Method of Ecological Risk Assessment for Land Use Based on Remote Sensing Image

Ling Chai
School of Geographical Sciences, Jining Normal University, Ulanqab, 012000, China
E-mail: cailing_85@163.com

Abstract: Ecological risk assessment for land use can provide the basis for scientific evaluation of the impact of current human activities on land and its ecological effects. For the issue on ecological risk of land use, the method of ecological risk assessment for land use based on remote sensing image is proposed. Using remote sensing image as the main data of land use change and ecological effects, the land use situation is classified by pre-processing and analysis of remote sensing image. Combined with the estimation of solar radiation, spatial interpolation of meteorological data, atmospheric correction and geometric fine correction operations, remote sensing data is processed to improve the classification accuracy of the target area. According to the remote sensing image of land use and the analysis results of the data, as well as the dynamic model and the comprehensive evaluation conceptual model for land use, the multi-indicator assessment framework of ecological risk for land use is designed and the risk indicator system is constructed. Furthermore, the ecological risk assessment for land use in the entire region and sub-regions is completed. The research results show that the proposed method can effectively realize the ecological risk assessment for land use in the study area, which has good robustness.
Key words: remote sensing image; land use; ecological risk assessment; indicator system; evaluation model
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1Introduction

The ecological risk assessment is a research field that has gradually emerged and developed in the past three decades. It was created to accommodate the changes in environmental management goals and concepts that emerged in the 1980s. In the 1970s, the environmental management policy objectives of industrialized countries were aimed at eliminating all environmental hazards or reducing the hazards to the lowest levels that could be achieved by technical means at the time. This “zero-risk” environmental management gradually exposed its weaknesses. After entering the 1980s, it created a new environmental policy of risk management. The risk management concept focuses on balancing risk levels and risk reduction costs, with a focus on addressing the relationship between risk levels and the risks that society can accept. The ecological risk assessment is the scientific basis and technical support for risk management, and it has been rapidly developed [1].

In the United States, ecological risk assessment develops on two different levels. One is the scientific research level, and the other is the technical application level closely related to environmental management. The early ecological risk assessment is mainly for human health. It evaluates the possible impact of chemical pollutants on humans after they enter the environment and through the food chain. In the early 1990s, American scientists proposed that ecological risk receptors should include the various levels of life systems (individuals, populations, communities, ecosystems, and landscapes), and should consider the interactions between organisms and the interrelationships between ecological risks at different levels. Scientists such as Gerba and Hass have studied the physical, chemical and biological aspects of ecological risk assessment. Research by scientists such as Hunsaker, Hope and Landis provided the comprehensive theoretical basis and technical framework for the application of ecological risk assessment [2]. A large number of research institutions represented by Oak Ridge National Laboratory and Brookhaven National Laboratory have played the guiding role in the development of basic theories and technologies related to ecological risks.

From the perspective of the theory and method of ecological environmental risk, the research of China's ecological risk assessment is still in its infancy and has not yet become the basis of management decision-making. Many scholars have discussed different aspects of the theory and technical procedures of ecological risk assessment. Some scholars believed that ecological risk assessment is an important part of environmental risk assessment. It refers to the assessment of the possibility of adverse ecological consequences after being affected by one or more stress factors. Many domestic scholars have conducted extensive and useful discussions on environmental risk assessment and related theories and research methods, which enrich the research content of ecological environment science.

The dynamic analysis of land use change and the study of ecological effects and ecological risks are the frontiers and hotspots of geo-environmental change research in recent years, and also an important part of global change research. Through quantitative analysis of the structural characteristics, dynamic mechanisms, ecological effects and ecological risks of land use change in areas with relatively weak ecological environment and more human activities in China, Some scholars believed that in the ecological environment caused by human activities, changes in land use/cover and its pattern play the decisive role in regional ecological security and maintenance of ecosystem services [3]. Through systematic and comprehensive research on ecological environment assessment and ecological risk analysis with land use change, the characteristics of ecological risk change and the theoretical system of quantitative research were discussed. This is very meaningful in terms of theoretical construction and practice, and has been widely concerned by researchers.

The current research on the ecological risk assessment method is mainly to establish the technical framework of the ecological risk assessment, and to carry out simulation research, which involves statistical methods, probability statistics, simulation technology, system science and many other aspects. The risk assessment needs to estimate the magnitude of the risk, as explained by probability and severity. Therefore, some quantitative or semi-quantitative methods are commonly used to measure risk. The simulation techniques commonly used in current risk assessment include physical models, statistical models, and mechanism models. The physical model is mainly used to study the process, law and ecological effects of environmental transformation of harmful substances, which is combined with mathematical simulation to study complex transportation processes. Statistical models mainly use regression, principal component analysis and other techniques to summarize experimental or observational data to obtain regular results. The primary purpose of using statistical models in risk assessment is to assume tests, descriptions, and extrapolations. The mechanism model is a mathematical model based on the internal mechanism of motion or change of things. It is not only used to quantitatively study the process, laws and consequences of the development of things, but also to predict the concentration distribution and outcome of pollutants. Exposure analysis models, regression models, and biological models are all mechanism models [4].

