Dynamic Evaluation and Prediction of the Ecological Environment Quality of the Urban Agglomeration on the Northern Slope of Tianshan Mountains

Yan Yibo
Xinjiang University
Chai Ziyuan
Xinjiang University
Simayi Zibibula (zibibulla3283@sina.cn)
Xinjiang University
Yan Haobo
North China Institute of Water Conservancy and Hydroelectric Power: North China University of Water Resources and Electric Power
Yang Xiaodong
Ningbo University
Yang Shengtian
Beijing Normal University

Research Article

Keywords: Ecological environment quality, Spatiotemporal variation, The Northern Slope of Tianshan Mountains, Spatial clustering, Principal component analysis

Posted Date: April 4th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1308788/v1

Abstract

In order to timely understand the dynamic changes of the ecological environment quality and future development laws of the urban agglomeration on the northern slope of the Tianshan Mountains, combined with the actual situation of the urban agglomeration, 11 indicators are selected from the three aspects of natural ecology, social ecology, and economic ecology. Based on RS and GIS technology methods, Principal component analysis, coefficient of variation and analytic hierarchy process are used to reduce the dimensions of the indicators, and the ecological environmental quality (EQI) from 2000 to 2018 is dynamically evaluated, and the CA-Markov model is introduced to simulate the development status in 2026 predict.The main results are as follows: the overall ecological environment of the area shows a gradually improving distribution change from southwest to northeast; the proportion of ecological environment classification shows a gradually decreasing change pattern; the spatial differentiation of ecological environment quality shows a significant spatial positive correlation; from the influencing factors It can be seen that natural ecological factors occupy a major position; the prediction accuracy verification shows that the CA-Markov model is suitable for the prediction of the ecological environment quality in the region and has high accuracy; the comprehensive regional ecological environment quality indexes are 5.7392, 6.1856 and 6.4366, respectively, and the forecast in 2026 The value is predicted to be 6.6285, indicating that the overall ecological environment quality of the region has been improved and developed well. The research reveals the law of dynamic changes and future development of the ecological environment quality in the region, which can be used as a theoretical reference for the formulation of ecological environmental protection measures in the region.

1 Introduction

The quality of the ecological environment refers to the pros and cons of the ecological environment. It is based on ecological theory and reflects the suitability of the ecological environment for human survival and the sustainable development of social economy within a specific time and space range from the level of the ecosystem. It is based on the specific requirements of human beings to evaluate the nature of the ecological environment and the results of its changing state (Liu et al., 2022). The quality of the ecological environment is directly affected by local natural resources and human life (Ma et al., 2021).Global changes and the intensification of human activities have had a huge impact on the ecosystems that humans rely on for survival and development, making ecological problems more prominent (Zhang et al., 2021). Worst of all, this change is much faster than the self-reorganization of the ecosystem, which has increased the natural and man-made pressure and disturbance in the ecological environment, which is the main reason for the degradation of the ecological environment (Garcia-Giron et al., 2022). A good ecological environment is the most important thing for people's livelihood, and it is also the basis for the sustainable development of people and society. Scientific cognition, evaluation, and reasonable regulation of the ecological environment are hot issues in the field of resources and environment research and an urgent requirement for the construction of ecological civilization (Zhao et al., 2019).

The general evaluation of the quality of the ecological environment helps to determine the current status of sustainable development in the region (Tokatli, 2022). This assessment relies on structured, semi-structured, and unstructured data analysis, as well as large data sets in many aspects of nature, society, and economy (Zhao et al., 2022). Using big data technology to manage big data sets, parallel computing provides a scientific and efficient method for regional ecology.

A single indicator cannot accurately reflect the actual situation of the regional ecological environment. With the development of remote sensing technology in recent years, it has provided a large amount of data for ecosystem monitoring and also provided reliable guidance for the evaluation of ecological conditions at different scales (Klobucar et al., 2021). Remote sensing technology has become an important technical means for studying the ecological environment due to its large amount of data, wide coverage, good timeliness, and easy access (Venturi et al., 2021). Apply various ecological indicators (such as forests (Li et al., 2019), cities (Venturi et al., 2021), water bodies (Concepcion et al., 2021)) to monitor and evaluate the ecological environment. Using remote sensing images with sufficient temporal and spatial resolution can extract ecosystem dynamics (Edney and Wood, 2021), and quickly and accurately monitor changes in corresponding ecological indicators (Knox et al., 2017).Therefore, remote sensing and GIS are currently the most effective tools for studying and analyzing regional ecological environment because of their multi-dimensional, multi-characteristic, regular and fast data availability (Liu et al., 2015).

In this study, the ecological indicators obtained by remote sensing are used to make timely decisions for the conservation, preservation and restoration of the urgently needed ecological status assessment, while the multi-index and high-resolution images can better reflect the changes of the ecological environment, providing rich information support for related research.

In recent years, the research on the quality of regional ecological environment has become one of the hotspots at home and abroad. Many scholars choose from different evaluation regions, national (Gennaro et al., 2022), and provincial (Niu et al., 2021) A lot of work has been carried out on the quality of regional ecological environment (Yan et al., 2021) from different scales and different analytical methods such as watershed (Yu et al., 2022).Based on the object-oriented classification of the LC database of multi-source high-resolution satellite images, the author uses the Remote Sensing Ecological Index (RSEI) model to quantify the changes in ecological quality, and at the same time conducts spatial autocorrelation analysis to detect the accumulation of ecological quality changes in the study area over time. Class trends (Shi and Li, 2021). Based on Landsat TM/ETM+/OLI/TIRS images, the comprehensive evaluation method of urban ecological quality is carried out, and the entropy method is combined with the principal component analysis method to construct an improved remote sensing integrated ecological index (IRSEI) evaluation model. To evaluate the ecological environment of Wuhan City, and perform spatial autocorrelation analysis on its geographic clusters (Li et al., 2021).Taking the Chengdu-Chongqing urban agglomeration as an example, based on the concept of high-quality development, panel data is used to construct a social economy and ecological environment coupling and coordination (CCD) evaluation index system. Analyzed the changing laws and characteristics of CCD from the perspective of time and space, and used regression analysis method to determine the key factors affecting the change of CCD (Wan et al., 2021).Taking Chongming Island, a typical estuarine island, as an example, a comprehensive evaluation system of ecological vulnerability of estuarine island ecosystem was constructed based on the pressure-state-response (PSR) conceptual model, and the spatial and temporal distribution characteristics of ecological vulnerability of estuarine island from 2005 to 2015 were discussed (Peng et al., 2021).

In terms of the research content, the ecological environment in a single year in a particular study area is mainly analyzed from the quantitative characteristics, spatial distribution, spatial differentiation, zoning of different spatio-temporal scales, etc., but the analysis of ecological environment change in different years and its driving forces is relatively insufficient. In addition, there are few reports about the spatial clustering analysis results of eco-environmental quality. The answers to these questions are of great significance not only to scientifically evaluate the effectiveness of current environmental regulation policies, but also to encourage policy makers to promote the optimization of relevant environmental regulation tools.

Taking the urban agglomeration on the Northern Slope of Tianshan Mountains as an example, this study dynamically evaluated the ecological environment quality of the urban agglomeration on the Northern Slope of Tianshan Mountains from the perspectives of natural ecology, social ecology and economic ecology by using spatio-temporal big data, quantitative analysis mathematical method, GIS and RS remote sensing technology. This paper aims at the following specific objectives :(1) using GIS technology and quantitative analysis of mathematical methods to establish a spatio-temporal big data based ecological environmental quality assessment model; (2)The spatial distribution and main influencing factors of eco-environmental quality were analyzed; (3)Determine the spatial autocorrelation of ecological environment quality; (4)simulate and predict the development of ecological environment, providing reference for the development and protection of urban agglomeration on the Northern Slope of Tianshan Mountains and the construction of ecological civilization.

2 Study Area

Urban group on the Northern Slope of Tianshan Mountain is located in the hinterland of Eurasia and the western edge of the second topological ladder of China, adjacent to gurbantunggut Desert in the north and Tianshan Mountain in the south. With superior resource endowment and favorable geographical conditions, it is an emerging urban group in the inland arid area of northwest China (Lifang et al., 2021). At the same time, it is also the core urban agglomeration for the development and construction of "One Belt and One Road" Economic Belt, playing an irreplaceable important role in the border consolidation of Xingjiang (Shen et al., 2021).

As shown in Fig. 2, the geographical location of urban agglomeration on the Northern Slope of Tianshan Mountains is between 81°33 '-93°32' E and 42°78 '-45°59' N. The annual average temperature and precipitation are about 7.5℃ and 185.34mm, respectively, which belong to the mountainous, oasingdesert zone. The desert oasis region has obvious characteristics of "developing by soil and water, expanding with Wells and canals, spreading around basins, and entrenched along the mountain front" (Qian, Li et al., 2021). Alpine snow and ice melt water provides water source for regional development (Zhao et al., 2021), and grassland is the main green space cover type (Shi et al., 2021). Under the background of silk Road Economic Belt construction, the urban agglomeration is facing the rapid development of economy and industry and the advancement of urbanization, which seriously threatens human health and ecological environment.

