Ecological risk assessment of ecological landscape pattern in Qin'an County

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Abstract. Based on the land use data of 1980, 2000 and 2018, combined with ArcGIS and fragstats4.2, the landscape index of the study area was calculated, and the spatiotemporal change process of landscape ecological risk in Qin'an County in the past 40 years was analyzed, which laid the foundation for the formulation of ecological risk control measures in the study area. The results show that: (1) from 1980 s to 2018, the landscape pattern of Qin'an County has changed obviously, the cultivated land decreased significantly, the construction land expanded obviously, and the expansion area mainly came from the transformation of cultivated land. From 1980 s to 2018, the landscape fragmentation of Qin'an County showed an overall increasing trend. (2) The landscape ecological risk level has a decreasing trend, the area of high risk area is significantly reduced, and the area of low risk area is increased. (3) From the spatial distribution analysis, the overall risk type of Qin'an County has an increasing trend from southwest to northeast. The high-risk areas are mainly distributed in the surrounding areas of Liuping, and the main landscape types in this area are cultivated land and grassland, which are easily disturbed by human activities; the low-risk areas are mainly distributed in Qin'an County, and the main landscape type is construction land, with strong anti-interference ability and lowest risk value.

1. Introduction

Ecological risk is the risk that the ecosystem and its components bear under the interference of natural or human activities. It refers to the possible adverse impact of uncertain accidents or disasters on the structure and function of the ecosystem in a certain area[1]. Ecological risk assessment is the assessment of the possibility of adverse ecological impact, which is of great significance to the establishment of ecological risk early warning mechanism and the reduction of ecological risk probability. Landscape ecological risk assessment originates from ecological risk assessment[2]. However, landscape ecological assessment pays more attention to the spatial and temporal heterogeneity and scale effect of the region, pays attention to the spatial and temporal differentiation characteristics of risk and the risk expression of specific spatial pattern for ecological function and process, rather than the quantitative assessment of the overall ecological environment risk that the traditional ecological risk assessment focuses on[3].
As one of the 50 important ecological function protection areas in the national ecological function zoning[4], the Loess Plateau Ecological Function Reserve has an important ecological function of soil conservation[5]. In recent years, under the dual effects of natural and human activities, soil erosion and vegetation damage are serious in the ecological function protection area of the Loess Plateau. In addition, the high multiple cropping index of land and the lack of water resources make the ecological environment in the region gradually worsen. Therefore, it is necessary to carry out a long-term sequence landscape ecological risk assessment for the ecological function reserve of the Loess Plateau[6]. Qin'an County is located in the inner part of the Loess Plateau, with ravines and undulating terrain, which is a typical landform of the Loess Plateau. Therefore, this paper studies the landscape ecological risk changes of Qin'an County in recent 40 years, taking Qin'an County as an example.

2. Overview of the study area
Qin'an County is subordinate to Tianshui City, Gansu Province. It is located in the southeast of Gansu Province, in the north of Tianshui City, and in the lower reaches of Hulu River, a tributary of Weihe River. Its center is located at 34°51′ N and 105°40′ e, with a total area of 1601 square kilometers, As shown in Figure 1. Qin'an County is located in the interior of the Loess Plateau, and its geomorphological characteristics reflect the typical loess ridge, gully and valley topography, which are interspersed with each other. The altitude of the county is 1179-2020 meters, with a height difference of 841 meters. The geomorphological characteristics of Qin'an County are that loess is widely distributed, with more mountains and less rivers, dense gullies, gourd shaped river valleys, and frequent gully mud flow and loess landslides.

![Figure 1. Qin'an county and risk area.](image)

3. Data and research methods
3.1. Data source and processing
The land use data used in this study are from the resource and environment science data center of Chinese Academy of Sciences. They are all made by visual interpretation of Landsat satellite images, with a resolution of 30m. Three periods are selected in 1980, 2000 and 2018. The accuracy of the data is more than 85%, which can meet the needs of this study. According to the standard of land use status classification and the actual situation of Qin'an County, the land use classification is divided into six categories: farmland, woodland, grassland, water, construction land and bare land, as risk receptors.
3.2. Construction of ecological risk index based on landscape pattern.

3.2.1. Landscape disturbance index \( (E_i) \) Landscape disturbance index \( (E_i) \) is often used to reflect the loss degree of different areas after being disturbed. The greater the disturbance, the greater the ecological risk. Landscape crush index \( (C_i) \), landscape split index \( (N_i) \) and landscape dominance index \( (D_{oi}) \) are commonly used to represent the degree of landscape disturbance.

