Time-space Evolutionary Characteristics of Ecological Sensitivity in Gannan Tibetan Autonomous Prefecture

Yuhan Wei, Guofeng Dang
College of Geography and Environmental Science, Northwest Normal University, Lanzhou 730070, China.

Abstract: Research on ecological sensitivity shares an important role in carrying out regional ecological civilization construction and advocating regional ecological sustainable development. In this paper where Gannan Tibetan Autonomous Prefecture is taken as an example, nine factors are selected from two aspects of the ecosystem and social system and the time-space changes of ecological sensitivity in Gannan Tibetan Autonomous Prefecture from 2000 to 2020 are analyzed by using the coefficient of variation method and cumulative model with the support of GIS. As demonstrated by the results, (1) the research area as a whole proves to be moderate in ecological sensitivity. By 2020, highly and extremely sensitive areas in the research area had decreased by 4435.68 km^2 while those insensitive and mildly sensitive areas increased by 213.1 km^2. The areas with high ecological sensitivity are mainly distributed in Xiahe County in the north of the research area, as well as in the north of Hezuo City and Zhuoni County, and the areas with low ecological sensitivity are mainly located in Diebu County and Zhouqu County in the southeast of the research area. (2) The ecological sensitivity of Gannan Tibetan Autonomous Prefecture has been fluctuating in the past 20 years, and the fluctuation enhancement area is mainly distributed in the southern part of Xiahe County and the central part of Zhuoni County, accounting for 25.86% of the total area of the research area. All these analyses and conclusions can provide a basic scientific basis for ecological protection in Gannan Tibetan Autonomous Prefecture.

Keywords: Ecological Sensitivity; Coefficient of Variation; Time-Space Analysis; Gannan Tibetan Autonomous Prefecture

Introduction

Ecological sensitivity refers to the degree of sensitivity of an ecosystem to external disturbances and environmental changes, and it characterizes the degree of difficulty in producing negative ecological effects in the research area when the environment is affected by inappropriate human development activities[1][2]. The concept of ecological sensitivity was defined by Chinese scholars Ouyang Zhiyun et al[3] when they conducted research on ecological sensitivity and its regional variation patterns in China in 2000. The current research methods on ecological sensitivity include the expert scoring method used by Lu Min et al[4] to study the ecological sensitivity of Jixi National Wetland Park, and the hierarchical analysis and mean square difference decision method adopted by He Suling[5] to jointly construct a comprehensive model of ecological sensitivity. The research objects of ecological sensitivity are mainly regional landscapes such as Fen River Basin whose ecological sensitivity was studied by Liu Hailong[6] et al; most scholars devoted themselves to the study of ecological sensitivity in the process of environmental evolution, for example, Guo Zecheng et al[7] explored the sensitivity of land desertification. By studying the ecological sensitivity of different scales of evaluation units in national, provincial, municipal, and county areas[8][9][10][11], research results provide a theoretical basis for urban planning and construction, how to draw ecological protection red line, and how to reasonably develop and utilize the land[12].

Based on the above-mentioned research status, Gannan Tibetan Autonomous Prefecture is then selected as the research object with nine factors from ecosystems and social systems. With the support of GIS, the time-space changes of ecological sensitivity in Gannan Prefecture from 2000 to 2020 using the coefficient of variation method and cumulative model, thus providing a basic reference for ecological protection and urban planning in Gannan Prefecture.

1. Data Sources and Research Methods

1.1 Data Sources and Preprocessing

The research data mainly include DEM, slope, aspect, NDVI, land utilization, population density, per capita GDP, precipitation, accumulated temperature and grazing capacity.

(1) DEM (30m resolution) data were obtained from the Geospatial Data Cloud (http://www.gscloud.Cn).

(2) NDVI data directly adopted the 250m spatial resolution MOD13Q1 product provided by MODIS data.

(3) Land utilization data were obtained from the China 30m land coverage dataset from 1990-2020 (https://zenodo.org/record/5210928#.YiF80nFoCQ4).

(4) Population density, per capita GDP and grazing capacity data were obtained from the Gansu Provincial Bureau of Statistics. ArcGIS software was used to interpolate the above data with inverse distance weights to obtain raster data.

