

Research Analysis of temporal and spatial characteristics of eco-environmental vulnerability in the Xianshui River basin based on GIS

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Abstract. The Xianshui River basin is an important ecological barrier and water conservation area of Qinghai-Tibet plateau. To master the spatial and temporal differentiation of ecological environment is beneficial to the realization of the protection of regional ecological environment and the development of restoration measures. In this paper, the evaluation index system of ecological environment vulnerability was constructed from topography, climate, soil, land use and social economy. In this study, GIS and information entropy theory are combined to complete the analysis of spatial and temporal variation of vulnerability of ecological environment vulnerability in 2000-2015 years, and the main results are as follows: The ecological vulnerability of the watershed is characterized by the obvious vertical distribution, which is characterized by the gradual increase of the vulnerability of the south to the north. The evaluation results were classified as potential, micro, mild, moderate and severe, with the proportion of each grade being Micro > mild > potential > moderate > severity. The proportion of light and below accounts for more than 80% of the whole area, and the whole basin is at a medium vulnerable level. The change of overall trend indicates that the overall ecological environment of the basin has improved obviously in 15 years. The driving force factor analysis shows that the national environmental protection and restoration project is playing a significant role and plays a major driving role in the obvious improvement of the ecological environment in the basin area. However, there are still a few parts of the region that are deteriorating. This is mainly due to the special natural environment and over exploitation of hydropower resources.

1. Introduction

Eco-environmental vulnerability is the result of the interaction of the ecosystem's internal replacement, natural and human factors, which is one of the objective indexes to measure the quality of ecological environment in the region^[1]. At present, the evaluation of regional eco-environmental vulnerability not only forms the evaluation model of SRP, PSR and PSE etc^[1-3], but also a variety of evaluation methods such as analytic hierarchy process, landscape pattern method and principal component analysis method^[4-6]. In addition, the research object is also expanding, not only limited to the traditional plateau cold region, basin wetland and natural disaster area and other typical areas^[7-9]. In the past, most of the researches on the temporal and spatial changes of eco-environmental vulnerability were based on a specific perspective, which is not conducive to fully grasp their actual



conditions. Therefore, it is of great significance to explore and analyze the temporal and spatial evolution law of regional ecological environment vulnerability from multiple perspectives, to a certain extent, it can make up for the above deficiencies.

The Xianshui River basin is located on the eastern edge of Qinghai Tibet Plateau, and is an important ecological barrier and water conservation area. In recent years, due to the change of natural environment and irrational human activities, the fragile ecological environment of the basin has been more impacted. Therefore, a comprehensive grasp of the spatial and temporal characteristics of the ecological environment vulnerability in the 2000-2015 years can provide a reference for the protection and comprehensive management of the regional ecological environment. In order to comprehensively describe the temporal and spatial distribution of ecological vulnerability in the watershed area, the analysis of the temporal and spatial characteristics of regional eco-environmental vulnerability has been studied by means of direct and indirect and holistic and local analyses, with a view to providing reference for the environmental protection and comprehensive management of the region.

2. Basic data

This paper divides the basic data into two categories: spatial data and attribute data. Spatial data mainly include: The spatial data mainly include: (1)2000 and 2015 Xianshui River basin 1:100,000 scale land use remote sensing interpretation results, respectively by Cold and Arid Regions Sciences Data Center at Lanzhou (<http://westdc.westgis.ac.cn>) and Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (<http://www.resdc.cn>) provided. (2) NDVI data of different years choose MODIS13Q1 products, spatial resolution 250m, time resolution 16 days, from NASA. (3)Study Area 1:1 million scale soil type spatial distribution map, originated from Chinese soil database. (4)The 90×90m grid digital elevation model (DEM) is provided by Geospatial Data Cloud site, Computer Network Information Center, Chinese Academy of Sciences. (<http://www.gscloud.cn>). The attribute data includes: (1)The hydrothermal data observed in the research area and the surrounding sites in different years are derived from China meteorological data network (<http://data.cma.cn/>). (2)The socio-economic data of the two periods were derived from the statistical yearbook of Ganzi (2001 and 2016).

3. Research Methods

3.1 Construction of Index system

In this paper, when the evaluation index of eco-environment vulnerability in Xianshui River basin is selected, it is mainly based on the existing research results^[10-12], combined with comprehensive analysis of the actual situation in the region, while following the principle of wholeness, dominance and operability, the altitude, slope, NDVI, land use type, soil type, average annual temperature, annual precipitation, population and GDP of nine indexes were selected from six aspects of topography, vegetation, land use, soil, climate and social economy.