The landscape disturbance index can be expressed as follows:

\[
E_i = aC_i + bN_i + cD_{oi}
\]

Landscape crush index \( (C_i) \):

\[
C_i = \frac{n_i}{A_i}
\]

Landscape split index \( (N_i) \):

\[
N_i = \frac{1}{2A_i} \sqrt{\frac{n_i}{A}}
\]

Landscape dominance index \( (D_{oi}) \):

\[
D_{oi} = \frac{Q_i + M_i}{4} + \frac{L_i}{2}
\]

Where \( a, b, \) and \( c \) are the weight of the landscape metrics and \( a + b + c = 1 \). Referring to relevant research[7], \( a, b, \) and \( c \) are assigned as 0.5, 0.3 and 0.2 respectively. \( A_i \) is the area of landscape type \( i \), \( A \) is the total area of landscape; \( n_i \) is the number of patches of landscape type \( i \); \( Q_i \) is the number of risk areas / total risk areas of patch \( i \); \( M_i \) is the number of patches \( i \) / total number of patches; \( L_i \) is the area of patch \( i \) / the total area of risk areas.

3.2.2. Landscape fragility index \( (F_i) \) \( F_i \) reflects the ability of different landscape types to resist external interference. The smaller the ability of landscape type to resist external interference, the greater the vulnerability and ecological risk. In this paper, the vulnerability of landscape types in the study area is divided into six levels[8], from high to low: bare land 6, water area 5, farmland 4, grassland 3, woodland 2, construction land 1. After normalization, the vulnerability index \( F_i \) of each landscape type is obtained.

3.2.3. Landscape ecological loss degree \( (R_i) \) The Landscape ecological loss degree can be reflected by the superposition of landscape disturbance index and Landscape fragility index[9], To express:

\[
R_i = E_i \times F_i
\]

3.3. Ecological risk analysis

3.3.1. Risk area division ArcGis10.5 was used to grid the study area, and then the risk area was divided. As the evaluation unit, this study followed the principle of landscape ecology. On the premise that the size and quantity of landscape samples were sufficient to reflect the landscape pattern information of the study area, the sampling units were divided into 4 km × 4 km by equal interval system sampling method according to 4 times of the average patch area[10]. The ecological risk value index of risk area is calculated and used as the sample of spatial interpolation analysis of ecological risk assessment.

3.3.2. Landscape ecological risk analysis The landscape ecological risk index \( (ERI_i) \) describes the comprehensive ecological environment loss degree of each risk area. The higher the value is, the higher the risk degree is:

\[
ERI_i = \sum_1^n A_{ki} / A_k \sqrt{E_i \times S_i}
\]

Where \( n \) is the number of landscape types; \( E_i \) is the vulnerability index of landscape type \( i \); \( S_i \) is the interference index of landscape type \( i \); \( A_{ki} \) is the area of landscape type \( i \) in the \( k \)th risk area; \( A_k \) is the area of the \( k \)th risk area, \( ERI_i \) is the landscape ecological risk index of risk area \( i \).
In this paper, the ecological risk index is divided into five grades\cite{11}: very high ecological risk (ERI > 0.05), high ecological risk (0.035 \leq ERI < 0.05), medium ecological risk (0.020 \leq ERI < 0.035), low ecological risk (0.014 \leq ERI < 0.020) and very low ecological risk (ERI < 0.014).

3.3.3. Spatial analysis
Semi variance analysis is generally considered as a part of geostatistics, which can be used to analyze spatial characteristics\cite{11}:

\[ r(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} \left[ Z(x_i + h) - Z(x_i) \right]^2 \]

Where \( r(h) \) is the number of sample points when the sample spacing is \( h \); \( h \) is the distance between samples; \( Z \) is the random variable of a system attribute; \( Z(x_i) \) and \( Z(x_i + h) \) are variables in \( x_i \) and \( x_i + h \) point value. In order to intuitively describe the spatial distribution characteristics of each ecological risk level in the study area, the spatial analysis and geostatistics functions of ArcGIS were used to generate the spatial distribution maps of ecological risk index in 1980, 2000 and 2018 through summation, sampling and ordinary Kriging spatial interpolation.

4. Results and analysis
4.1. Evolution of land use types
As shown in Figure 2, the area of different land use types in Qin'an County from 1980 to 2018 shows obvious changes. For example, compared with 1980, the construction land area in 2018 increased by 15.8km\(^2\). And it shows a rapid growth trend, which is inseparable from the acceleration of urbanization and urban expansion, while the cultivated land area, woodland area, grassland area, water area and unused land area are on the decline, indicating that the expansion of construction land occupies a large number of other land types.