3 Data Sources And Research Methods

3.1 Data source and preprocessing

When analyzing urban agglomerations, this paper constructs an index system of the ecological environment of urban agglomerations on the northern slope of Tianshan Mountain from three aspects: ecology, economic ecology, and social ecology. The data used in this study include: normalized difference vegetation index (NDVI) data(Yue et al., 2022): Landsat remote sensing images were selected as the main data in the three time periods of 2000, 2010, and 2018 Source, the data comes from NASA (https://gpm.nasa.gov/), the selected data seasons are the same, and the element status is relatively consistent, which ensures that the research is comparable and can meet the research accuracy requirements; Digital Elevation Model (DEM) data (Raczkowska and Cebulski, 2022): The spatial resolution is 90m×90m, and the data comes from the geospatial data cloud platform (http://www.gscloud.cn), which is spliced after downloading; temperature and precipitation data(Mao et al., 2022): source China Meteorological Data Network (http: / /data.cma.cn); population density data(Martin-Turrero et al., 2022): provided by the geographic and national conditions monitoring cloud platform (http://www.dsac.cn/); Social and economic statistical data were obtained from The Bureau of Statistics of Xinjiang Uygur Autonomous Region (http://www.xjtj.gov.cn/) (2000–2018) (Zibibula·Simayi et al., 2020). Extraction of soil PH value and soil organic carbon content(Cervera-Mata et al., 2022): Soil organic matter content data were provided by the World Soil Database (HWSD) (HTTP: //www. fao.org) (Wang et al., 2015). Extraction of land use types(Li et al., 2022): provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn), the data of 2000, 2010 and 2018 were selected (Wang and Su, 2018).

3.2 Data preprocessing

(1) DEM data: Obtain slope and topographic undulation data through the Surface and Neighborhood tools on the ArcGIS software platform.

(2) Comprehensive index data of land use degree: The comprehensive index of land use degree comprehensively reflects the degree of land use in a certain area. The calculation formula is shown in formula (1).

$$L_a = 100 \times \sum_{i=1}^{n} A_i \times C_i \quad (1)$$

$$L_a \in 100,400$$

In the formula, L_a is the comprehensive index of land use degree; A_i is the grading index of land use degree of the i-th level; C_i is the area ratio of the grading land use degree of the i-th level.

(3) Meteorological data: The average annual temperature and annual precipitation are based on the data of 7 meteorological stations around the urban agglomeration on the northern slope of Tianshan Mountain. For precipitation, use Anusplin tool to complete the spatial interpolation of meteorological data.

(4) Socio-economic data: Population density is the total population/total area of each city (county); the proportion of the secondary industry is the total output value of the secondary industry of each city (county)/the total output value of the secondary industry of the city. For the socio-economic data, ArcGIS software is used to complete the inverse distance weight interpolation model.
The spatial visualization of index data can be realized by obtaining various index factors that characterize the quality of the ecological environment. Because the projection methods, coordinate systems, and scales of various data are not the same, the spatial resolution of all data is unified into a 1 km×1 km grid form, and the same Krasovsky ellipsoid coordinates and Albers projection are used. In order to calculate. For data with missing spatial attributes in data processing, it is obtained indirectly based on data collection technology on the basis of reference to existing research results. Then the natural ecological index (NE1), social ecological index (SEI) and economic ecological index (EEI) were calculated on the ArcGIS platform, and grid calculation was carried out. The natural fracture method is used to obtain the classification map of ecological environment quality evaluation, finally, the dynamic changes and influencing factors of the ecological environment quality of the urban agglomeration on the northern slope of Tianshan Mountain are analyzed, and the future development of ecological environment quality is predicted.

3.2 Rationality of indicators

The result of the long-term interaction of various natural, social, and economic elements in the regional ecological environment is the basis for the formation of the local conditions of the regional ecological environment(Eckenwiler, 2018). This research follows the basic principles of comprehensiveness, scientificity, systemicity, easy accessibility, independence, simplicity, etc.(Lin et al., 2021), and combines the ecological environment and social economy of the urban agglomeration on the northern slope of Tianshan Mountain, and selects 11 indicators to construct the northern slope of Tianshan Mountain. The evaluation index system of the ecological environment of urban agglomerations. Specifically: As a single indicator cannot reflect the relationship between urban agglomerations and the ecological environment, factors affecting the quality of the regional ecological environment(Komarova et al., 2021).

By verifying whether there is overlap of information among the 11 indicators, to ensure the accuracy of the evaluation results. Therefore, this study uses the method of multicollinearity diagnosis to make judgments(Mihreteab et al., 2020). Commonly used diagnostic indicators of multivariate collinearity mainly include variance inflation factor (VIF) and tolerance (TOL)(Sahani and Ghosh, 2021). These two indicators have a reciprocal relationship. When VIF < 10 (that is, TOL > 0.1, it indicates that there is no obvious multiple collinearity in the selected indicator(Arabameri et al., 2019). The specific method is: In ArcGIS, a 5km×5km fishing net is used to penetrate the entire boundary layer of the urban agglomeration on the northern slope of Tianshan Mountain, and a total of 5275 points are uniformly generated. With these points, 11 indicators and EQI values are read, and a collinearity diagnosis is calculated in SPSS The index (Table 1) is the statistics of these two indicators. Through the correlation test of all variables, the correlation coefficient between the variables can be observed from Fig. 3. The results show that there is no obvious collinearity among the 11 indicators, and there is no information overlap. Therefore, these 11 indicators are reasonable for this study.

Table 1
Results of multicolliearity diagnostics

Index	2000		2010		2018	
	VIF	TOL	VIF	TOL	VIF	TOL
p1	1.762	0.568	1.673	0.598	1.603	0.624
p2	9.281	0.112	1.547	0.646	1.242	0.805
p3	6.904	0.145	1.051	0.952	1.051	0.952
p4	1.561	0.64	1.571	0.636	1.403	0.713
p5	1.223	0.817	1.195	0.837	1.178	0.849
p6	1.338	0.748	1.343	0.745	1.365	0.732
p7	1.753	0.57	1.712	0.584	1.668	0.6
p8	1.225	0.816	1.19	0.84	1.194	0.837
p9	1.316	0.76	1.426	0.701	1.441	0.694
p10	1.018	0.983	1.058	0.945	1.018	0.982
p11	6.974	0.159	1.527	0.655	1.224	0.817

p1: NDVI; p2: Annual average rainfall; p3: Annual average temperature; p4: Surface undulation; p5: Distance to the river; p6: Soil type;p7: Soil effective water content; p8: Land use intensity; p9: Distance from road; p10: Population density; p11: The proportion of tertiary industry. The same below.

3.3 Ecological environment quality evaluation model

Evaluation indicators often have different dimensions, positive and negative terms, and the data vary greatly(Gottero and Cassatella, 2017). In order to achieve comparability, testability and ease of comparison among indicators, it is necessary to standardize the original data of each evaluation index before determining the weight of indicators(Pozsgai et al., 2021).

3.3.1 Natural ecological index spatial principal component analysis method, under the premise of ensuring the minimum loss of data and information, transforms multiple related indicators into a few uncorrelated comprehensive indicators by rotating the original spatial coordinate axis, which can maximize The information of the original indicators is reflected to the limit(Arabameri et al., 2019). At the same time, the whole process of spatial principal components does not need to artificially set weights, and the evaluation results are objective. Based on the above theories, this research is based on the ArcGIS platform and will evaluate in the index system, the ecological environment quality index, Surface undulation, annual average precipitation, annual average temperature, river network density, Soil type value, soil organic carbon content and other indicators related to natural ecology in the index system are analyzed by spatial principal component analysis to calculate the natural ecological index (NEI). The calculation formula is as follows:

$$NEI = R_1X_1 + R_2X_2 + R_3X_3 + \cdot \cdot \cdot + R_iX_i(2)$$

In the formula: R_i is the contribution rate corresponding to the i-th principal component; $X_i$is the i-th principal component.

When the cumulative variance contribution rate is greater than or equal to 80%, it can replace most of the relevant information of the original data(Zemni et al., 2022). In order to obtain the natural ecological information of the urban agglomeration on the northern slope of Tianshan Mountain truly and objectively, the cumulative contribution rate of the first four principal component factors has reached more than 80% (Table 2). Therefore, this study selects the first four principal component factors for fitting calculation .

Table 2
Results of spatial principal component analysis

Principal component	eigenvalue			rate of contribution (%)			Cumulative contribution rate(%)		
	2000	2010	2018	2000	2010	2018	2000	2010	2018
p1	2.187	2.194	2.175	31.238	31.337	31.071	31.238	31.337	31.071
p2	1.772	1.212	1.841	25.316	27.314	26.295	56.554	58.651	57.366
p3	1.125	1.06	1.174	16.078	15.144	16.772	72.632	73.795	74.138
p4	0.84	0.86	0.829	11.998	10.281	11.836	84.63	83.076	85.974
p5	0.53	0.714	0.568	7.57	6.194	8.109	92.2	89.27	94.083
p6	0.403	0.577	0.414	5.754	5.241	4.184	97.954	94.511	98.267
p7	0.143	0.384	0.116	2.046	5.489	1.733	100	100	100

3.3.2 Social Ecological Index The importance of social ecological index indicators is closely related to the amount of information. The coefficient of variation method starts from the attributes of the data and uses the standard deviation of each indicator as the amount of information. The weighted average is used to determine the weight of the indicator(Yang et al., 2022). It has an elimination dimension. The advantages of the weighting impact. Considering that the three indicators of social ecology-related population density, land use type, and road network density in the indicator system are difficult to determine the impact on the ecological environment of the basin, this study starts with Starting from the characteristics of the selected indicators, the weight is determined by the importance of the indicators, and the coefficient of variation method is used to calculate the social ecological index (SEI). The calculation formula is as follows:

$$V_i = \sigma_i / \bar{X}_i (3)$$

$$W_i = V_i / \sum_{i=1}^{n} V_i (4)$$

$$SPI = \sum_{i=1}^{n} W_i Y_i (5)$$

Where: V_i is the coefficient of variation of the i-th index; σ_i and $\bar{X}_i$ are the standard deviation and average of the i-th index, respectively; W_i is the weight of the i-th index; Y_i is the i-th index after indexing, which is used in this study To calculate the coefficient of variation and weight of the three indicators of SPI, as shown in the Table 3.

