increasing fragmentation of arable land, shrubs, and waterbodies, which were less resistant to human disturbance. At the same time, the expansion of construction land caused the modification of a large number of natural surfaces affecting the natural succession of the original landscape and compressing the habitat area of plants and animals. Areas of high ecological risk are consistent with areas of high human activity. Therefore, by rationalizing the use of land resources and optimizing the landscape pattern of very high risk areas, the increase in landscape ecological risk caused by human activities and urban expansion can be effectively reduced, thereby Lanzhou can be sustainably developed.

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