Some scholars have carried out the ground ecological risk assessment: Lu Leting et al. used the Liaohe River Basin as the research object to quantitatively analyze the dynamic characteristics of land use in the region over the past 30 years according to the remote sensing image interpretation of land use, and constructed the model of ecological risk assessment for land Use. It completes the risk assessment through the regional risk assessment unit [5]. Eight evaluation factors including elevation, slope, land-use type, soil erosion status, distance from scenic spots, distance from water body, distance from road, and distance from residential area were selected. Wang Qi et al. used GIS analysis method to divide the energy level of ecological suitability of land-use in Zanhuang County [6]. Taking Huainan City of Anhui Province as an example, Chen Guangyu used the pressure-state-response (PRS) framework to select 20 indicators to establish an evaluation index system for land ecological security in line with the conditions of the region. Weights are determined by analytic hierarchy process and entropy method. The land ecological security assessment model was used to evaluate and study the status of land ecological security in Huainan City [7].

The above methods are mainly for assessing the ecological status of land use in a certain aspect. On the basis of relevant research, the method of ecological risk assessment for land use based on remote sensing image is proposed:

(1) By preprocessing, the influence of interference factors is eliminated, and the sharpness of the remote sensing image and the contrast in the regions of different land use types were improved. The land use classification was carried out by the interpretation result of the remote sensing image. Remote sensing data processing was performed through

correlation operations to improve the classification accuracy of the target area;

(2) Based on the remote sensing image and field research data, combined with the land use dynamics model and the comprehensive assessment conceptual model, the multi-indicator assessment framework for ecological risk of land use was designed and the indicator system for land use risk assessment was established. On this basis, ecological risk assessment for land use was carried out.

(3) Through the simulation experiment, the feasibility and comprehensive effectiveness of the proposed method are tested.

2 Materials and methods

2.1 Division of land use types and handling of remote sensing images

2.1.1 Data collection and division of land use types

Currently, remote sensing image is the main data for studying land use change and ecological effects. The existing remote sensing data types are diverse, and the resolution, band information, and collection period are all different. Therefore, appropriate remote sensing data should be selected based on different research purposes. In this study, according to the vegetation growth law of the study area and the distribution of interannual precipitation, the remote sensing data of plant growth stability and little water level change were selected. The image is used for image acquisition after image correction, image enhancement, projection transformation, and splicing and cropping. In addition, select the corresponding time period of the image, conduct three comprehensive investigations on the study area, and establish an interpretation of the remote sensing image. Through the field investigation of the vegetation in the key areas of the ecological environment in the study area, as well as the conversion of farmland to forests and rocky desertification, the results of land use classification were corrected. Local residents were interviewed to collect socio-economic statistics such as rural socio-economic development and village changes in the region [8]. The study also collected graphic data, DEM data, socio-economic statistics and related planning data in the basin. For example, the 1:50,000 topographic map of the city under study, the 1:100 land use status map in recent years, the municipal administrative division map, the digital elevation model of 30m resolution, the socioeconomic statistical yearbook, and the statistical bulletin of national economic and social development, the overall planning of land use, tourism development and the city, and the planning of key tourist areas.

Land use classification is the basis of research on remote sensing image interpretation, pattern analysis, dynamic simulation, etc. It is an important premise for studying land use change and ecological effects, which not only affects the expression of classification results, but also determines the adaptation field of data. For the construction of the land use classification system, the first is to adapt to the actual situation of land use in the study area. Secondly, the classification system should have good compatibility and continuity with relevant national standards and existing survey data. In addition, it is necessary to ensure a high degree of discrimination between the land types on the remote sensing image, which is easy to interpret the image accurately. According to the land use situation of the study area, comprehensive research needs, with reference to the research results of Liu Jiyuan et al., using the land use classification method used in the China

Resource Environment Remote Sensing Survey Database, the land use situation is divided into six basic types, as shown in Figure 1.

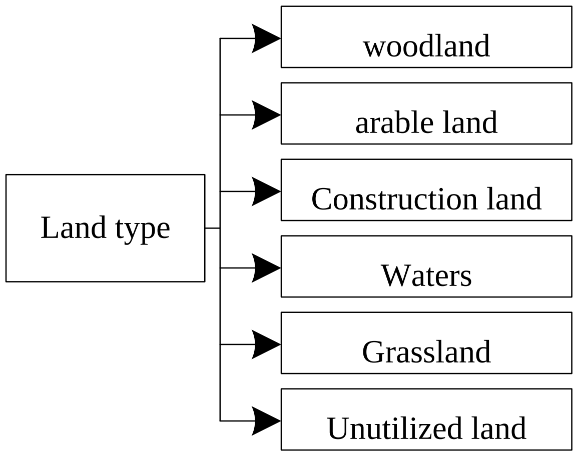

Figure 1 Classification of basic land types

The definitions and specific contents of each basic type are as follows:

(1) Forest land: forestry land for growing trees, shrubs and bamboos. It includes forest land with a canopy closure of more than 30%, shrub land with a canopy closure of more than 40%, sparse forest with a canopy range of 10-30%, and orchards and tea gardens.

(2) Cultivated land: land suitable for growing crops. It includes paddy fields and dry land. (3) Construction land: industrial and mining and transportation land outside urban and rural residential areas. It includes urban land, rural residential land, and construction land for factories, mines, transportation roads, airports, etc.

(4) Waters: Naturally formed waters and land for water conservancy facilities. It includes rivers, lakes, reservoirs, ditches, pits, beaches and so on.

(5) Grassland: mainly grasses with growing herbs and coverage of more than 5%. It includes shrub grassland and sparse forest grassland with less than 10% canopy closure.

(6) Unutilized land: land that has not been utilized yet. It includes undeveloped plots such as bare land, sandy land, and bare rock texture.