Table 3
Variation coefficients and weights of three indexes

	2000			2010			2018		
	p8	p9	p10	p8	p9	p10	p8	p9	p10
Mean value	0.551	0.867	0.999	0.535	0.867	0.997	0.507	0.867	0.999
standard deviation	0.390	0.153	0.017	0.390	0.153	0.032	0.381	0.153	0.017
variable coefficient	0.708	0.177	0.017	0.729	0.177	0.032	0.751	0.177	0.017
weight	0.786	0.196	0.018	0.778	0.188	0.034	0.795	0.187	0.018

3.3.3 Economic ecological index Economic development will affect the changes of the ecological environment in surrounding areas to a certain extent. The indicators related to economic ecology in the index system are the proportion of the tertiary industry representing the economic development status of the basin(Jiang et al., 2021). To a certain extent, it can reflect the intensity of economic development on the environmental protection and capital investment in the surrounding areas. Therefore, the economic ecological index (EEI) in this study is equivalent to the proportion of the tertiary industry.

3.3.4 Eco-environmental quality evaluation index This research starts from the three aspects of nature, society and economy, and calculates NEI, SEI and EEI respectively to characterize the ecological environment quality status of the urban agglomeration on the northern slope of Tianshan Mountain. Combining the unique characteristics of the urban agglomeration on the northern slope of Tianshan Mountain Regional characteristics and the importance of the factors affecting the regional ecological environment are ranked from high to low: natural factors>social factors>economic factors(Ren et al., 2022).This study uses a hierarchical analysis(Zhong et al., 2022) to determine the weight of NEI, SEI and EEI.The specific method is: construct a pairwise discriminant matrix according to the interrelationship between the indicators, and then perform a consistency test, and finally calculate the weight value of each indicator. (Table 4) The discriminant matrix constructed based on this , The maximum characteristic root = 3.014, the consistency index CI = 0.007, the random consistency index RI = 0.520, the random consistency ratio CR .= 0.013�0.1, passed the consistency test(Jahanger, 2021). After calculation, the weights of NEI, SEI and EEI Respectively 0.570, 0.333, 0.097. The calculation formula of the eco-environmental quality evaluation index (EQI) is as follows:

$$EQI = 0.570NEI + 0.333SEI + 0.097EEI(6)$$

Table 4
Pair-wise comparison matrix

Index	NEI	SEI	EEI
NEI	1	2	5
SEI	1/2	1	4
EEI	1/5	1/4	1
NEI: Natural ecological index ; SEI: Social ecological index ; EEI : Economic ecological index			

In order to compare and analyze the differences in ecological environment quality in local areas, it is necessary to classify the EQI. Here, this study mainly uses the natural break point method (Jenks) for classification(Guo and Yuan, 2021). The classification criteria for each period should be unified, otherwise no comparative analysis can be performed(Bjelle et al., 2021). Therefore, both 2000 and 2018 adopted the 2018 grading standard. The grading standards (Table 5) are shown.

Table 5
Classification criterion of eco-environmental quality

class	Criterion	EQI
1	Extremtly bad	□0.425
2	Bad	0.425 ~ 0.491
3	Poor	0.491 ~ 0.556
4	Moderate	0.556 ~ 0.617
5	Better	*0.617 ~ 0.675*
6	Good	*0.675 ~ 0.736*
7	Excellent	*□0.736*

2.4 Comprehensive Index of Ecological Environment Quality

The comprehensive index of ecological environment quality is an objective indicator to measure the overall condition of the regional ecological environment. The model is:

$$E = \sum_{i=1}^{n} P_i \frac{A_i}{S}$$

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In the formula: EEQI is the comprehensive index of ecological environment quality; P_i is the ecological environment level; A_i is the number of grids of the i-th level; n is the total number of levels; S is the total number of grids. The smaller the value of E in the study, the worse the overall ecological environment quality of the region.

3.5 spatial clustering model

Spatial autocorrelation analysis is to examine a certain geographical phenomenon or the overall dispersion state of a certain variable, and then determine whether it has agglomeration characteristics in space(Haak et al., 2022). The global spatial autocorrelation index is used to verify the spatial correlation index of a certain element in the entire research area. This paper selects the global Moran's I index index, and with the support of the GeoDa software platform, analyzes the agglomeration characteristics of the ecological environment quality index in 2000, 2010 and 2018 respectively, The calculation formula is as follows(5):

Global Moran's I Index: $I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n}(x_i - \bar{x})^2}$ (8)

Local Moran's I Index: $I = \frac{\left(X_i - \bar{X}\right)}{S^2} \sum_j W_{ij}\left(X_j - \bar{X}\right)$ (9)

In the formula, I represents Moran's I index; X_i and X_j represent the mean value of the ecological environment quality of the i-th and j-th grids; W_{ij} refers to the spatial weight matrix.

Where I stands for Moran's I index; Xi and Xj stand for the mean value of the ecological environment quality of the i-th and j-th grids; Wij means the spatial weight matrix, S Represents the sum of the elements of the spatial weight matrix.

Based on the calculation of the global Moran's I index(Bai et al., 2021), the Moran scatter plot is obtained, and the ecological environment quality index is further divided into 5 different types, namely, high-high aggregation area (H-H), high-low aggregation area (H-L), low-high aggregation area (L-H), low low aggregation area (L-L) and not significant (No significant). The specific meaning is shown in Table 6:

Table 6
The connotation of different Moran clustering models

Clustering types	**Connotation**
High-High clustering (H-H)	The spatial agglomeration characteristics of the region's own ecological environment and the surrounding level are high.
High-Low clustering (H-L)	The region's own ecological environment is of high quality, but the surrounding area has low spatial agglomeration characteristics.
Low-High clustering (L-H)	The fragility of the ecological environment of the region itself is low, but the surrounding area has high spatial agglomeration characteristics.
Low-Low clustering (L-L)	The spatial agglomeration characteristics of the region's own ecological environment and the surrounding level are low.
No significant	There is no significant spatial agglomeration feature.

3.6 Geodetector

Geodetector is a new statistical method proposed by Wang Jinfeng to detect spatial differentiation and reveal its driving factors (Liu et al., 2021). This study uses a factor detector to analyze the causes of the ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains. The factor detector can detect whether a factor is the cause of the spatial and temporal distribution pattern of the ecological environment quality and to what extent it explains the space of the ecological environment quality. Differentiation mechanism, the specific method is: use EQI as the dependent variable, take the selected 11 indicators as independent variables, use the natural breakpoint method for stratification, and convert the numerical value to the type value. In ArcGIS, use the Create Fishnet tool to construct the fishing nets of 5 km×5 km cover the entire study area, and a total of 5275 fishing nets are uniformly generated. Then the dependent variable values and the independent variable values are matched through the fishing nets to detect the influence of each factor. Available Q value measurement, its expression is:

$$Q = 1- \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \quad (10)$$

Where: h = 1,..., L is the stratification (Strata) of variable Y or factor X, that is, classification or division; N and N are the number of units in layer h and the whole area respectively;$\sigma$and σ^2 are layers respectively The variance of h and the Y value of the whole area. The value range of is [0,1], the larger the value, the more obvious the spatial differentiation of Y; if the stratification is generated by the independent variable X, the larger the value of q, the greater the influence of the independent variable on the attribute Y Larger, conversely, smaller.

3. 6 CA-Markov model

Cellular automata (CA) is a mathematical model that can simulate the spatiotemporal evolution process of a huge complex system(Zhou et al., 2022). The model is:

$$S_{ij}^{t+1} = f_q\left(S_{ij}^{t}\right)$$

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In the formula: S is the state of the ij-th cell; t and t + 1 are moments; f is the transfer function; q is the neighborhood.

The basic principle of Markov is to realize the simulation prediction of its future development status by using the experience transfer probability of the existing discrete state of the system. If there is Markov property in the change process of a system, Se is its state at the initial moment, then the state after e cycles can be defined as:

$$S_e = S_0 P_e$$

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Where: S_e is the state after e cycles; e is the number of cycles; P_e is the system experience transfer probability matrix.

The research is based on IDRISI17. 0 software is used as a tool to calculate the probability matrix based on the data of 2000 and 2010, 2010 is the base period, the number of iterations is set to 8, the filter is 5 × 5, and the proportional coefficient is set to 0.15. The spatial pattern of the ecological environment quality in 2018 is simulated and compared with the actual ecological environment quality status in 2018. The CROSSTAB module is used to complete the calculation and accuracy verification of Kappa coefficients of real and simulated results. In the same way, complete the simulation forecast for the region in 2026.

4 Results And Analysis

4.1 Spatial distribution

The study combined with the analysis of the spatial distribution characteristics (Fig. 4) shows that the overall ecological environment vulnerability of the urban agglomeration on the northern slope of Tianshan Mountain has gradually increased from southwest to northeast, and the quality of the ecological environment in the southwest is relatively lower than that in the northeast.

At the same time, the spatial distribution of the ecological environment quality of each level of the urban agglomeration also shows obvious regional differences. In general, the quality of the ecological environment has gradually improved. In 2000, the areas below the medium-level ecological environment had the widest spatial distribution, accounting for about 73.2% of the entire area. District, combined with the type of land use, it can be known that it is the core residential area and the main concentrated area of construction land for the social and economic development of urban agglomerations.In 2010, the ecological environment was relatively improved compared to the ecological environment above the middle level in 2000. Areas above the middle level accounted for about 35% of the entire area. Most of them were concentrated in the middle mountain areas on both sides of the river. The population density was relatively low and human activities were not obvious., Combined with the analysis of topographic data, it can be known that it is an important buffer zone and key monitoring and prevention area for regional ecological environmental protection. The main ecosystem is relatively complex and diverse, and the land landscape is dominated by medium-coverage grassland. Compared with 2010, areas with excellent ecological environment have improved significantly in 2018. The main reason is that with the implementation of my country's "returning farmland to forest" and "returning farmland to grass" and other policies and ecological projects, people's awareness of environmental protection has increased and people's awareness of ecological protection has been strengthened., Making the quality of the ecological environment gradually improve.