According to the analysis of the land use area transfer matrix of Qin'an County from 1980 to 2018 (Table 1), the construction land has grown fastest in the past 40 years. Among them, the area converted from cultivated land to construction land is the largest, accounting for 18.48 km\(^2\), which is the main source of the increase of construction land area. The large growth of grassland area is also transformed from cultivated land, with the conversion area of 195.05 km\(^2\) for construction. However, due to the large amount of farmland transferred out, the overall cultivated land area shows a downward trend. In the past 40 years, the change of unused land area is the smallest. The possible reason is that the development is difficult and the utilization efficiency is low.

|                | Farmland | forest | Grassland | Water | Construction land | Bare land | 2018 Total |
|----------------|----------|--------|-----------|-------|-------------------|-----------|------------|
| Farmland       | 690.17   | 16.34  | 195.09    | 2.86  | 18.48             | 2.50      | 925.43     |
| forest         | 15.58    | 34.35  | 8.37      | 0.09  | 0.84              | 0.06      | 59.30      |
| Grassland      | 195.05   | 7.05   | 321.80    | 0.81  | 5.46              | 0.62      | 530.79     |
| Water          | 2.84     | 0.16   | 0.58      | 4.45  | 0.40              | 0.75      | 9.18       |
| construction land | 30.27   | 2.41   | 7.17      | 1.18  | 29.07             | 0.07      | 70.18      |
| Bare land      | 2.21     | 0.05   | 0.53      | 0.66  | 0.05              | 5.83      | 9.34       |
| 1980 Total     | 936.12   | 60.36  | 533.54    | 10.06 | 54.29             | 9.84      | 0.00       |

The analysis of landscape pattern features shows that with the development of urbanization (Table 2), the fragmentation and separation degree of landscape of construction land are declining, and the dominance is on the rise. Compared with other landscape types, the mechanism of landscape pattern change of construction land is relatively complex, mainly because the landscape type of construction land is affected and disturbed by both natural and social and economic factors. The index of separation degree is on the rise, which reflects that the distribution of regional landscape types tends to change from concentration to dispersion, and the degree of aggregation and connectivity of landscape types decreases.
Therefore, it is necessary to strengthen the management and control of the fragmentation degree of farmland, woodland and water landscape types, so as to avoid the adverse impact of excessive fragmentation on the land ecosystem.

4.2. Temporal and spatial changes of landscape ecological risk
It can be seen from Figure 3 that from 1980 to 2018, the ecological risk degree of land use in Qin'an County has shown an overall decreasing trend. The low-risk areas are mainly distributed in the mountainous areas in the west of the study area, mainly in Weidian town. The woodland is widely distributed in the land, and the land-use type is single. The overall ecological risk is low, and the area of the low-risk area is decreasing year by year. The areas with lower ecological risk are located in Longcheng town and Xichuan. On the whole, the ecological risk value of cultivated land and grassland is the highest in the east of the central part, because the ecological environment of cultivated land and grassland is fragile, and it is easy to be restricted by human activities and natural factors.

Figure 2. Land use change in Qin'an County in 1980, 2000 and 2018.

Figure 3. Spatial distribution of ecological risk in Qin'an County in 1980, 2000 and 2018.
Table 2. Landscape pattern index of different landscape types in Qin'an County.