2.1.2 Processing of remote sensing image

The data processing software used in this research mainly includes: remote sensing image processing software ERDAS9.2, geographic information system software ARCGIS10.0, Fragstats3.3 and Geo9.5. Among them, remote sensing image processing software ERDAS9.2 is mainly used for classification interpretation of remote sensing image and land use transfer matrix calculation. Among the three GIS softwares, Fragstats3.3 is used for land use pattern index calculation, Geo9.5 is used for spatial autocorrelation analysis, and ARCGIS10.0 is mainly used for spatial analysis of ecosystem services, ecological risks, and mapping thematic maps.

The following pre-processing operations were performed on the remote sensing image: using the ERDAS9.2 software, the topographic map of the study area was used as a geographic reference, and 20 ground control points were selected at the easily identifiable features. Through the polynomial transformation model, geometric correction of the remote sensing image of the four phases and eight scenes is performed. Regression analysis was used to remove atmospheric radiation, and orthorectification was used to reduce the effect of hillshade on images. The image stitching function was used to merge the corrected remote sensing images, and the 4 remote sensitive images were adjusted to the corresponding coordinate system of the region. Taking the digitized boundary of the study area as Mask, using the Extract extraction function in ARCGIS10.0 spatial analysis, the four-stage image was irregularly cropped according to the boundary, and finally the remote sensing image of the study area was obtained.

After the above pre-processing is completed, the interpretation of the remote sensing image is performed. The interpretation of remote sensing image can be divided into computer interpretation and visual interpretation, among which there are many computer interpretation methods. Considering the advantages and disadvantages of each method, the actual situation of the study area and the specific data of the study area, this study uses the maximum likelihood method to interpret the land use types in the study area. The specific process is shown in Figure 2.

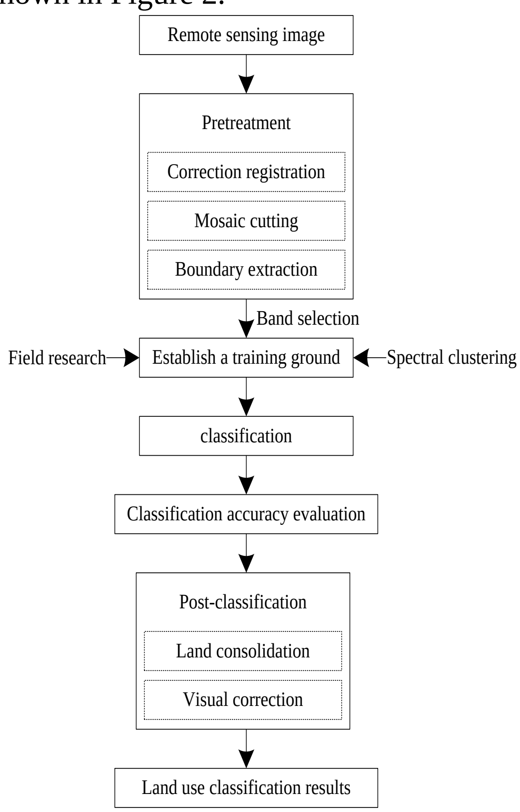

Figure 2 Interpretation of remote sensing image

According to Figure 1, the interpretation of remote sensing image includes the following:

(1) Preprocessing of remote sensing image. In the process of image preprocessing, image correction registration, stitching and cutting, and boundary extraction are required. Through the pre-processing operation, a complete and clear target area remote sensing image is obtained.

(2) Establish a training ground. After the remote sensing image preprocessing is completed, the selected clusters are clustered by the spectral clustering algorithm, and the field research data is integrated to establish a training ground.

(3) Remote sensing image division of land use categories. According to the established training field and land use classification system, the remote sensing image land use category is divided by the combination of supervised classification and unsupervised classification of maximum likelihood method.

(4) Classification result evaluation and post-classification processing. The classification results are evaluated for classification accuracy, and classified and processed according to the evaluation results. The post-classification treatment includes two parts: land use classification and visual correction, and the results obtained after processing are the final land use classification results.

Among them, the accuracy evaluation of image classification is an indispensable component in the classification process, mainly including user accuracy, charting accuracy, overall classification accuracy and KAPP coefficient. The Accuracy assessment module in ERDAS 9.2 was studied for accuracy evaluation. Using random sampling, a certain number of random points are generated in each of the four land use classification maps. Combine the land use status map and the field survey data to compare the random points with their actual types. Enter the actual category of each random point to generate a classification accuracy report. With the improvement of science and technology, the classification accuracy has also been continuously improved. According to the accuracy evaluation data, the overall classification accuracy in recent years is above 86%, which can reach the level required for research.

Post-processing of image clas sification. It mainly uses the cluster (eliminate) modules in ERDAS9.2 to classify the small maps of less than 4 pixels into the ground class, and merge the multi-division classes through the classification re-encoding. Combined with field survey photos, land use status maps, land change visit records, and Google Earth image data, visually correct and test the classified images, paying particular attention to adjusting the shadows of the mountains and the water body. The traffic land and streams that cannot be interpreted can be supplemented according to the large-scale traffic map and water distribution map, thereby improving the accuracy of the remote sensing image interpretation results.

2.1.3 Processing of remote sensing data

The weathering indicators of remote sensing image include: average temperature, average minimum temperature, average maximum temperature, precipitation and sunshine time. In the process of obtaining data, for the meteorological data missing in individual months, the missing data is revised based on the monthly value data of many years and the average of the adjacent month value data of the same year. At the same time, in order to realize the spatio-temporal analysis of solar radiation in the study area, the estimation data of solar radiation is mainly obtained based on the sunshine time of the past 10 years [9].