4.2 Structural features

Statistical analysis of the grid ratios of different levels of ecological environment quality can help to further understand the differences and change characteristics of the regional ecological environment quality.

Analysis of Fig. 5 shows that there are obvious differences in the structure distribution of the grid ratios of each level. The ratio in 2000 is Better＞Moderate＞Good＞Poor＞Bad＞Extremtly bad＞Excellent, The scale relationship in 2010 was Moderate > Better > Good > Poor > Bad > Extremtly bad > Excellent, and the scale relationship in 2018 was Better > Good > Moderate > Poor > Excellent > Bad > Extremtly bad. At the same time, from 2000 to 2018, the proportion of grids above the intermediate level accounted for more than 65% of the entire area. Objectively, it can be determined that the overall ecological environment quality of the area continued to be at a medium level during the study period. The proportion of high ecological environment quality index is gradually increasing. It reflects that the ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains from 2000 to 2018 has shown a clearly good trend.

4.3 Spatial aggregation mode of ecological environment quality

Using GeoDa and GIS software, the Queen spatial weighting method is used to carry out spatial autocorrelation analysis of the ecological environment quality. Moran's I is used to determine whether a variable is spatially correlated and its degree of correlation to quantitatively describe the spatial dependence of elements.

It can be seen from Fig. 6 that the regional ecological environment quality is concentrated, with fewer discrete points, showing a continuous distribution trend. The scattered points are mainly distributed in the first and third quadrants. The Moran's I index from 2000 to 2018 was higher than 0.85. It shows that the ecological environment quality of the study area has a significant positive spatial correlation, that is, the ecological environment quality presents a significant clustering state of high-value area and high-value area close to each other, and low-value and low-value area close to each other.

The analysis of the local spatial autocorrelation spatial distribution map (Fig. 7) shows that the ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains roughly presents a “banded” distribution pattern, with obvious spatial clustering characteristics and uniform distribution. On the whole, the ecological environment of the urban agglomeration on the northern slope of Tianshan Mountain There are two types of spatial correlation patterns in environmental quality, namely high-high aggregation type (H-H), low-low spatial aggregation type (L-L), and present high-high aggregation, low-low height aggregation, and contiguous and large The characteristics of the spatial distribution of the area, the southeast area is mainly high-high agglomeration area, the low-low agglomeration type is mainly in the central and northwestern areas of the urban agglomeration on the northern slope of Tianshan Mountain, and most of them are located in the lower elevation area on the northern slope of Tianshan Mountain. Desert area and low mountain and hilly area. The quality of the ecological environment in these areas has positive spatial autocorrelation. The eco-environmental quality of the above-mentioned areas is greatly affected by the eco-environment of the surrounding areas. In the remaining areas, the agglomeration is not obvious, the spatial autocorrelation is not obvious, and the ecological environment quality is randomly distributed, that is, the ecological environment quality has little impact on the surrounding areas. When carrying out ecological management, priority can be given to areas with high spatial autocorrelation, so as to improve work efficiency and quickly improve the quality of the ecological environment.

4.4 Influencing factors of ecological environment quality

The ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains is inseparable from the natural ecology, social ecology, and economic ecology. Figure 6 shows the relationship between NEI, SEI, EEI and EQI. Points with better ecological conditions are mainly distributed at the top of the three-dimensional scatter plot, which are clustered in areas with large SEI values and high NEI; points with weaker ecological conditions are located at the bottom, The pooled EEI value is higher, and the NEI value is lower.

The ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains is inseparable from natural ecology, social ecology, and economic ecology. It can be seen from (Fig. 8) that the high value of NEI is mainly concentrated in the middle and lower reaches of the artificial oasis area, and the low value is mainly concentrated in the desert and low The natural ecological content of the mountainous and hilly areas, especially the lower reaches of the desert, the junction of the desert and the vast area to the north is extremely scarce; the spatial distribution of the SEI value is relatively fragmented, and the high value is mainly concentrated in the woodland, grassland and water area of the artificial oasis, and the low The value is mainly located in urban construction land, desert area and low mountain and hilly area; the high value of EEI is mainly concentrated in the economically developed southeast area. As far as the entire urban agglomeration on the northern slope of the Tianshan Mountains is concerned, the industrial structure has always been "two-three-one" order of. In the tertiary industry, Urumqi, Shihezi, Kuytun and Changji have a better foundation, among which Shihezi has stronger competitiveness but Kuytun and Changji are not. The tertiary industry in Fukang is a fast-developing industrial sector with a poor foundation. Karamay and Usu have poor tertiary industry foundation and weak competitiveness. Karamay, Urumqi, Changji, Fukang and other cities in the urban agglomeration on the northern slope of the Tianshan Mountains all take energy and chemical machinery manufacturing and electric power as their main industries, but the industrial division of labor has not formed an orderly gradient level.

In order to further analyze the internal reasons for the changes in the ecological environment quality of the urban agglomeration on the northern slope of the Tianshan Mountains, this study introduces the factor detector in the geographic detector as an analysis tool to reveal the internal driving factors of the ecological environment quality. The q value indicates the degree of influence of the factor on the ecological environment), and the P value indicates whether the factor passes the significance test level. (Table 7) The statistics of the results of the Geographic Detector show that from the overall ranking of 11 indicators according to the q value, the natural ecology, social ecology and economic ecology have three aspects of the impact of the ecological environment of the basin, and the natural ecology occupies a dominant position. Among them, the vegetation coverage and annual precipitation are both greater than 0.5. The natural ecological spatial distribution of the urban agglomeration on the northern slope of the Tianshan Mountains is quite different. The vegetation coverage, altitude gradient distribution, soil type, precipitation status, water resources reserves, etc. of different regions are relatively different. Large differences; the impact of social ecology is the second, among which, the q value of land use types are all above 0.54, and the impact is relatively high, mainly because the urban construction land and large-scale desert area have brought economic development to the urban agglomeration on the northern slope of Tianshan Mountain A large burden, the least impact on the economic ecology. The urban agglomeration on the northern slope of the Tianshan Mountains is deep inland, with sparse precipitation, strong evaporation, and sparse vegetation. The vegetation coverage is mainly low and medium-low. Affected by topographical factors, river flow, flow direction, oasis distribution and human activities, the different levels of ecological environmental quality indexes are roughly distributed in a northwest-southeast direction. The regional population is concentrated in the oasis, and there are few human activities in the mountains and deserts of the region. The quality of the ecological environment is relatively stable. The stable pattern of the change map mostly overlaps with the regions with low ecological environment quality index. This phenomenon also verifies the rationality of the EQI construction from the side. The EQI was established in the order of the importance of natural factors > social factors > economic factors in the initial stage of construction, which is consistent with the actual situation, and the results are true and reliable.

Table 7
Geographical detector results on 11 impact factors of eco-environmental quality

Factor	**2000**			**2010**			**2018**		
	q value	**P value**	**q ranking**	**q value**	**P value**	**Q ranking**	**q value**	**P value**	**q ranking**
p1	0.777	0.000	1	0.805	0.000	1	0.820	0.000	1
p2	0.636	0.000	2	0.788	0.000	2	0.733	0.000	3
p3	0.422	0.000	5	0.587	0.000	4	0.629	0.000	4
p4	0.260	0.000	7	0.217	0.000	10	0.583	0.000	5
p5	0.287	0.000	6	0.427	0.000	6	0.482	0.000	7
p6	0.550	0.000	4	0.456	0.000	5	0.495	0.000	6
p7	0.157	0.000	10	0.256	0.000	8	0.305	0.000	9
P8	0.567	0.000	3	0.697	0.000	3	0.786	0.000	2
P9	0.251	0.000	8	0.366	0.000	7	0.409	0.000	8
P10	0.137	0.000	11	0.149	0.000	11	0.122	0.000	11
P11	0.184	0.000	9	0.187	0.000	9	0.214	0.000	10

During the changes from 2000 to 2018, the influence of vegetation coverage has gradually increased, and the increase in vegetation coverage has played a key role in the restoration and management of the ecological environment. The local government should take the initiative to improve policies and measures related to ecological environment protection, implement the responsibilities of all parties, guide and encourage local residents to increase their awareness of environmental protection; locally, for urban expansion and economic development zones, coordinate the ecological environment and socio-economic development. For the oasis and the desert Gobi area where the ecological environment has been damaged to a certain extent, it is necessary to find the cause in time and remediate it as soon as possible. Ecological environment is the foundation and necessary condition for people's survival and development, and it needs to be paid close attention to.

4.5 Forecast result

Import the ecological environment quality classification raster data of 2000, 2010 and 2018 into IDRISI, obtain the ecological environment quality transfer area matrix and transition probability matrix from 2010 to 2018 through the Markov module, and predict 2018 through the CA-Markov model The ecological environment quality spatial distribution map, and compared with the actual 2018 ecological environment quality distribution map, the calculated Kappa value is 0.8972. The value of Kappa coefficient is between 0.75-1, indicating that the simulation effect is good. This model can be applied to the spatial simulation of ecological environment quality changes in the urban agglomeration on the northern slope of Tianshan Mountain. At the same time, in order to further study the future development of the fragility of the ecological environment in this area, a simulation forecast of its situation in 2026 was carried out (Fig. 10).