3.2 Basic data space visualization

In the space visualization processing of population and GDP data, this paper takes the county administrative unit as the boundary, and uses the inverse distance weight (IDW) to carry out spatial interpolation. Temperature and precipitation were completed by the international meteorological interpolation software ANUSPLIN4.37. This paper stipulates that all data are unified by Albers projection coordinate system, and data are raster format. The pixel size is 250×250m.

3.3 Ecological environment vulnerability assessment

3.3.1 Classification and grading of index data.

All the selected indicators were divided into 5 grades. In view of the types of land use, based on the existing results^[11,12,13], the soil erosion intensity and land use type map of the watershed are

superimposed, and then the classification and grading are carried out according to the actual situation of the region. Soil is classified according to its erosion resistance, water holding capacity and barren degree^[8,12]. In addition to land use and soil types, because other indicators are continuous raster data, were studied using a “Natural discontinuity” to complete^[10,12].

3.3.2 Standardization of index data.

In this paper, all the index data are standardized by using the range mathematical model. The mathematical model is as follows:

$$V_{ij} = \frac{a_{ij} - a_{i,\min}}{a_{i,\max} - a_{i,\min}} \quad (1)$$

$$V_{ij} = 1 - \frac{a_{ij} - a_{i,\min}}{a_{i,\max} - a_{i,\min}} \quad (2)$$

In mathematical expressions: V_{ij} is the result of the standardization of the index; a_{ij} is the real value of the index i in the pixel j ; $a_{i,\max}$ is the maximum value of the index i in the pixel j .

3.3.3 Information entropy calculation index weight.

After the standardization of each evaluation index, the weights of each index are determined according to the information entropy theory. Information entropy stipulates that the weight of the indicator i is:

$$u_i = \frac{1 - e_i}{n - \sum_{i=1}^n e_i} \quad (3)$$

Math formula: $e_i = -k \sum_{j=1}^m f_{ij} \ln f_{ij}$, $f_{ij} = \frac{V_{ij}}{\sum_{i=1}^m V_{ij}}$, $k = \frac{1}{\ln m}$ (if $f_{ij} = 0$, $f_{ij} \times \ln f_{ij} = 0$), u_i is the weight of

index i , e_i is the information entropy of index i . Information entropy and weights of different indices in the Xianshui River basin in 2000 and 2015 are shown in table 1.

Table 1 Information entropy and weight of each index in 2000 and 2015

Index	2000		2015	
	Information entropy	Weight	Information entropy	Weight
DEM	0.9460922	0.0488954	0.9460922	0.0471182
LUCC	0.6329034	0.3329638	0.6353664	0.3187086
GDP	0.9505664	0.0448372	0.9378932	0.0542845
Precipitation	0.9775603	0.0203533	0.9721756	0.0243200
NDVI	0.7679903	0.2104373	0.7734314	0.1980327
Slope	0.9665699	0.0303217	0.9665699	0.0292197
Temperature	0.9602461	0.0360575	0.9510519	0.0427831
Population	0.9008393	0.0899407	0.8785779	0.1061292
Soil type	0.7947200	0.1861930	0.7947444	0.1794040

3.3.4 Comprehensive evaluation.

In this paper, the multi factor weighted superposition data model is used to calculate the comprehensive index EVI of the ecological environment vulnerability in different periods. The mathematical model is as follows:

$$EVI = \beta_1 Y_1 + \beta_2 Y_2 + \beta_3 Y_3 + \cdots + \beta_n Y_n \quad (4)$$

Mathematical expressions: EVI is the ecological environment vulnerability index; Y_i is the index i ; β_i is the weight of index i .

3.3.5 Classification of ecological environment vulnerability.

The Regional vulnerability index (EVI) computed in each period is a continuous data. By classifying the data and giving different values, it can not only describe the spatial distribution differences of the fragile conditions of the regional ecological environment more comprehensively, but also be beneficial to the overall grasp of the regional ecological environment vulnerability from the global perspective. By referring to the existing research^[6,14] results and combining with the regional reality, the EVI is divided into five different grades of potential, micro, mild, moderate and severe vulnerability. The classification and grading of eco-environmental vulnerability in the fresh water river basin is shown in Table 2.