Solar radiation is the main source of energy for physical, biological, and chemical processes on the Earth's surface, and is a necessary parameter for ecosystem processes and biophysical models. In order to accurately describe the variation characteristics of solar radiation in the study area, the longitude, latitude and sunshine hours of each meteorological site are used to simulate the daily solar radiation of each meteorological site based on the Angstrom-Prescott equation:

$$\frac{R_S}{R_a} = a_S + b_S \frac{n}{N}$$

(1)

Where, R_S 111 represents the actual solar radiation of the day, the unit is KJ/m2•day; R_a is solar radiation over the atmosphere; n is the sun sunshine time in hours (h); N is the maximum possible sun sunshine time on the day, ie the length of the day; a_S and b_S are empirical coefficients and can be simulated based on measured values of solar radiation.

Considering the transparency coefficient of the atmosphere, the sum of the empirical constants a_S and b_S is considered to be 0.73, and R_a is the total ground radiation in the sunny state, namely:

$$R_a = \frac{1}{\pi} G_{SC} d_r \left[\cos\varphi_{rad} \cos\delta \sin\omega_S + \omega_S \sin\varphi_{rad} \sin\delta\right]$$

(2)

Where, G_{SC} is the solar coefficient, usually 118.108 MJ/m2•day; d_r represents the earth orbit eccentricity correction factor, φ_{rad} represents the meteorological site dimension, δ

represents the solar declination; ω_S is the time angle.

$$d_r = 1 + 0.33\left(\frac{2\pi}{365}J\right)$$

(3)

$$\delta = 0.409\sin\left(\frac{2\pi}{365}J - 1.39\right)$$

(4)

During the course of the study, the number of meteorological sites was very limited and showed a certain degree of correlation within a certain range. The Kriging interpolation method is used to spatially interpolate meteorological data to realize the spatial expression of meteorological data, which provides a basis for understanding the spatial differences of ecological vulnerability. Kriging interpolation is the method based on the theoretical analysis of semi-variograms to unbiased optimal estimation of variables in the finite region. In order to consider the influence of terrain on meteorological factors, the ordinary Kriging interpolation is used to spatially interpolate the meteorological data, and the elevation is introduced as the second influencing factor into the spatial interpolation of meteorological factors, which can be expressed as:

$$Z(x_o) = \sum_{i=1}^{n''} \lambda_i Z(x_i) + \lambda_i [E - E_w + C_w]$$

(5)

Where, $Z(x_o)$ is an estimate at x_o; $Z(x_i)$ is the observation at x_i; λ_i is the Kriging weight coefficient; n'' is the number of observation points; E is the elevation value at x_i; E_w and C_w are the global averages of elevation and meteorological factors, respectively.

Through the interpolation of meteorological data, the spatialized expression of meteorological factors is realized, and then the spatial superposition analysis is carried out according to the administrative boundary of the study area to obtain the average value of each meteorological factor in the area.

In order to verify the feasibility of MODIS for vegetation coverage mapping, the Landsat ETM+remote sensing image was acquired from the international scientific data service platform, and the data was subjected to radiation correction and geometric precision correction to generate NDVI and vegetation coverage. Based on the vegetation coverage estimated by MODIS NDVI and Landsat ETM+ data, the coverage results of these two plants were graded to obtain the area and spatial characteristics of different hierarchical vegetation coverage, and the feasibility of MODIS for vegetation coverage mapping was verified.

The FLAASH model is an atmospheric correction module based on the MODTRAN4 atmospheric radiation transmission code jointly developed by the American aerodynamics laboratory, the spectrum science research institute, and the spectral information analysis technology application center. It can perform atmospheric correction analysis on any remote sensing data that conforms to the standard MODTRAN4 atmospheric model and aerosol type, and effectively eliminates the effects of atmosphere and illumination on ground reflections. It also eliminates spectral noise, corrects adjacent pixel effects, and calculates the visibility of the entire landscape remote sensing image. Finally, physical parameters such as water vapor, aerosol, reflectivity, radiance and radiation temperature, as well as classified images of cirrus and thin cloud can be generated, which is the current high precision atmospheric radiation correction model. Atmospheric radiation correction was performed on Landsat

ETM+ remote sensing data using the FLAASH module as follows:

(1) Radiation calibration of the data according to the gain and deviation parameters of the Landsat ETM+ remote sensing data. The dimensionless DN value is converted to a dimensional spectral radiance value using the following formula:

$$L_\lambda = \left(\frac{L_{max} - L_{min}}{QCAL_{max} - QCAL_{min}} \right) \times \left(DN - QCAL_{min} \right) + L_{min} \quad (6)$$

Where, $QCAL$ is the DN value of the pixel on the remote sensing image; $QCAL_{max}$ and $QCAL_{min}$ are the maximum and minimum values respectively; L_{max} and L_{min} are the corresponding spectral radiance respectively, which can be obtained from the header file of Landsat ETM+ remote sensing data.