Through the analysis of the prediction simulation results in 2018, it can be seen that the spatial distribution characteristics are basically consistent with the real results. As shown in Fig. 11,the proportions of each grid in 2018 are 8.24%, 10.63%, 17.35%, 16.02%, 19.16%, 17.31% and 11.29%. Comparing the true proportions of each category in this year, it can be found that the accuracy of the predictions of each category presents a relatively consistent state of change; the accuracy test shows that the CA-Markov model not only has a higher overall prediction accuracy when realizing the prediction and analysis of the ecological environment quality in the region., The prediction accuracy of each category is also high; the prediction results in 2026 show that the urban agglomeration on the northern slope of Tianshan Mountain as a whole shows a gradual improvement in the quality of the ecological environment, and the grid ratios of each category are 11.07%, 7.01%, 12.05%, and 15.86% 22.07%, 16.77% and 15.17%, compared with the above-average level of ecological environment in 2018, the proportion of ecological environment grades showed an increasing trend, while the ecological environment quality below the intermediate level showed a decreasing trend of change.

4.6 Trend changes

As shown in Fig. 12, the research uses formula (8) to calculate the EEQI value of the area in 2000, 2010 and 2018, 5.7392, 6.1856 and 6.4366, showing a gradually increasing trend, which objectively characterizes the ecological environment of the basin area in the past 20 years. The overall state of development is improving. At the same time, the study predicts that the EEQI of this area will be 6.6285 in 2026, which also shows an increasing trend. Some areas with extremely poor ecological environment have an increasing trend, which may be due to the harsh natural environment in the northern slope of the Tianshan Mountains and the arid climate conditions in the area. Exacerbate the deterioration of the ecological environment; however, the number of areas where the ecological environment is getting better gradually increases, which indicates that with the effective implementation of a series of environmental measures, the overall regional ecological environment will continue to develop in the direction of continuous improvement.

5 Discussion

5.1 Literature review

The results show that the ecological environment quality system of urban agglomeration on the Northern Slope of Tianshan Mountain is an effective method for ecological environment assessment based on spatio-temporal big data, quantitative analysis mathematical method, GIS and RS remote sensing technology. Taking Chongming Island, a typical estuarine island, as an example, a comprehensive evaluation system of ecological vulnerability of estuarine island was established based on the pressure-state-response (PSR) conceptual model, and the spatial and temporal distribution characteristics of ecological vulnerability of estuarine island were discussed from 2005 to 2015(Peng et al., 2021). Research in chongqing wansheng economic development zone as an example, the urban planning from the land, the hydrology, resources, ecological and geological environment five aspects of selecting 20 evaluation indicators, using the analytic hierarchy process (AHP) to determine the weights of evaluation indexes, analyzes the geological environment quality present situation from 2007 to 2019, using fuzzy comprehensive evaluation method of urban geological environment quality evaluation(Lu et al., 2021). Based on a series of Landsat images, the improved remote sensing ecological index was used to monitor and evaluate the ecological environment quality of Yangquan Coal mine in Shanxi Province from 1987 to 2020. The temporal and spatial evolution law of ecological environment quality was quantitatively evaluated quickly and accurately, which is of great significance to the ecological restoration and development planning of coal mine area(Nie et al., 2021). Primary productivity, land surface temperature, land exposure and vegetation coverage were selected to reflect the ecological environment quality of wuzhong District, Suzhou. The spatial principal component analysis method was used to construct the ecological environment comprehensive index to characterize the temporal and spatial variation characteristics of ecological environment quality in the red line area of wuzhong District(Jia et al., 2017). Based on the Modified Remote sensing Ecological Index (MRSEI) retrieved from Google Earth Engine (GEE), we evaluated and analyzed the ecological and environmental quality of the Qaidam Basin from 1986 to 2019, combining meteorological and socio-economic auxiliary data(Jia et al., 2021).

In contrast, our method has a more comprehensive perspective to evaluate the eco-environmental system of the urban agglomeration on the Northern Slope of the Tianshan Mountains. Its advantages are as follows: on the one hand, it considers multiple pressures brought by social changes (such as economic development and human influence, etc., and combines multiple state and response indicators). In addition, the method can also provide spatial ecological environment information. More importantly, by putting forward a comprehensive evaluation system, we can understand the spatial and temporal distribution of ecological environment quality from the perspectives of natural ecology, social ecology and economic ecology, which is helpful for managers and decision makers to carry out protection planning and environmental management. At the same time, the ecological environment development of the study area in 2026 was simulated and predicted to provide reference for urban agglomeration development and protection and ecological civilization construction.

5.2 Research deficiencies and prospects

The ecological environment is a complex, comprehensive and fuzzy aggregate, but the current evaluation methods and evaluation index system cannot be scientifically and comprehensively evaluated. This research still has some shortcomings in the selection of indicators. From the perspective of natural factors, the influence of factors such as groundwater, soil moisture, and windy days is not considered; from the perspective of human factors, this research only considers population, economy, and land. The impact of utilization methods on the ecological environment of the urban agglomeration on the northern slope of the Tianshan Mountains. Human disturbance activities include many aspects. Environmental issues such as mining intensity and industrial and agricultural development have certain impacts on the regional ecological environment. In future research, analysis should be conducted based on the specific conditions of the study area and comprehensive consideration of various ecological influencing factors. There is still a need for further exploration to establish a reasonable, scientific and comprehensive evaluation index system for ecological environmental quality.

6 Conclusion

1. Based on RS and GIS, this study evaluated the ecological environment quality of the urban agglomeration on the northern slope of Tianshan Mountain on a macro scale. Generally speaking, the ecological environment quality of the urban agglomeration on the northern slope of Tianshan Mountain showed a trend of improvement as a whole, and there was a strong positive space. Correlation, there is a certain internal connection, and the spatial distribution shows cluster characteristics, not random distribution.Areas with poor and poor ecological environment quality are mainly distributed in unused land areas such as bare land, deserts, and Gobi; while areas with good and excellent ecological environment quality are mainly concentrated in oasis areas and the middle and lower reaches of rivers. Natural ecological factors have a dominant influence on the area, where the q value of vegetation coverage, soil type, altitude, and annual precipitation is greater than 0.5, which has a greater impact; the second is social ecological factors, and the q value of land use type is 0.540, The degree of influence is relatively high; while the influence of economic and ecological factors is the least.Carry out regression analysis on the selected sample points and establish a CA-Markov model suitable for evaluating and predicting the quality of the ecological environment. The prediction results show that the overall ecological environment quality of the region will continue to improve.

2. Research shows that the combination of RS and GIS for ecological environment vulnerability assessment has high accuracy; the method of using the CA-Markov model to realize its future development forecast is basically feasible. At the same time, unlike previous studies, this study has realized the exploration of long-term changes in the results of multiple periods and predicted and analyzed the future development of the regional ecological environment, which more effectively made up for the vacancy.

Declarations

Funding: This research was funded by the National Natural Science Foundation of China (Grant Nos. 41661036), National Natural Science Foundation of China—Xinjiang Joint Fund (Grant Nos. U1603241), Xinjiang local government sent overseas study group supporting projects (No. 117/40299006).

Acknowledgments: Thanks to the hard-working editors and valuable comments from reviewers.

·Ethics approval and consent to participate

Not applicable

·Consent for publication

All the authors agreed to be published

·Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

The statistical data used in this study can be found in various statistical yearbooks in China. NDVI data were obtained from NASA (https://gpm.nasa.gov/). DEM data come from geospatial data cloud platform (http://www.gscloud.cn); Population density data: provided by the Cloud platform of Geographic National Conditions Monitoring (http://www.dsac.cn/); Soil data are provided by the World Soil Database (HWSD) (HTTP: //www. fao.org). Extraction of land use types: Provided by Data Center for Resources and Environmental Sciences, Cas (http://www.resdc.cn).

·Competing interests

The authors declare that they have no competing interests

·Funding

The research is funded by the National Natural Science Foundation of China (Grant Nos. 41661036), National Natural Science Foundation of China—Xinjiang Joint Fund (Grant Nos. U1603241), Xinjiang local government sent overseas study group supporting projects (No. 117/40299006).