(5) The meteorological data were provided by Gansu Meteorological Bureau, and the raster data were obtained by using inverse distance weight interpolation.

Finally, the resolution of all data was resampled to 30m×30m.

1.2 Research Methods

1.2.1 Coefficient of Variation

The coefficient of variation, an objective weighting method, can reduce the subjective judgment and grading of the factors in this paper, thus greatly ensuring the scientific and objective results. By examining the variability of the internal information of each index, the corresponding weights of each index are calculated. In the evaluation index system, the greater the difference in the values of the indicators taken, the more reflective of the gaps in the evaluated units, and the greater the weights are accordingly[13].

The expression is:

$$W = \frac{v}{\sum_{i=1}^{n} v_i} = \frac{S/\overline{X}}{\sum_{i=1}^{n} (S_i - \overline{X}_i)} \quad (1)$$

where W represents the evaluation factor weight; v is the coefficient of variation; S refers to the standard deviation; $\overline{X}$ means the mean value, and i denotes the number of factors.

1.2.2 Comprehensive Evaluation

The coefficient of variation method was applied to determine the weights of evaluation factors, and the factors in the evaluation system were weighted and superimposed to obtain comprehensive evaluation results of ecological sensitivity in Gannan. It not only reflects the current situation of the research area visually, but also serves as an important reference base for future ecological restoration and planning of the area.

The expression is:

$$F = \sum_{i=1}^{n} [W_i P_i] \quad (2)$$

where F refers to the comprehensive ecological sensitivity index; Wi is the factor weight; Pi denotes the evaluation

factor index.

1.2.3 Change Analysis of Ecological Sensitivity

It can be seen by analyzing the results of the change model that how the ecological environment of Gannan State fluctuates and changes with the formula:

$$L = \sum_{i=1}^{n-1} (G_i - G_{i+1}) \quad (3)$$

L is the result of ecological sensitivity change within a certain image element[14]; n is the sample year; and G_i characterizes the ecological sensitivity code of one sample year; G_{i+1} is the ecological sensitivity code of the latter sample year. When $G_i - G_{i+1}=0$, the ecological sensitivity of the region is characterized as unchanged; when $G_i - G_{i+1} < 0$, the ecological sensitivity is characterized as developing in the poor direction; and when $G_i - G_{i+1} > 0$, the ecological sensitivity tends to develop in the favorable direction.

3. Results and Analysis

3.1 Index Selection and Weight Calculation

3.1.1 Index Selection

Based on investigation and research and in light of the actual situation of the ecological environment in Gannan Tibetan Autonomous Prefecture, six factors from two aspects of the social system and ecosystem were selected, including elevation, slope, aspect, vegetation coverage, annual precipitation and annual accumulated temperature (≥10℃), which represent the internal pressure of the ecosystem. In addition, three human disturbance factors were included, namely population density, per capita GDP and grazing capacity whose changes in ecological sensitivity were mainly caused outside the ecosystem. Together, these nine factors were applied to evaluate the ecological sensitivity of the research area.

3.1.2 Weight Calculation

According to the impact of the index factors on the environment, they are divided into positive and negative indicators, and the formula is applied to do the dimensionless processing. The processed data are substituted into the variation coefficient calculation formula to get the weight values as follows(Table 1).

Table 1 Ecological Sensitivity Index Weights

System	Factor	Weight				
		2000	2005	2010	2015	2020
Ecosystem	Elevation	0.04	0.04	0.04	0.04	0.04
	Slope	0.11	0.11	0.12	0.12	0.11
	Aspect	0.11	0.11	0.11	0.11	0.11
	Annual Accumulated Temperature	0.05	0.06	0.05	0.07	0.07
	Annual Precipitation	0.08	0.08	0.08	0.08	0.10
	Vegetation Coverage	0.09	0.11	0.10	0.10	0.10
Social System	Population Density	0.24	0.24	0.25	0.26	0.27
	Per capita GDP	0.13	0.11	0.10	0.10	0.08
	Grazing Capacity	0.15	0.14	0.13	0.13	0.11

3.2 Single-factor Evaluation

The temperature distribution in the research area shows a decreasing trend from southeast to northwest and southwest (see Figure 1).