(2) Start the FLAASH module, set the relevant parameters, and enter the scale conversion factor of the remote sensing image reflectivity. The main parameters to be input in the FLAASH model are the center point coordinates of the image, the sensor type, the average altitude of the study area, the Landsat ETM+ remote sensing data acquisition date and satellite transit time, the atmospheric model, the water-gas inversion, and the aerosol model. At the same time, in the advanced setting options of the FLAASH model, the MODTRAN resolution can be set to 1cm^{-1}, 5cm^{-1} or 15cm^{-1} according to the actual situation or the acquisition time of the remote sensing image, and the remaining parameters can use the default values. The default scale factor of the reflectance output based on the FLAASH model calculation is 10000, that is, the range of the reflectance image obtained after atmospheric correction is 0 to 1000. Therefore, the scale factor needs to be modified before the model is run, and the data can be scaled after obtaining the reflectance data [10]. After the atmospheric correction of the Landsat ETM+ image, the visual effect is significantly improved, and the spatial difference of the feature type is improved. After atmospheric correction, the edges of the object type are clearer, the texture is clearer, and the difference and contrast are significantly improved. In particular, the thin clouds in the image and the shadow areas in the mountains have been largely corrected, and the brightness and contrast of the images have been improved. The ground objects became clearly visible and the original surface of the underlying surface was restored. The image quality is effectively improved, the spatial and spectral differences of the feature types are improved, and the different types of feature types on the remote sensing image are significantly different.

In order to ensure the accuracy of the spatial location of land use and land cover type information based on Landsat ETM+ remote sensing data extraction, the Landsat ETM+ remote sensing data is geometrically refined by means of ERDAS LPS module. In order to match the land cover classification result with the acquired land use data, the land use vector data in a certain relative time is taken as reference. At the beginning, several object objects whose images have not changed are selected as reference points. The ASTER GDEM data (spatial resolution 30m) was used as the elevation control information, and the Landsat ETM+ data was geometrically corrected using the quadratic polynomial model.

$$x = a_0 + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 \quad (7)$$

$$y = b_0 + b_1X + b_2Y + b_3X^2 + b_4XY + b_5Y^2 \quad (8)$$

$$RMS=\sqrt{\left(x^*-x\right)^2+\left(y^*-y\right)^2}$$

(9)

Where, (x,y) is the coordinate of the ground control point in the original image, (X,Y) is the reference coordinate, RMS is the root mean square error of the ground control point; (x^*,y^*) is the coordinate position of the control point calculated by the corresponding quadratic polynomial.

The control points selected on the image are adjusted before the data correction value. Remove the control points with large geometric deformations and add some control points to ensure that the control points are evenly distributed in space. The finalized control point is used as the reference point for the geometric fine correction of Landsat ETM+ remote sensing data, and the corrected accuracy is within 1 pixel. The projection type is a conical projection of double standard latitude [11].

2.2 Ecological risk assessment for land use based on remote sensing image

2.2.1 Land use dynamics assessment model and transfer flow

The single land use type dynamic degree refers to the basic situation of the change of the quantity of a certain land use type in a certain time range. The expression is as follows:

$$K=\frac{U_b-U_a}{U_a}\times\frac{1}{T}\times 100\%$$

(10)

Where, K is the dynamic degree of a single type of land use; U_a and U_b represent the number of certain types of land use at the beginning of the study and at the end of the study; T is the duration.

The comprehensive land use dynamic degree refers to the intensity of regional land use change within a certain period of time, and the expression is given by formula (11):

$$LC=\left(\frac{\sum_{i^*=1}^{n^*}\Delta LU_{i^*-j^*}}{2\sum_{i^*=1}^{n^*}LU_{i^*}}\right)\times\frac{1}{T}\times 100\%$$

(11)

Where, LC represents the comprehensive land use dynamics; LU_{i^*} represents the area of the i^*-th land type at the beginning of the study; $\Delta LU_{i^*-j^*}$ represents the absolute value of the i^*-th land type converted to other land area within the study period; i^* represents the land type, and n^* represents the total number of land types.

In order to reflect the two attributes of directionality and quantity of land use change, the concept of “flow” in dynamic material changes is introduced. The case of transferring land use change from one type of land use to another type of land use is defined as “land use transfer flow”, which is used to express the process, direction and magnitude of land use change. For any type of land use, the change from this type to other types is called “land use transfer flow”, and the change from other types to this type is called “land use transfer flow”. The total of the inflow and outflow flows is the “land use transfer flow” with the land type at a specific time period. Essentially the total amount of all land-use changes in the type of land use [12]. The difference between the inflow and the outflow is the net transfer of land. When the value is positive, it means net inflow; otherwise, when its value is negative, it means net outflow. The formula is as follows:

$$L_f=L_{out}+L_{in}$$

(12)

$$L_{nf}=L_{in}-L_{out}$$

(13)

Where, L_f represents land transfer flows, L_{out} and L_{in} represent land use transfer flows and transfer flows, respectively, L_{nf} represents the net value of land transfer flows.

Among the models describing the temporal and spatial variation of land use, the most common is the land use transfer matrix. The transfer analysis method based on the land use transfer matrix is a quantitative analysis method of land use/cover change first proposed by Pontius in 2004. The matrix table can clearly reflect the number of mutual conversions and conversion rates between different land use types in the two periods. The Markov transition matrix is the method for studying the state change process, which is used to quantitatively describe the state and processes of state transition originating from system analysis. Its mathematical form is:

$$S_{i*j*}=\begin{bmatrix} S_{11} & S_{12} & L & S_{1n*} \\ S_{21} & S_{22} & L & S_{2n*} \\ L & L & L & L \\ S_{n*1} & S_{n*2} & L & S_{n*n*} \end{bmatrix}$$

(14)

Where, S represents the land area; S_{i*j*} is the $i*$ th land use type in the k period converted to the $j*$ th land use type in the $(k+I)$ period.