·Authors' contributions

Simayi Zibibula: Funding acquisition. Yan Yibo: Methodology, Formal analysis, Software, Data Curation, Writing-Original Draft, Visualization. Chai Ziyuan: Conceptualization, Project administration. Yan Haobo: Writing - Review & Editing. Yang Xiaodong: Supervision. Yang Shengtian: Data

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Figures

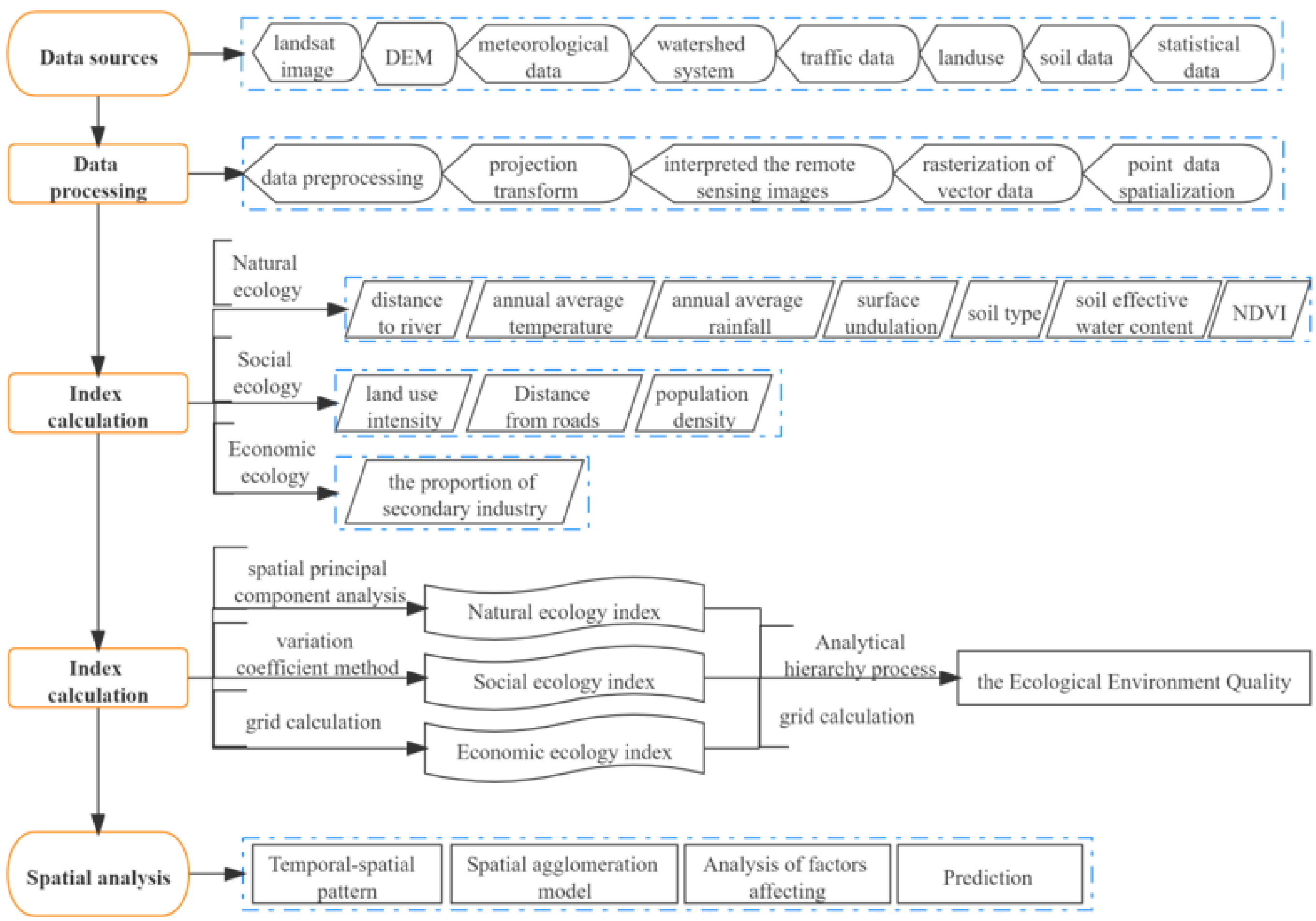

Figure 1

Research framework and path diagram

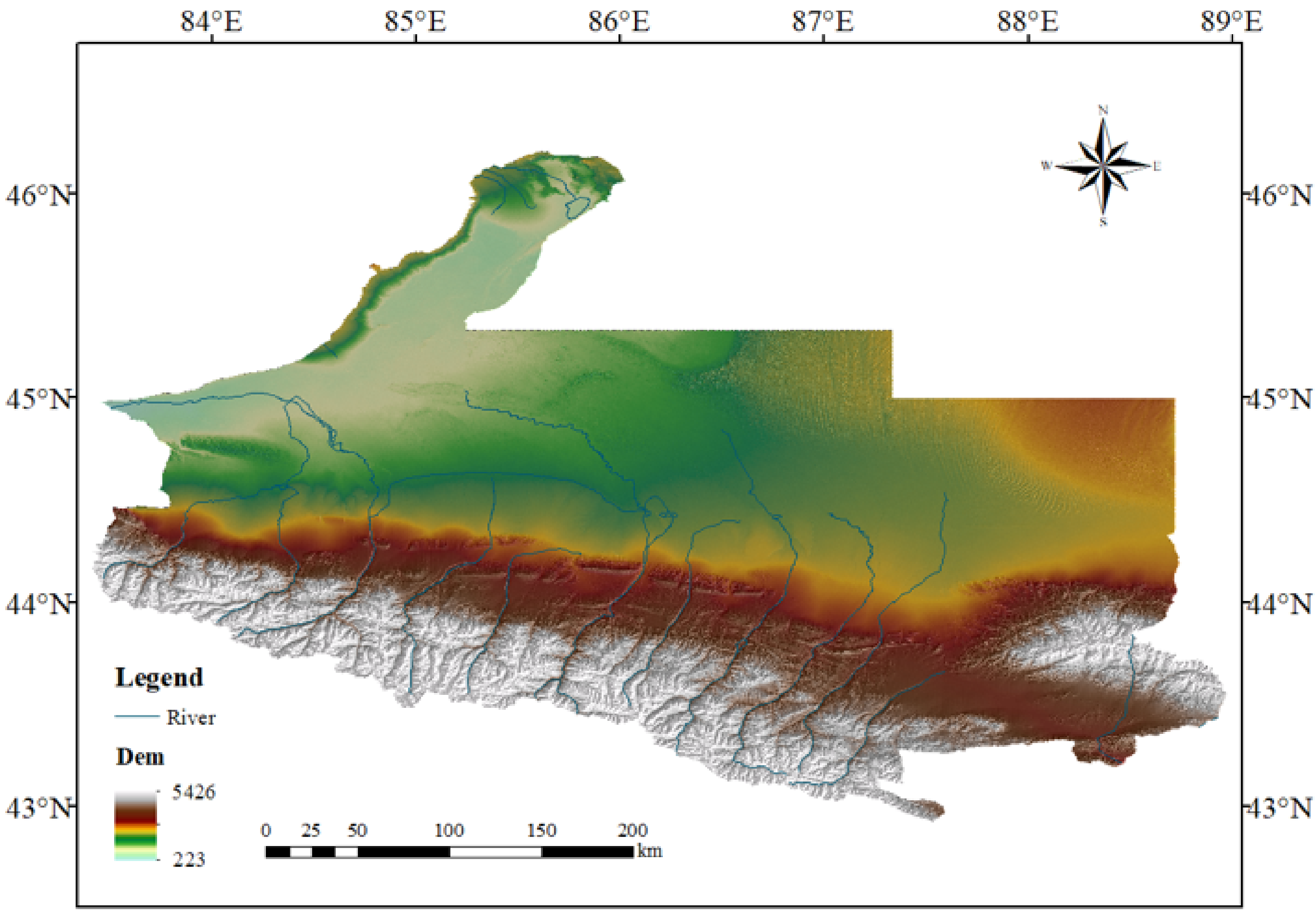