| Landscape type  | Time  | Time | Area/km² | Number | Fragmentation index | Abruption index | Predominance index | Obstruction index | Fragility index | Damnnify index |
|----------------|-------|------|----------|--------|---------------------|----------------|--------------------|-----------------|----------------|----------------|
| Farmland       | 1980  | 936.27 | 308      | 0.33   | 0.38               | 2.25           | 0.73              | 0.19            | 0.14           |                |
|                | 2000  | 937.82 | 309      | 0.33   | 0.38               | 2.25           | 0.73              | 0.19            | 0.14           |                |
|                | 2018  | 925.58 | 363      | 0.39   | 0.41               | 2.27           | 0.77              | 0.19            | 0.15           |                |
| Woodland       | 1980  | 60.37  | 351      | 5.81   | 6.22               | 2.03           | 5.30              | 0.10            | 0.50           |                |
|                | 2000  | 60.33  | 349      | 5.79   | 6.20               | 2.62           | 5.28              | 0.10            | 0.50           |                |
|                | 2018  | 59.31  | 351      | 5.92   | 6.33               | 2.64           | 5.38              | 0.10            | 0.51           |                |
| Grassland      | 1980  | 533.63 | 484      | 0.91   | 0.83               | 2.41           | 1.18              | 0.14            | 0.17           |                |
|                | 2000  | 530.47 | 486      | 0.92   | 0.83               | 2.41           | 1.19              | 0.14            | 0.17           |                |
|                | 2018  | 530.88 | 513      | 0.97   | 0.85               | 2.43           | 1.23              | 0.14            | 0.18           |                |
| Water area     | 1980  | 10.06  | 8        | 0.80   | 5.63               | 3.22           | 2.73              | 0.24            | 0.65           |                |
|                | 2000  | 9.09   | 8        | 0.88   | 6.23               | 3.36           | 2.98              | 0.24            | 0.71           |                |
|                | 2018  | 9.18   | 9        | 0.98   | 6.55               | 3.43           | 3.14              | 0.24            | 0.75           |                |
| Constructio n land | 1980 | 54.30  | 543      | 10.00  | 8.59               | 2.77           | 8.13              | 0.05            | 0.39           |                |
|                | 2000  | 56.92  | 562      | 9.87   | 8.34               | 2.68           | 7.97              | 0.05            | 0.38           |                |
|                | 2018  | 70.19  | 590      | 8.41   | 6.93               | 2.62           | 6.81              | 0.05            | 0.32           |                |
| Unused land    | 1980  | 9.84   | 6        | 0.61   | 4.98               | 2.92           | 2.39              | 0.29            | 0.68           |                |
|                | 2000  | 9.84   | 5        | 0.51   | 4.55               | 2.93           | 2.20              | 0.29            | 0.63           |                |
|                | 2018  | 9.34   | 13       | 1.39   | 7.73               | 3.01           | 3.62              | 0.29            | 1.03           |                |

5. Conclusions

The pattern and evolution characteristics of landscape ecological risk are not only the direct representation of ecological environment quality, but also the ability of ecosystem to resist external interference and disturbance. In order to intuitively describe the spatial distribution characteristics of landscape ecological risk degree in Qin'an County, this paper integrates landscape features with ecological risk assessment, analyzes the spatial pattern and process characteristics of landscape ecological risk in the study area from 1980 to 2018, laying a solid foundation for the formulation of ecological risk control measures. The results show that:

From 1980 to 2018, the landscape pattern of Qin'an County has undergone obvious changes. The area of woodland and cultivated land decreased significantly, and grassland, water body and construction land expanded significantly. The expansion area mainly came from the transformation of cultivated land and grassland area. From 1980 to 2018, the landscape fragmentation increased as a whole. In 1980, the fragmentation degree of construction land was the highest, followed by cultivated land, woodland, water area and grassland. After nearly 40 years of change, except for construction land and water area, the fragmentation of other landscape types has increased. From 1980 to 2018, the degree of separation of Qin'an County also changed significantly. Except for the water area and construction land, the degree of separation of other landscape types increased to varying degrees. From 1980 to 2018, the overall landscape dominance of Qin'an County did not change significantly. The landscape dominance of construction land was the largest, followed by woodland and water area, and farmland and grassland were the smallest. In 2018, the area of moderate risk area decreased significantly, while the area of mild risk area increased, and the area of high risk area decreased significantly.

From the spatial distribution analysis, the overall distribution of landscape risk types in Qin'an County is from south to north, which has a decreasing trend. The area with high risk is mainly cultivated land, which has a large number of rural residential areas, and is vulnerable to human activities, and the ecological environment is fragile; the northwest is mainly the type of low-risk areas; most of the low-risk areas are in the north of the study area, and the main landscape type is woodland, with low degree of fragmentation, strong anti-interference ability and lowest risk value.
In this paper, the risk management and control measures are discussed. Most of the cultivated land intensive coverage areas belong to moderate risk areas, and the ecological risk sources mainly include agricultural non-point source pollution and soil fertility loss. Extensive agricultural production mode not only brings pollutants such as pesticides and chemical fertilizers to destroy the ecological environment, but also is prone to soil component erosion, which increases the ecological risk degree of risk areas and has a large degree of human interference. The ecological environment changes with the change of land use. From 1980 to 2018, the cultivated land and forest land decreased, the construction land expanded, and the ecological environment was damaged. We should optimize the land use pattern, increase the vegetation coverage, implement the policy of returning farmland to forest and grassland, and increase the landscape connectivity; It is forbidden to expand construction land to ecological function areas, water conservation areas, conservation forest areas and key tourist attractions, so as to reduce regional ecological risks, strengthen soil environmental management, and reduce the use of highly polluting pesticides and chemical fertilizers.

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