2.2.2 Comprehensive assessment system for ecological risk of land use

2.2.2.1 Comprehensive assessment framework for ecological risk of land use

Based on the analysis of typical land ecosystem components in the study area, the US National Environmental Protection Agency's ecological risk assessment process is highlighted. On the basis of regional ecological risk assessment research, many scholars put forward the comprehensive evaluation index system of ecological risk of land use, which mainly includes the steps of problem formation, risk analysis, risk characterization and risk management decision-making. Among them, the index system for ecological risk assessment of land use is based on risk source of risk indicators and land habitat vulnerability indicators. The comprehensive evaluation indicator systems for ecological risk of land use are shown in Figure 3.

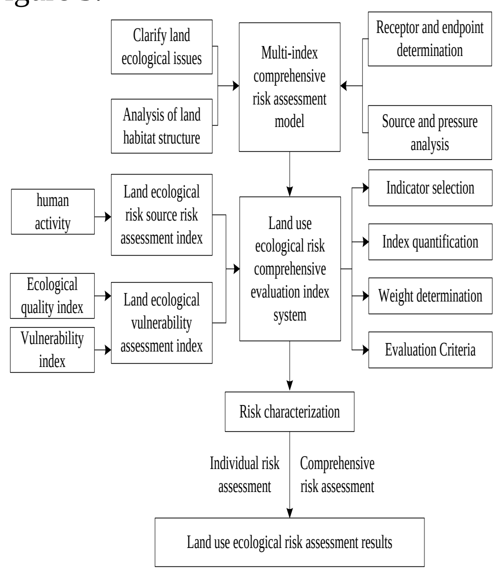

Figure 3 Comprehensive evaluation index systems for ecological risk of land use

The formation of the problem is the process of determining the scope and purpose of the ecological risk assessment for the land. The study determines the receptors, ecological endpoints, sources and pressures of land ecological risk assessment in the study area based on the specific negative effects of land ecology. After a clear evaluation of the endpoint, determine the analytical method and collect relevant data. The analysis method is mainly to determine the multi-index comprehensive model used according to the research purpose. The risk characterization is to combine the two parts of the analysis step with the risk source evaluation and benefit evaluation, summarize the process of regional land ecosystem degradation caused by the risk source, and organize participants to discuss the uncertainty in the risk assessment. According to the research results, the objectives and plans corresponding to the risk control are determined to provide the scientific basis for the ecological protection of the land and the sustainable use of resources.

2.2.2.2 Comprehensive assessment model for ecological risk of land use

According to relevant research data, the current ecological risk of land use comprehensive assessment conceptual model mainly includes two aspects:

(1) The comprehensive risk probability assessment based on risk sources is based on the probability, intensity and extent of natural disasters or man-made hazards to quantitatively describe the risk sources;

(2) It is based on the assessment of the degree of ecological loss of the receptor. Finally, based on this quantitative calculation, the ecological risk of land use index of the study area is characterized. Its development forms are diverse, such as: risk = probability × loss; risk = probability + vulnerability; risk = risk + vulnerability; risk = risk × result; risk = (risk × land system × social ecological economy / resilience); risk value = probability × ecological index × ecological vulnerability; risk = risk × vulnerability [13]. The above quantitative methods have positive reference for the research work of regional ecological risk assessment for land use, such as:

$$R = P \cdot D \quad (15)$$

Where, R represents the ecological risk value of the regional land; P represents the probability or intensity of the risk source in the region; D represents the potential risk loss of the land ecosystem.

Where, the probability of composite risk source in the region P is defined as:

$$P = \sum_{j'}^{n'} \sum_{i'}^{m'} \beta_{j'} P_{j'I'} \quad (16)$$

Where, $P_{j'I'}$ is the probability of occurrence of j' categories of I' ecological risks in the assessment area, $\beta_{j'}$ represents the weight of the j' th ecological risk, n' is the total number of ecological risk of land use source types, and m' is the number of levels of such risk sources.

The ecological loss index of land use indicates the difference of ecological loss caused by various types of risk exposure; the vulnerability index reflects the vulnerability of regional land ecosystem; and the ecological index reflects the ecological significance and status of regional land ecosystem.

The potential risk vulnerability of land use in the study area D is defined as:

$$D_{i*} = W_{i*} e_{i*} + W_{j*} F_{i*} \quad (17)$$

Where, D_{i*} represents the risk loss degree of land use type $i*$ in the study area; e_{i*} represents the ecological index of land use type $i*$; F_{i*} represents the vulnerability index of land use type $i*$; W_{i*} and W_{j*} represent the index weight value.

2.2.2.3 Indicator system for ecological risk assessment of land use

Since the land ecosystem is the complex giant system, and the land ecological change caused by land use is a rather complicated phenomenon and process, the indicator system needs to be established to explore the ecological security status of the land. According to the construction principle of the evaluation model and the indicator system, based on the multi-level framework of “target layer-category layer-factor layer-index layer”, Evaluation index system for ecological risk of land use are constructed from the aspects of the risk source probability and ecological vulnerability (including ecological index and vulnerability index). Select appropriate indicators to assess the magnitude of the ecological risk.

The source hazard index mainly refers to the different levels of risk stress caused by the disturbance of human activities caused by the structure, process and function of the land ecosystem. The establishment of risk source indicators should combine the historical data of the research area and the characteristics of development activities to analyze and predict the qualitative, quantitative and spatial distribution of various potential ecological risks, and deeply understand the generation and mechanism of various ecological risk sources. This provides reliable data support for hazard assessment of ecological risk sources [14]. According to the analysis of remote sensing data in the study area, the main influencing factors of the risk index of the ecological risk include land use change, pollutant emission accumulation and resource consumption. For the ecological vulnerability of land use, based on the review of relevant data, a group discussion was carried out. Based on the key factors that characterize the fragility of the land ecological environment in the region, evaluation index system for ecological vulnerability of land use in the study area were constructed from the two aspects of ecological quality index and vulnerability index. The constructed Ecological Risk Assessment for Land Use indicator system is shown in Table 1.