Figure 2

study area

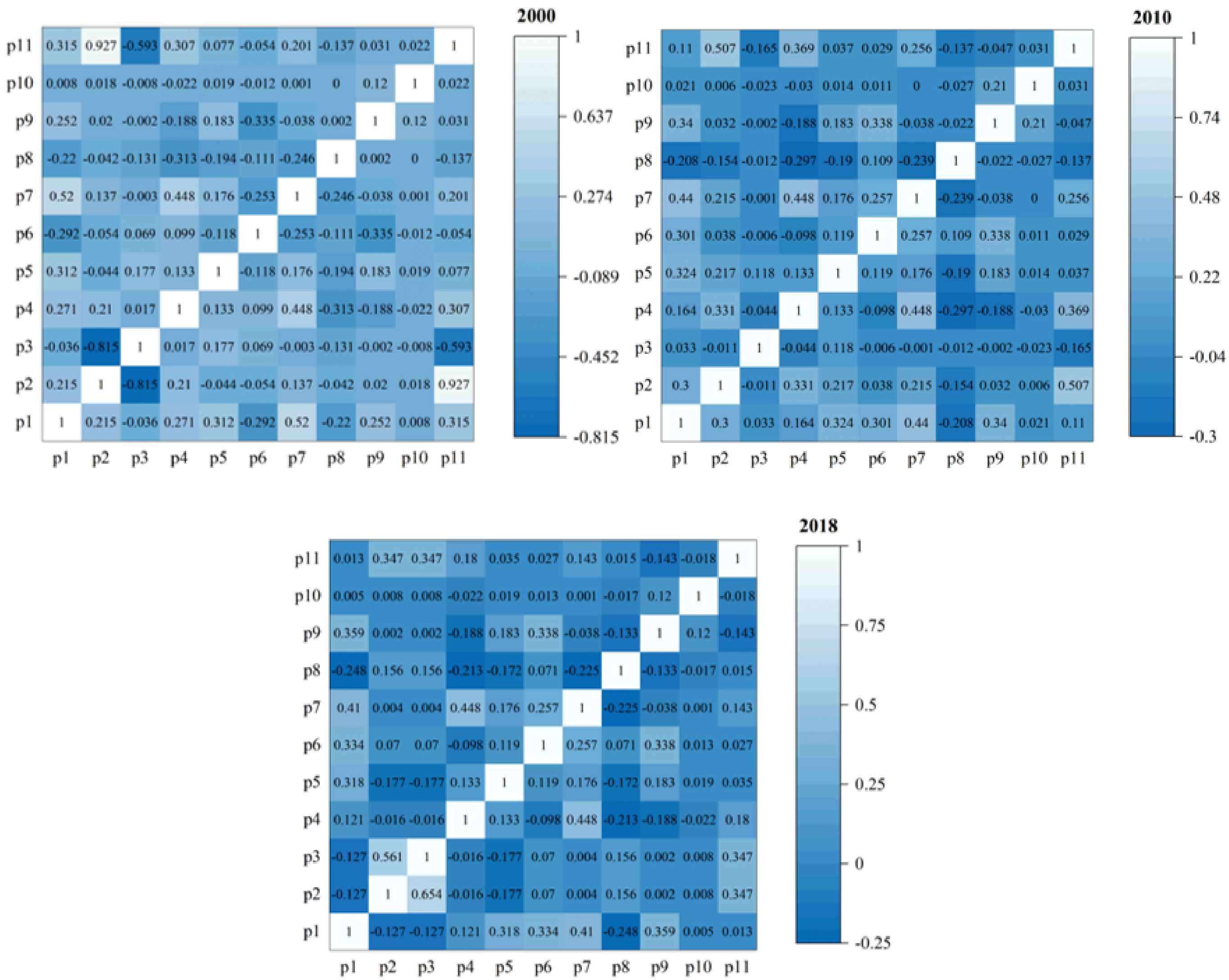

Figure 3

Correlation thermodynamic diagram of each index

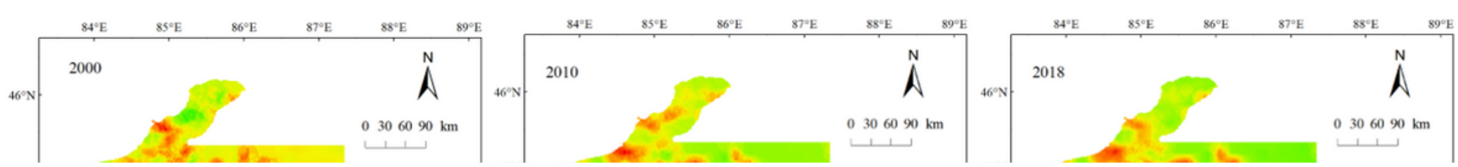

Figure 4

Spatial distribution of eco-environmental quality

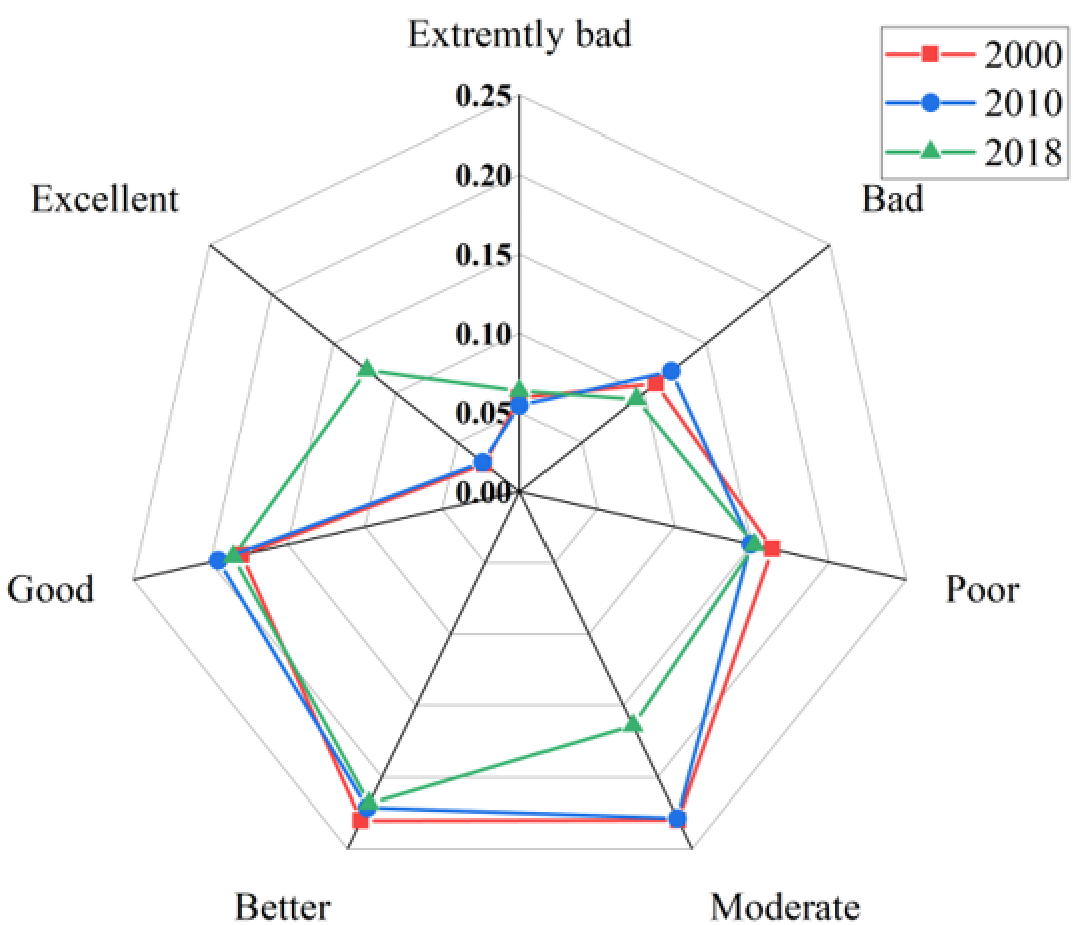

Figure 5

Eco-environmental quality classes and area statistics

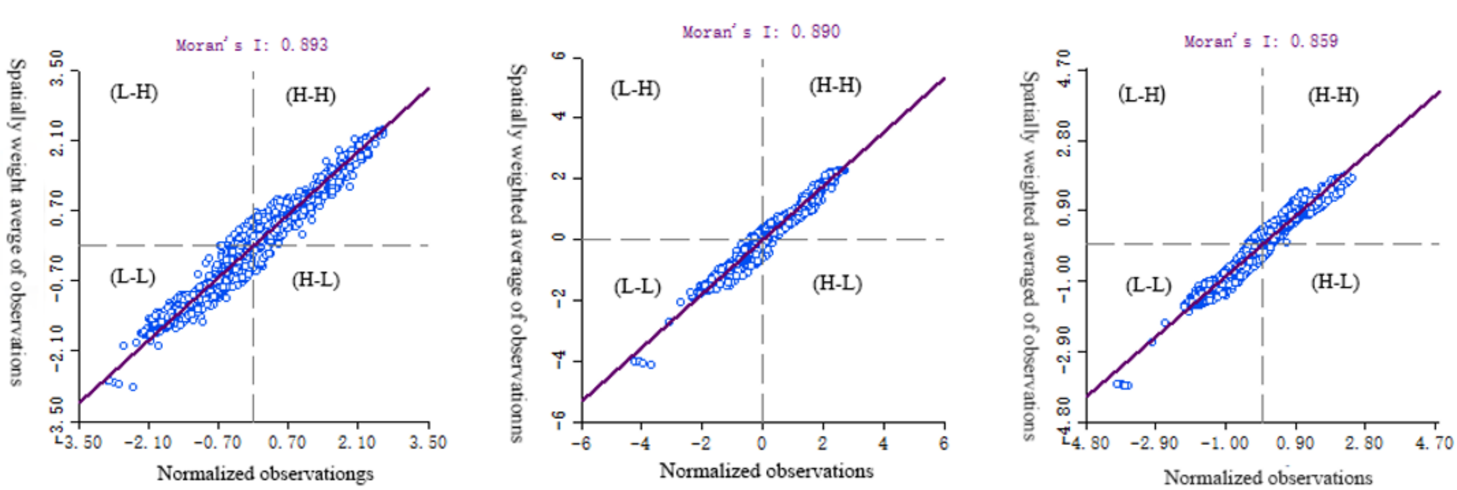

Figure 6

Moran scatter plot of the eco-environmental quality from 2000 to 2018

Figure 7

Spatial agglomeration of ecological environment quality

