

Study on Ecological Vulnerability of Dianchi Lake Basin Based on GIS-Based Principal Component Analysis

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Abstract. Ecological vulnerability is one of the key concerns of global environmental change, sustainable development, and human-land relations. This paper takes the Dianchi Basin as a research area, uses GIS principal component analysis method, selects relevant index factors to determine the weight, and finally combine evaluation index model to comprehensively analyze the ecological vulnerability of the Dianchi Basin. After research, it is found that: ①The ecological vulnerability of the Dianchi Basin is relatively high as a whole, of which 69.72% of the ecological vulnerability grades are above Grade 3. ②The ecologically fragile areas in the Dianchi Basin are generally scattered and concentrated in a small area, and the closer to the area of Dianchi, the higher the vulnerability level. ③The ecological vulnerability of the Dianchi Basin is the result of multiple factors. The research has reference significance for the ecological construction and economic development of Dianchi Basin in the future.

1. Introduction

In recent years, with the development of social economy, the increase of population and the irrational use of resources, the coordination capacity of the ecosystem itself has been declining, and the ecological environment has become more and more fragile. In this context, in order to seek harmony between man and nature, better organize human production and construction activities, and carry out related ecological restoration work, it is essential to effectively evaluate the ecological environment of a certain region. The ecological vulnerability research is an important evaluation method for regional ecological environment assessment, and it is also the research method that best reflects the correlation between various natural and human impact factors in the region.

The research on "ecological vulnerability" can be traced back to the beginning of the last century. American ecologist Clements introduced the concept of ecological transition zone into the field of ecological research [1]. Later, with the increasing attention of scholars and people, the research on "ecological vulnerability" has been flourishing, especially in the 1980s and 1990s, "ecological fragile zone" and "human-land coupled system vulnerability". Etc. began to appear more and more frequently in related research fields [2-4]. After entering the 21st century, the study of "ecological fragility" has entered a brand-new stage. It has realized the transition from the single factor study of early ecological transition to the multi-factor study of comprehensive ecological environment, from the application of simple analytical models to the new statistical model of data rate use. In China, with the development concept of "Clear waters and green mountains are mountains of gold and silver", research based on ecological environment vulnerability has become increasingly hot. Therefore, there have been some



evaluation and analysis methods with high matching and accurate results in China, especially in recent years, based on GIS principal component analysis, the obtained vulnerability evaluation results are closer to reality. For example, Fu Gang et al. Evaluated the ecological vulnerability of Beijing based on the GIS spatial principal component analysis method and found that the overall ecological vulnerability of Beijing was at a medium level, and different surface coverage showed different levels of vulnerability [5]. Ma Jun et al. Evaluated the ecological vulnerability of the Three Gorges Reservoir area based on spatial principal component analysis and found that the ecological vulnerability of the Three Gorges Reservoir area is the result of the interaction between human activities and the natural environment [6].

Therefore, this paper draws on the above research results, taking Dianchi Basin as the research area, based on the GIS spatial principal component analysis method, selecting relevant index factors and assigning weights, establishing an evaluation index system, and obtaining the vulnerability distribution data of different spaces in Dianchi Basin. Comprehensively evaluate the ecological fragility index by comprehensively influencing factors to determine the ecological vulnerability of Dianchi Basin, so as to provide a reference for the socio-economic sustainable development and ecological restoration of Dianchi Basin.

2. Study Area Overview and Data Sources

2.1. Overview of the Study Area

Dianchi Basin is a collective term for the runoff area around Dianchi. The basin area is about 2920km², the average elevation is 2048m, height difference up to 1094m. The basin involves nine districts and counties in Kunming, including Wuhua, Panlong, Guandu, Xishan, Chenggong, Xundian, Fumin, Songming, and Jinning. The basin concentrated 54.23% of the city's population and contributed 78.58% of the city's GDP with a land area of approximately 13.9% of the city. The highly clustered economies and highly dense population distribution make the natural environment of the region affected by human activities frequently, and the ecological environment becomes more and more fragile. At the same time, ecological and environmental problems have increasingly become an important factor restricting the economic and social development of the Dianchi Basin. Therefore, it is of great significance to study the ecological environment vulnerability of the region, which can not only guide the ecological environment restoration and reconstruction, but also provide a basis for regional sustainable development.