Table 1 Index system of ecological risk assessment

Target layer	Category layer	Feature layer	Indicator layer (observation variable)
probability assessment indicator for comprehensive risk sources (risk assessment)	land use change	population growth	the population density
		town construction	the level of urbanization
		cultivated land development	water, forestland to farmland intensity, cultivated land use intensity
		mining	mining scale
		traffic road construction	road density
		water resources and hydropower engineering	engineering distribution density
	accumulation of pollutant emissions	point source	industrial pollution
		surface source	agricultural pollution
	resource consumption	water demand	industrial and agricultural production and domestic water intensity
		biological resource requirements	forest harvesting and forage intensity

		topography and climate	ground elevation and slope area ratio average annual precipitation
		habitat index	
		vitality index	species richness vegetation coverage water network density
ecological vulnerability index	ecological quality index		ecological elasticity value primary productivity of land
		interference index	landscape fragmentation shannon diversity index
		environmental quality index	water environmental quality index soil quality index atmospheric index
	vulnerability index	socioeconomic stress index	land use land reclamation rate human health threat level regional fiscal revenue

2.2.2.4 Risk characterization and evaluation

After the risk data processing is assigned, the risk assessment for land use is used throughout the region and sub-region through the exposure-response design. Based on the principle of relative risk assessment model, the “source-pressure-habitat-end point” exposure response design in different risk sub-areas is multiplied and summed to obtain the final ecological risk value. The relative risk assessment reflects the risk characteristics of the overall region and sub-regions at risk sources, habitat receptors, and ecological endpoints, such as threats to habitats, potential hazards in the endpoints, and overall risk. At the same time, the calculation of relative risk is based on relevant assumptions: the ecological mechanism of risk is unanimously recognized throughout the risk area.

The risk pressures in the ecological risk assessment of land use include single or multiple chemical, physical, and biological pressures. Chemical pressure is toxic and nutrient; physical pressure has both habitat changes brought by human activities, geological structural changes, and natural sedimentary changes and magnetic fields. Biological stresses are foreign or genetically engineered organisms. Geoscience stress is caused by desertification, floods, earthquakes, goaf, and debris flows. Biological pressure In addition to genetic variation in species, alien invasion is the main factor leading to the extinction of dominant species [15].

Assume that the number of sub-regions in the study area is m_*, the risk pressure and the number of risk sources are n_* and l_*, respectively, and the number of habitat types and habitat end points are o_* and p_* respectively, then the total risk value of the corresponding i_*-th region can be indicated as follows:

$$Risk_{i_*} = \sum_{h_*=1}^{o_*} Risk_{i_*,h_*} = \sum_{h_*=1}^{o_*} \sum_{j_*=1}^{n_*} Risk_{i_*,j_*,h_*}$$

(18)

Where, In the i_*-th sub-region, the risk value of the j_*-th risk pressure generated by the h_*-th habitat is $Risk_{i_*,j_*,h_*}$, and the corresponding calculation formula is:

$$Risk_{i_*,j_*,h_*} = Exposure_{i_*,j_*,h_*} \times Effect_{i_*,j_*,h_*}$$

(19)

$$Exposure_{i_*,j_*,h_*} = \left(\sum_{k_*=1}^{l_*} SR_{i_*,k_*} \times CR_{k_*,j_*} \right) \times ExF_{j_*,h_*} \times HR_{i_*,h_*}$$

(20)

$$Effect_{i_*,j_*,h_*} = \sum_{e_*}^{p_*} EfF_{e_*,h_*}$$

(21)

Where, SR 11 is the division of risk sources in region i_*; CF 33 is the release layer for the specific risk source in region i_*; Exf is the exposed layer in region i_* for a particular risk pressure in a particular habitat; HR is the habitat division in area i_*; EfF is the response layer for a specific ecological endpoint in a particular habitat in region i_*.。

In addition, the exposed layer and the response layer are decomposed as follows:

$$ExF_{j_*,h_*} = SHCF_{j_*,h_*} \times SHMF_{j_*,h_*}$$

(22)

$$EfF_{e_*,h_*} = HECF_{e_*,h_*} \times HEMF_{e_*,h_*}$$

(23)

Where, $SHCF$ is the release layer for a particular habitat for a particular risk pressure, and $SHMF$ is the dimension layer for a particular habitat for the particular risk pressure. $HECF$ is the specific ecological endpoint response layer for the particular habitat, and $HEMF$ is the dimension layer for the particular ecological endpoint to which a particular habitat is oriented.

Derive all the above formulas together to get the simultaneous formula of ecological risk of land use:

$$Risk_{i_*} = \sum_{h_*=1}^{o_*} \sum_{j_*=1}^{n_*} \sum_{k_*=1}^{l_*} \sum_{e_*=1}^{p_*} SR_{i_*,k_*} \times CF_{k_*,j_*} \times SHCF_{j_*,h_*} \times SHMF_{j_*,h_*} \times HR_{i_*,h_*} \times HECF_{e_*,h_*} \times HEMF_{e_*,h_*}$$

(24)

The scores are calculated through the training of the relative risk assessment model, and the land ecological risk characteristics of the entire region and sub-regions, as well as the risk sources, pressures, receptors and endpoint effects are quantitatively characterized. Finally, the ecological risk assessment for land use is completed.