Table 2 Classification criteria for vulnerability in the study area

Vulnerability	potential	Micro degree	Light	Moderate	Severe
Range	<0.16	<0.35	<0.48	<0.67	>0.67
Grade	I	II	III	IV	V

3.3.6 Change in the overall trend of regional vulnerability.

In this paper, the analysis of the overall trend change of ecological environment vulnerability in Xianshui River basin is carried out by indirect and direct two ways. Indirectly, the EVI index spatial distribution map of the two periods is superimposed and analyzed to explore the change state of its spatial distribution, and to explore the change of the overall trend through the analysis of the changes in most regions. In the direct analysis, the overall vulnerability index $EEVI$ is calculated by calculating the overall vulnerability of the region at different periods, and its numerical changes are analyzed and quantified to describe the overall environmental changes in the region. The mathematical model is as follows:

$$EEVI = \sum_{i=1}^n P_i \times \frac{A_i}{S} \quad (5)$$

Mathematical expressions: $EEVI$ is the overall vulnerability index of the basin; P_i is the grade for each degree of vulnerability; A_i is the area of grade i ; P_i is the total area of the whole basin; T is the study period.

4. Results and analysis

4.1 Analysis of the characteristics of spatio-temporal differentiation

The EVI indices in different periods of watershed were calculated by using the weighted superposition mathematical model of multiple factors, and its grading is delineated. By analyzing the number and proportion of the grid in each fragile region in different periods, the difference of regional vulnerability in structure distribution can be characterized. Percentage of vulnerable areas in the Xianshui River basin in 2000 and 2015 are shown in table 3.

Table 3 Different fragility ratios in the Xianshui River basin in 2000 and 2015

Vulnerability	2000		2015	
	Grid number	Proportion (%)	Grid number	Proportion (%)
Potential	60658	14.25	64532	15.16
Micro	175856	41.31	181295	40.93
Light	109019	25.61	112293	28.04
Moderate	51612	12.12	49634	11.66
Severe	28531	6.71	17921	4.21

According to the percentage distribution of the regional grid pixels, there are obvious differences in the structure of different vulnerability regions in the basin. In this paper, the percentage of each vulnerability region in 2015 was analyzed as an example. The proportion of micro and severe in the whole basin is 40.93% and 4.21%, respectively, and occupies the largest and the smallest in the real area. Secondly, the mild, potential and moderate ratios were 28.04%, 15.16% and 11.66%, respectively, in order to rank second, third and fourth. At the same time, the distribution of regional structure is further analyzed. The results show that the percentage of grid in mild and below vulnerable areas is 84.13%, which occupies the majority of the region, and this objectively reflects that the overall ecological vulnerability of the watershed is in the middle level.

4.2 Differences of spatial distribution characteristics

The scientific representation of the differences in the spatial distribution of the ecological vulnerability of the research area is beneficial to the further understanding of the fragile state of the ecological environment in the region, and it is also significant for the follow-up area's ecological restoration and reconstruction reference. Based on the overall and local two perspectives, this paper makes a comprehensive analysis on the differences of regional ecological environment vulnerability in spatial distribution characteristics.

By studying the spatial distribution of EVI in the watershed area, we can see that the ecological vulnerability of the region is characterized by the obvious vertical distribution of spatial variation, which shows the trend of increasing vulnerability from south to north. At the same time, in order to further explore the regional differences in spatial distribution of vulnerable units in different grades, the spatial distribution characteristics of each vulnerability unit are further distributed in the paper. The study found that the potential and micro-vulnerable areas are the most widely distributed in the watershed area, most of the areas are high coverage grassland, woodland and shrub woodland, and the regional overall vegetation cover is high, which promotes the alleviation of ecological environment pressure objectively. Mild and moderately vulnerable areas are mainly distributed around the potential and micro-vulnerable areas and spread outward, and the regional land is predominantly of medium-coverage grassland and farmland.