2.2. Data Source

This paper selects three main data, including: 1) Remote sensing image data, Landsat 8 OLI_TIRS data of Dianchi Basin in 2017, with a spatial resolution of 30m, derived from geospatial data cloud for obtaining land use type data and vegetation coverage data. 2) DEM data, ASTER GDEM data of Dianchi Basin in 2017, with a spatial resolution of 30m, derived from geospatial data cloud, used to obtain elevation data and topographic data of the study area. 3) Demographic and economic data, derived from the Yunnan Statistical Yearbook and the Kunming Statistical Yearbook, used to obtain population density data and per capita GDP data.

3. Research Methods

3.1. Construction of Ecological Vulnerability Evaluation Index Model

The construction of the evaluation index system will affect the accuracy of the final evaluation results. Based on the regional characteristics of the Dianchi Basin, this paper builds a single unit of ecological vulnerability assessment for the Dianchi Basin by selecting natural and human factors based on the four basic principles of ease of selection, scientificity, significance, and integrity. Factor evaluation level model (see Table 1).

Table 1. Single factor evaluation level model

Indicators	Potentially vulnerable areas(1)	Negligible vulnerable areas(3)	Light vulnerable areas(5)	Medium vulnerable areas (7)	Strong vulnerable areas(9)
Elevation(m)	>2400	2200-2400	2000-2200	1900-2000	<1900
Slope(°)	0-5	5-10	10-15	15-25	>25
NDVI	>0.3	0.2-0.3	0.1-0.2	0-0.1	<0
Land use type	Forest	Plow land	Grass Water	Unused land	Urban
The population density(person/km ²)	200-300	300-500	500-700	700-1000	>1000
Per capita GDP(Ten thousand yuan/person)	>19	16-19	12-16	10-12	<10
Rainfall(mm)	>1000	950-1000	900-950	850-900	<850

3.2. Evaluation Index Data Processing

In order to eliminate the problem of the inaccuracy of the evaluation results due to the inconsistency of the index dimension and the order of magnitude, the selected index factors need to be standardized. Formula (1) is used when the standardized value is positively correlated with ecological vulnerability; formula (2) is used when the standardized value is negatively correlated with ecological vulnerability [7].

$$X'_i = \frac{X_i - X_{i_{\min}}}{X_{i_{\max}} - X_{i_{\min}}} \quad (1)$$

$$X'_i = 1 - \frac{X_i - X_{i_{\min}}}{X_{i_{\max}} - X_{i_{\min}}} \quad (2)$$

In formulas (1) and (2): X'_i is the standardized value of the i -th index, X_i is the initial value of the i -th evaluation index, and $X_{i_{\min}}$ and $X_{i_{\max}}$ are the minimum and maximum values of the i -th evaluation index in the study area. Generally, the normalized value is between (0,1). The larger the standardized value, the more vulnerable the ecosystem is, and the more vulnerable it is to external disturbances [3].

3.3. Selection of Evaluation Factors

Transform based on the GIS principal component analysis tool to obtain the eigenvalues and contribution rates of the converted principal factors (see Table 2). From Table 2, it can be seen that the contribution rate of the first six principal component factors has reached 95.9635%, with only 4.03% information loss and high credibility. Therefore, the number of main factors is determined to be 6.

Table 2. Eigenvalue and contribution rate of each main factor

Main factor	Eigenvalues	Contribution rate /%	Cumulative contribution rate /%
1	7.8645	36.5536	36.5536
2	6.1357	28.5182	65.0718
3	2.5042	11.6393	76.7111
4	2.2812	10.6029	87.314
5	1.0817	5.0277	92.3417
6	0.7792	3.6218	95.9635
7	0.6042	2.8085	98.772

3.4. Factor Weight Determination

Calculate the common factor variance of each evaluation factor according to the factor matrix [7], see formula (3) for details.

$$T_j = \sum_{j=1}^m \lambda_{jk}^2 (j=1,2,\dots,7, \quad k=1,2,\dots,6) \quad (3)$$

In the formula(3), j is the number of original indicators, k is the main component number, m is the total number of main components, and m=6.

After calculating the data, the weight coefficients of the ecological vulnerability impact factors in the Dianchi Basin can be obtained. The specific data are shown in Table 3.