3 Results

The proposed method was used for the ecological risk assessment of land use, and the evaluation results were compared with the expert evaluation results, and the performance of the proposed method was tested by comparative analysis.

In the experiment, according to the area of the study area and the land use situation, a square grid of 10 km×10 km was selected as the minimum evaluation analysis unit, and the typical sample zone was determined. The typical sample band is divided into 20 plots, and the value of the ecological risk of land use index for each plot is calculated. Combining logical information classification and feature classification methods, the degree of ecological risk of land use is divided into five levels. The specific grading situation and the corresponding risk index range are shown in Table 2.

Table 2 Level of ecological risk of land use

Risk level	range of risk index
low	<0.1

general	0.1~0.2
middle	0.2~0.4
higher	0.4~0.9
highest	>0.9

The scores were calculated using the proposed method of ecological risk assessment for land use based on remote sensing image, and the individual risk of land use index was obtained and compared with the risk index assessed by experts, as shown in Table 3.

Table 3 Ecological risk index of land use

number	Ecological risk index		number	Ecological risk index	
	The proposed method	Expert assessment		The proposed method	Expert assessment
1	0.05	0.09	11	0.17	0.19
2	0.30	0.28	12	0.27	0.30
3	0.07	0.05	13	1.45	1.50
4	1.25	1.26	14	0.47	0.46
5	0.42	0.47	15	0.22	0.22
6	0.82	0.80	16	0.25	0.23
7	0.15	0.18	17	0.85	0.81
8	0.67	0.71	18	0.14	0.17
9	0.04	0.07	19	0.07	0.08
10	0.55	0.54	20	0.68	0.70

Based on Tables 2 and 3, the ecological risk classification of each soil is carried out, and the results are as follows:

Table 4 Classification results of ecological risk of land use

Risk level	number
low	1、3、9、19
general	7、11、18
middle	2、12、15、16
higher	5、6、8、10、14、17、20
highest	4、13

Based on the land use data of the selected experimental research area for nearly 10 years and the interpretation results of remote sensing image, the index of land use efficiency (A), cultivated land colonization index (B), and vegetation coverage (C) , species diversity (D), dominance (E), and changes of fragmentation (F) in the area were obtained. It was shown in Figure 4.

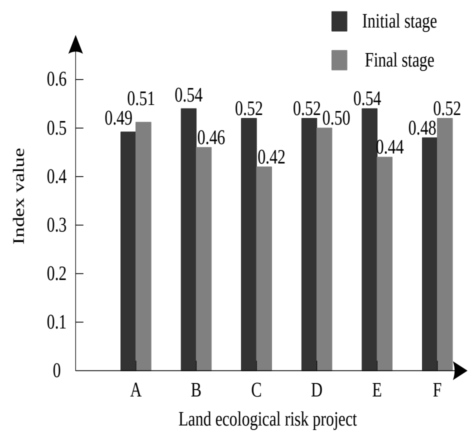

Figure 4 Comparison of ecological assessment index for land use in the study area

4 Discussion

Analysis of Table 3 data shows that the risk index of land use obtained by the proposed method is close to the expert evaluation index, and the deviation is between 0.00 and 0.05. According to the contents of Table 2, Table 3 and Table 4, the results of land use risk grading based on the proposed method are the same as those of the expert evaluation indicators, which verifies the feasibility and effectiveness of the proposed method. .

As can be seen from Figure 4, the land use index (A) and the degree of fragmentation (F) in the study area increased compared with the initial stage, while the cultivated land index (B), vegetation coverage (C), species diversity (D)), and dominance (E) show the downward trend. According to research data, when the comprehensive index of land use, cultivated land reclamation index, vegetation coverage, diversity, and dominance are relatively large, the ecological risk of land use is small. The greater the degree of fragmentation is, the greater the degree of ecological risk of land use is. The calculations are available. At the beginning and end of the study period, the area's ecological risk of land use was -2.13 and -1.81, respectively. This shows that in the process of urban development, urban construction and mining development and other industrial projects have made the land use landscape pattern tend to be fragmented, and the vegetation coverage rate has dropped significantly, which in turn has led to the increase in land ecological risk.

5 Conclusions

Ecological risk assessment for land use is an emerging field in current land resources and ecological environmental protection. On the one hand, its birth is an urgent need for the sustainable use of land resources, and on the other hand, it is also the inevitable result of the development of ecological environment science. The management of polluted land is transformed into risk prediction and management before pollution. It is valued by many national environmental protection agencies and relevant international organizations.

The technical framework for comprehensive assessment of ecological risks remains to be improved, and risk assessment lacks a comprehensive approach to integrating all factors into a specific and unique assessment method. Uncertainty is a difficult point in ecological risk assessment. The research on ecological risk assessment needs to be further expanded in the analysis of complexity and uncertainty. In the ecological risk assessment for land use, based on spatial information technology (remote sensing and GIS systems), the more scientific approach can make the assessment results more reasonable.

In addition, the destruction of the land ecosystem is not only caused by chemical and physical pressures, but also biological, so the future ecological risk assessment of the land will be more complicated. In short, as land ecological protection enters the new era, it can be foreseen that the research on land ecological risk assessment will make new contributions to the protection and improvement of human survival and natural environment. It will have new advances in the study of ecological environment science.

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Ling Chai, female, was born in September 1984, lecturer, master 's degree. She graduated from Inner Mongolia Normal University in 2016, and majored in land resource management. At present, She works in Geographical Sciences Collage of Jining Normal University as a teacher, research on land ecological environment and safety assessment, land remote sensing and information technology. So far, she has published 9 academic articles and participated in 16 scientific research projects.