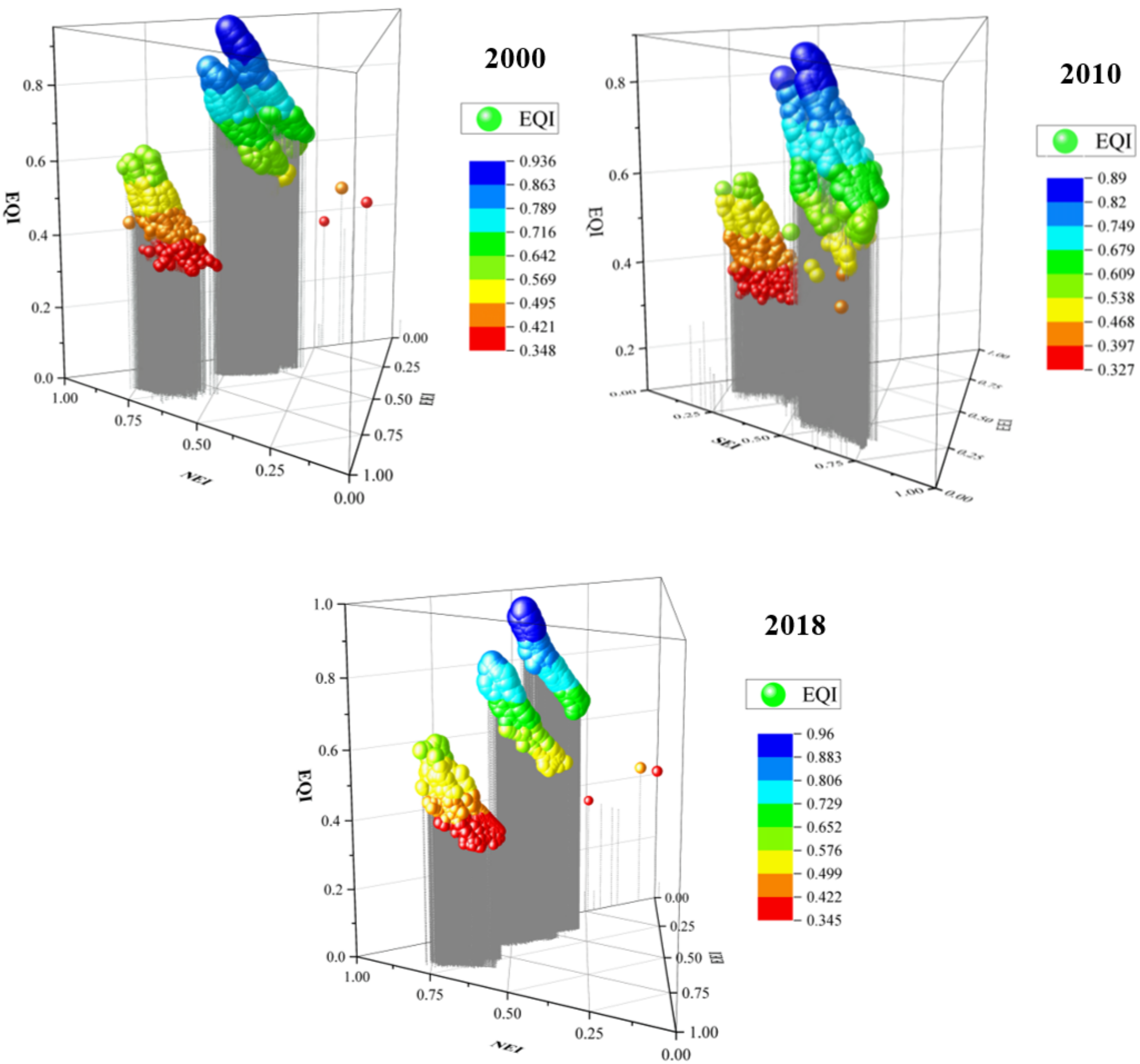

Figure 8

3D - scatter plots of feature space

Figure 9

Spatial distribution of evaluation factors

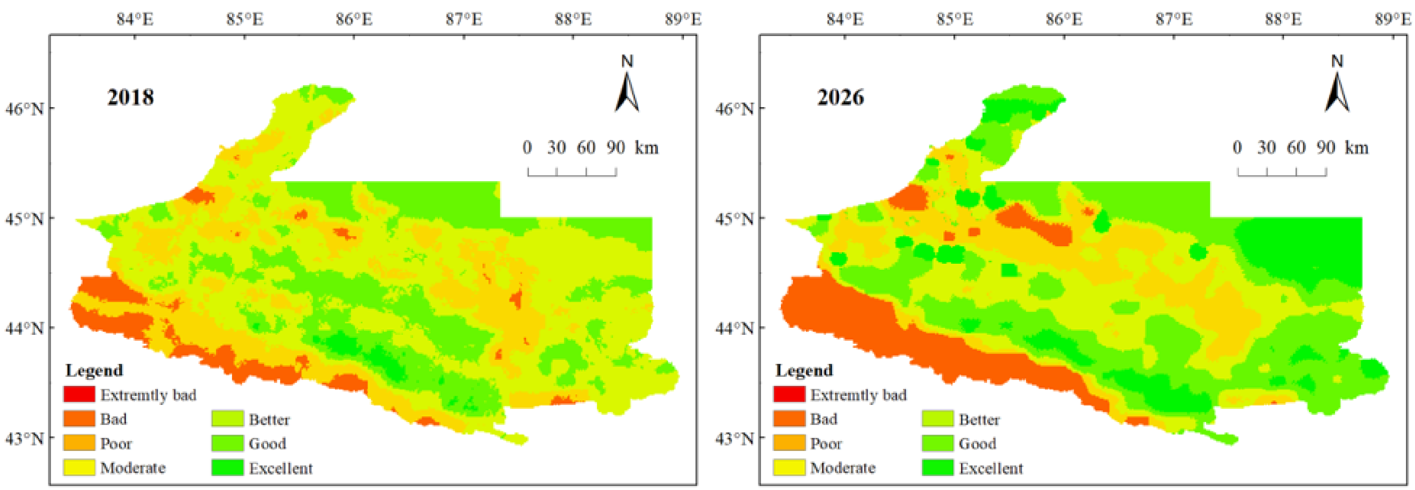

Figure 10

Simulation results of eco-environmental quality prediction in 2018 and 2026

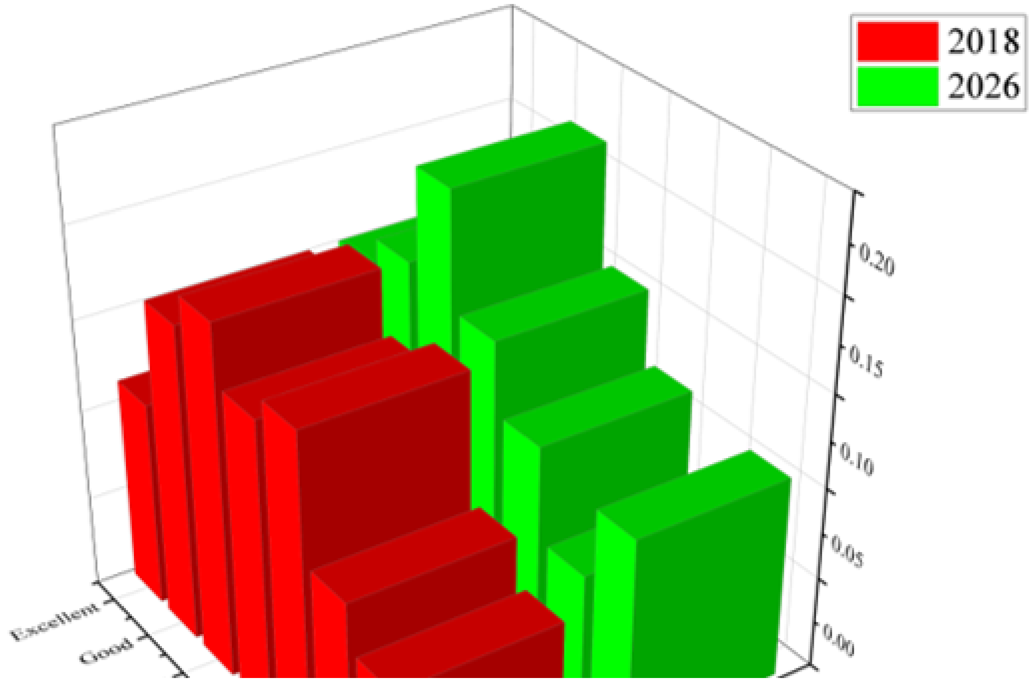

Figure 11

Simulation results of eco-environmental quality classes forecast

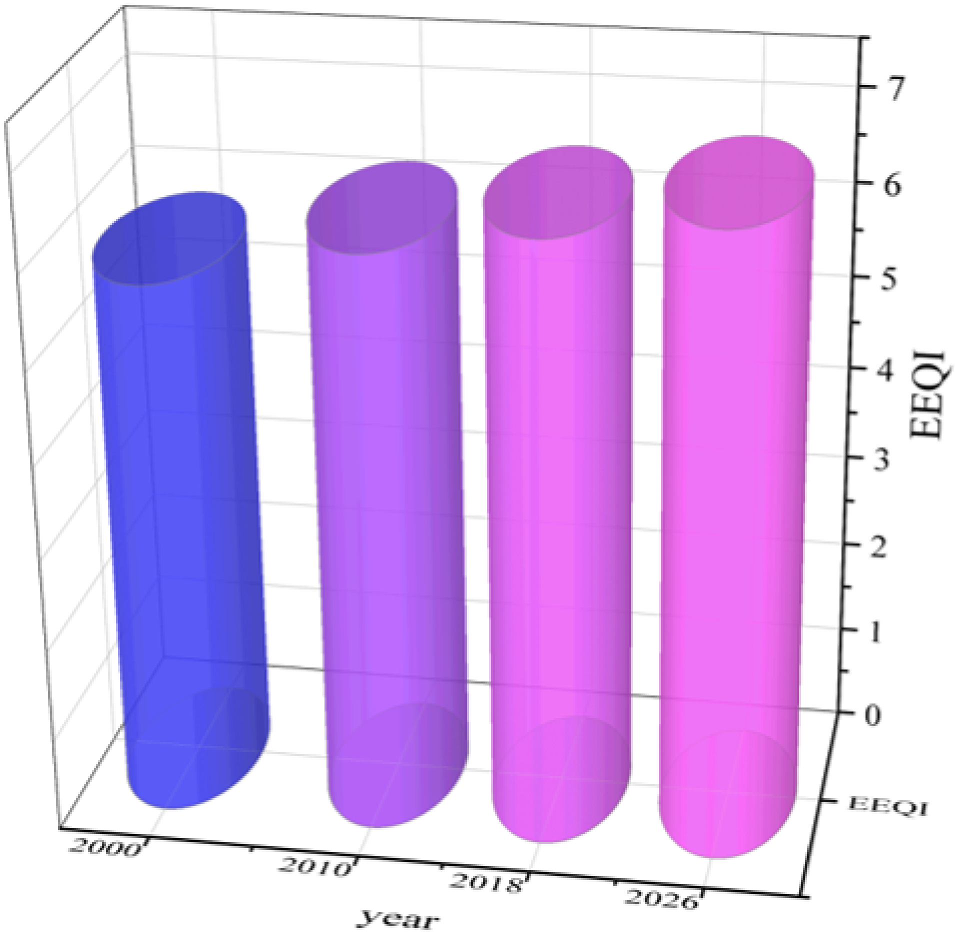

Figure 12

Eco-environmental quality trend change graph