Table 3. Factor weights

Factor	DEM	Slope	NDVI	Land use	Population density	Per capita GDP	Rainfall
Weights	0.1377	0.1872	0.1964	0.1826	0.1497	0.0781	0.0683

3.5. Comprehensive Evaluation Method of Ecological Vulnerability

Through the multi-factor superposition analysis, formula (4) is used to calculate the ecological vulnerability, and the ecological vulnerability of Dianchi Basin is comprehensively evaluated from the aspects of resources, environment, and economic and social development.

$$EVD_i = \sum_{j=1}^7 P_{ij} W_j \quad (4)$$

In formula (4), EVD_i is the ecological vulnerability of the i-th evaluation unit, and the final result is a composite value, whose value is between 0-1; P_{ij} is the j-th index of the i-th unit; W_j is the weight of each index (See Table 3).

4. Results and Analysis

4.1. Analysis of Ecological Vulnerability Level in Dianchi Basin

According to the results of superposition principal component analysis, the vulnerable areas of Dianchi Lake Basin are divided into five types(see Table 4): I potentially vulnerable area, II micro-fragile zone, III mildly vulnerable area, IV moderately vulnerable area and V highly vulnerable area. On the whole, the ecological vulnerability of the Dianchi Basin is relatively high, and the vulnerable areas of mild and above account for 69.72%, of which the highly vulnerable areas account for 13.29%, the moderately vulnerable areas account for 22.06%, and the mildly vulnerable areas account for 34.37 %, potentially vulnerable areas and micro-fragile zone account for a relatively small proportion.

Table 4. Statistical table of ecological vulnerability of Dianchi Basin

Grade	Fragile type	Area(km ²)	Area ratio(%)
I	Potentially vulnerable area	337.66	11.62
II	Micro-fragile zone	542.39	18.66
III	Mildly vulnerable area	999.07	34.37
IV	Moderately vulnerable area	641.22	22.06
V	Highly vulnerable area	386.39	13.29

4.2. Distribution of Ecological Vulnerability of Main Factors to Dianchi Basin

Based on the ArcGIS principal component analysis method, the distribution map of the influence of each principal factor on the ecological vulnerability of the Dianchi Basin was obtained (Figure 1). It can be found that the ecologically fragile areas of the Dianchi Basin show different distribution characteristics on each factor: 1) Except for Dianchi, the lower the NDVI value, the higher the vulnerability level, such as the main urban area of Kunming. 2) The lower the per capita GDP value,

the higher the vulnerability level, such as Jinning County, a traditional agricultural area. 3) The higher the slope, the ecological risk is affected by landslides, mudslides and other geological disasters, such as upstream mountainous areas. 4) The lower the elevation, the higher the vulnerability level. For example, Dianchi has the lowest elevation, and a large amount of production and domestic sewage flows into the Dianchi along with the river, which aggravates the pollution of the Dianchi. 5) Urban land types have the highest levels of vulnerability, mainly because cities are the most densely populated areas and the most frequent areas of human activity. 6) The higher the population density, the higher the vulnerability level, such as the main urban area. The above conclusions have effectively verified the correctness of the experimental model, and the calculation results are consistent with the model preset results.