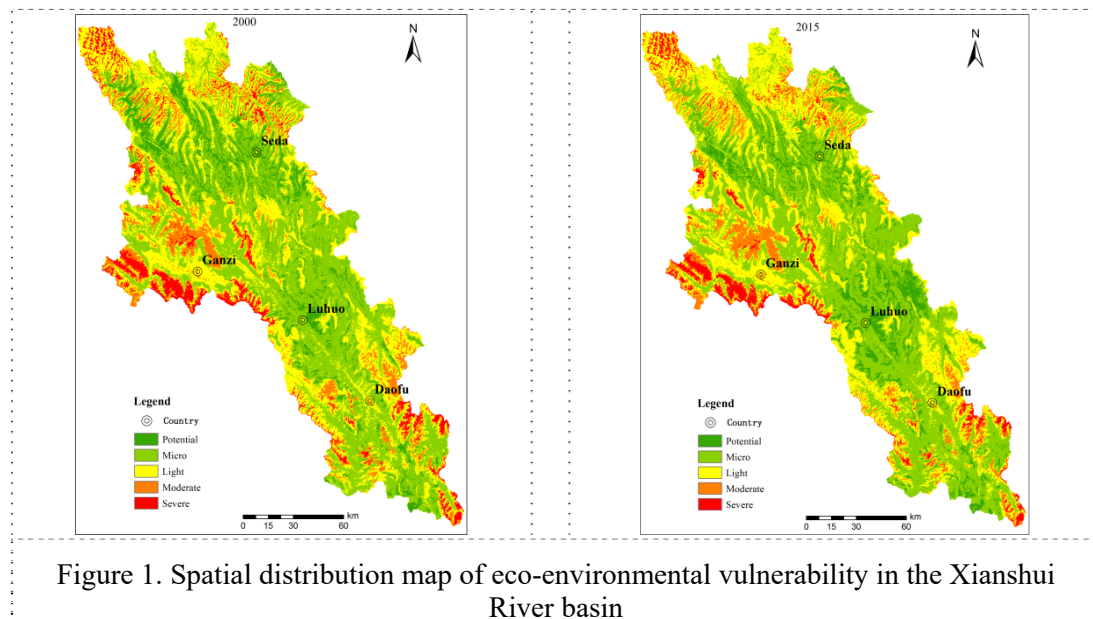


Figure 1. Spatial distribution map of eco-environmental vulnerability in the Xianshui River basin

4.3 Trend change

On the one hand, the spatial distribution characteristics of EVI in two periods are superimposed and analyzed. The results showed that the ecological environment in most areas in the 15 years was in good condition, the ecological pressure was improved and the overall quality of the environment was increased, but there was a trend of unsatisfactory development state in the local minima, and overall analysis of the overall development of ecological environment in the watershed area was good.

On the other hand, using the synthetic index model of eco-environment vulnerability, the ESVI of the region in the 2000 and 2015 were calculated. The ESVI values for different years in the watershed area were 2.5573 and 2.4883 respectively. By comparing the comparative status of ESVI values in different periods, the results show that the ESVI values are obviously reduced, which shows that the ecological environment in the basin area is obviously improved in 15 years.

5. Discussion and conclusion

5.1 Discussion

In order to further explore the evolvement law of ecological environment vulnerability in watershed area, it is necessary to analyze its driving force. On the basis of factor analysis, elevation, slope and soil type, the stability of the three indexes is the strongest, and the long-term stability is almost unchanged. Although the fluctuation of precipitation and temperature has changed, the effect of the small area variation on the environment change is not significant. It can be found that human activities are the main factors that affect the change of ecological environment vulnerability in watershed area during the whole study period.

It is found that the spatial distribution characteristics of EVI and NDVI and land use types in watershed area are similar, especially the similarity degree of land use type is the highest. In 15 years, the area of woodland and grassland in the basin increased greatly, and the NDVI index in most areas showed a significant rising trend, which greatly improved the ecological environment in the region. This is mainly due to the region in 2000 before and after the implementation of the "Return of cropland to forest (also grass)" and "Natural forest protection" series of ecological protection and rehabilitation projects, they played a positive role in promoting.

However, in the whole stage, there are still some parts of the region where the ecosystem is still deteriorating. There are two main reasons. One is the complex natural conditions of these areas, and the manual intervention can't play a role. The other possibility is that the regional water resources are

relatively abundant, the construction of hydropower facilities in the drainage area has a certain impact on the ecological environment.

5.2 Conclusion

This paper combines GIS technology with information entropy theory to complete the ecological environment vulnerability assessment in 2000 and 2015 in this region, and a variety of models are introduced to realize the spatial and temporal differentiation of regional eco-environmental vulnerability from multiple perspectives, and the following conclusions are drawn:

The proportion of the area structure of each grade vulnerability area in the whole river basin shows obvious difference, and the micro and severe fragile area occupy the largest and the smallest two ends of the whole basin. The percentage of mild and below vulnerable areas accounted for more than 80% per cent of the entire basin, reflecting, in an objective sense, the overall level of the basin as a medium vulnerability. Both direct and indirect analysis indicated that the ecological environment in the watershed area was in good development state in 15 years, and the ecological environment had a better trend. The eco-environmental vulnerability of the watershed area is characterized by the obvious vertical distribution, which shows the gradient change from the south to the north. Human activities are the main driving factors that affect the vulnerability of regional ecological environment, and the improvement of ecological environment mainly benefits from the implementation of national series of ecological environmental protection and rehabilitation construction projects.

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