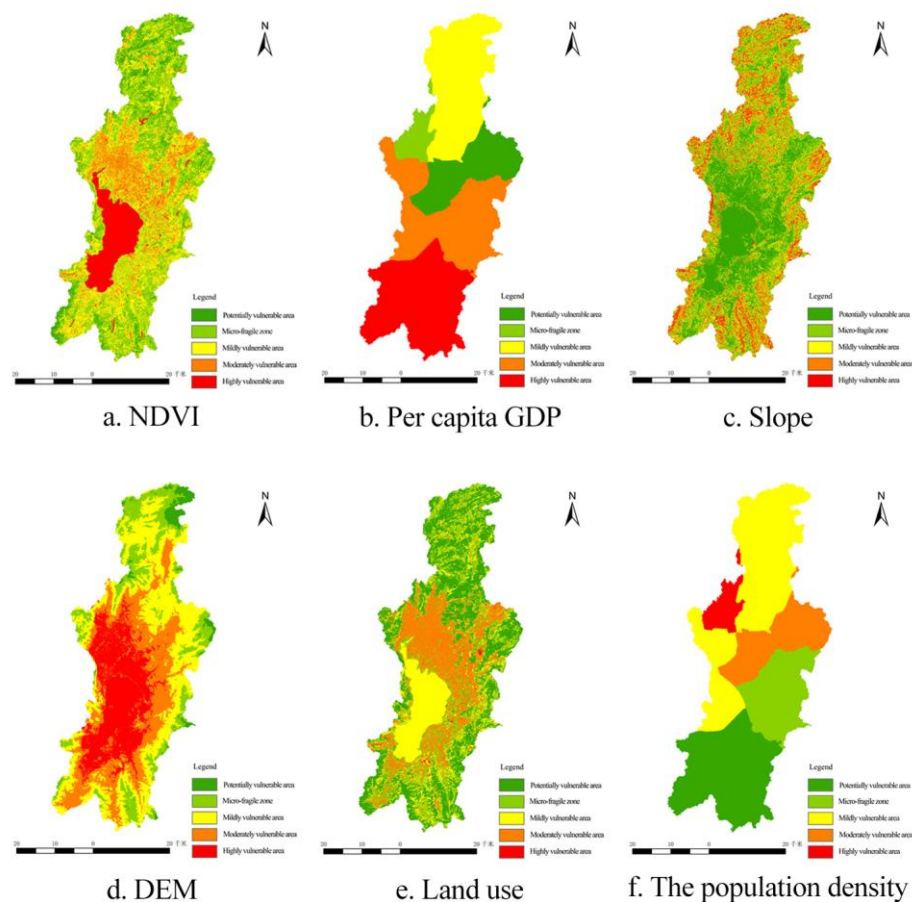


Figure 1. Distribution of main factors affecting ecological vulnerability in Dianchi Basin

4.3. Analysis of Spatial Characteristics of Ecologically Fragile Areas in Dianchi Basin

In order to better display the spatial characteristics of the ecologically fragile areas in the Dianchi Basin, a hierarchical distribution map of the ecological vulnerability in the Dianchi Basin was obtained by superposition analysis of principal factors (see Figure 2). According to the distribution map, the ecologically fragile areas in the Dianchi Basin are generally scattered and concentrated in a small area. The entire Dianchi surface is concentrated in highly vulnerable areas, and most of the remaining areas are distributed in different levels of fragile areas. And, the closer to the Dianchi area, the higher the vulnerability level. Although the ecologically fragile areas are scattered in space, the overall index factors affect each other and make different areas show the same vulnerability characteristics.

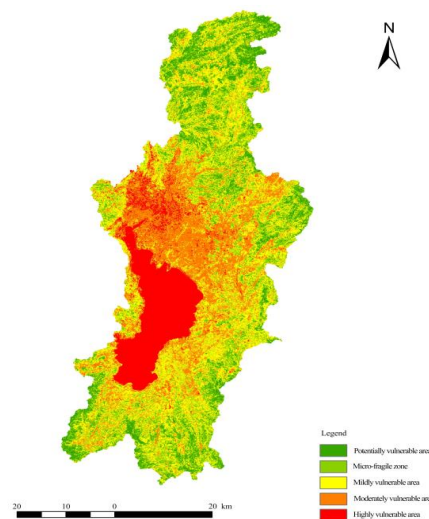


Figure 2. Dianchi Basin ecological vulnerability level distribution map

5. Conclusion

The ecological environment is constrained and affected by a variety of factors, and different factors have different weights on the regional ecological environment, resulting in different results. Therefore, this paper takes the Dianchi Basin as the research area, uses the GIS principal component analysis method, selects the relevant index factors and assigns weights based on natural and human factors, and finally establishes an evaluation index system to analyze the characteristics and causes of the ecological environment vulnerability in the river basin. The study found that the ecological vulnerability of the Dianchi Basin is generally high, and 69.72% of the regions with a vulnerability level of III or higher should be given sufficient attention. In terms of spatial distribution, the ecologically fragile areas in the Dianchi Basin are scattered and concentrated in a small area, and the closer to the area of Dianchi, the higher the vulnerability level. In addition, the ecological fragile areas of the Dianchi Basin show different distribution characteristics on each single factor, but these single factors as a whole interact and interact with each other, which makes different regions also show the same vulnerability characteristics. After researching these characteristics, it is consistent with the model presets, which shows the reliability and authenticity of the evaluation results, and further proves that the ecological vulnerability of the Dianchi Basin is the result of multiple factors acting together, thus providing ecological construction and sustainable development for the Dianchi Basin Provide important reference.

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7. References

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