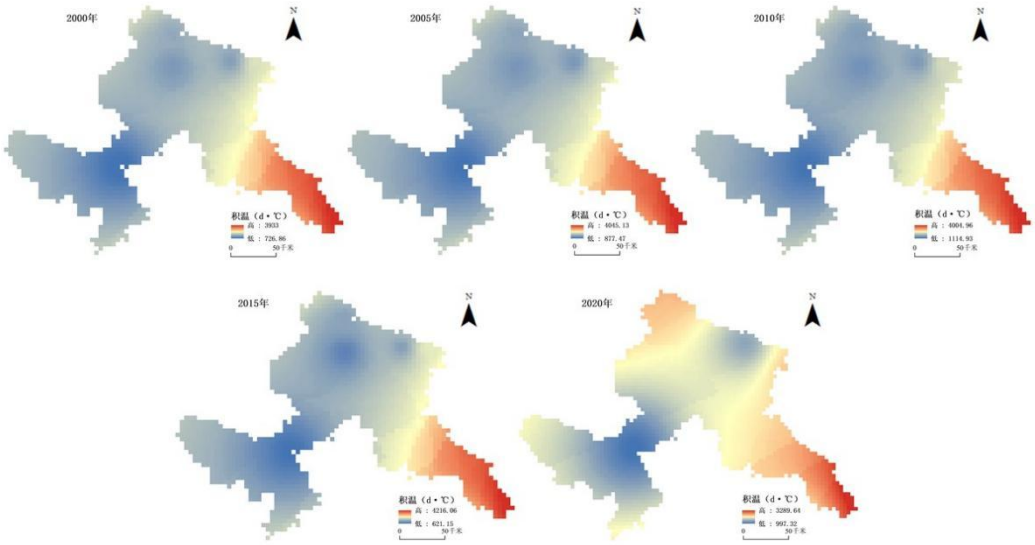

Figure 1 Grading Chart of Accumulated Temperature Sensitivity

Precipitation is abundant in the southwest and southeast and decreases toward the north, with less precipitation and relatively higher sensitivity in the north and more precipitation and lower sensitivity in the south (see Figure 2).

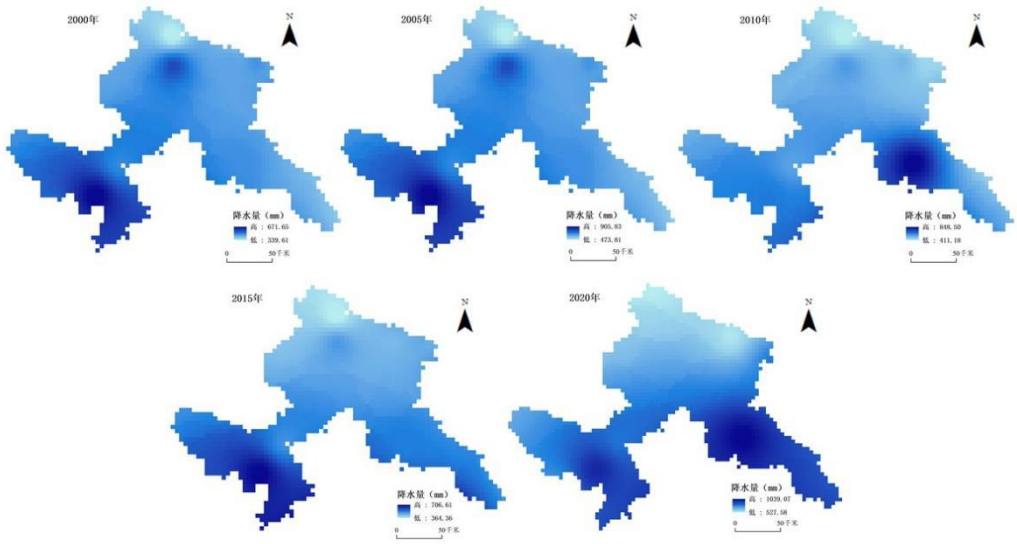

Figure 2 Grading Chart of Precipitation Sensitivity

Places with higher population density have low biodiversity, rich economic activities, and a single type of environment that is susceptible to external influences, and therefore have higher ecological sensitivity. The overall population density of Gannan Tibetan Autonomous Prefecture is low, and the whole region is dominated by insensitive areas (see Figure 3).

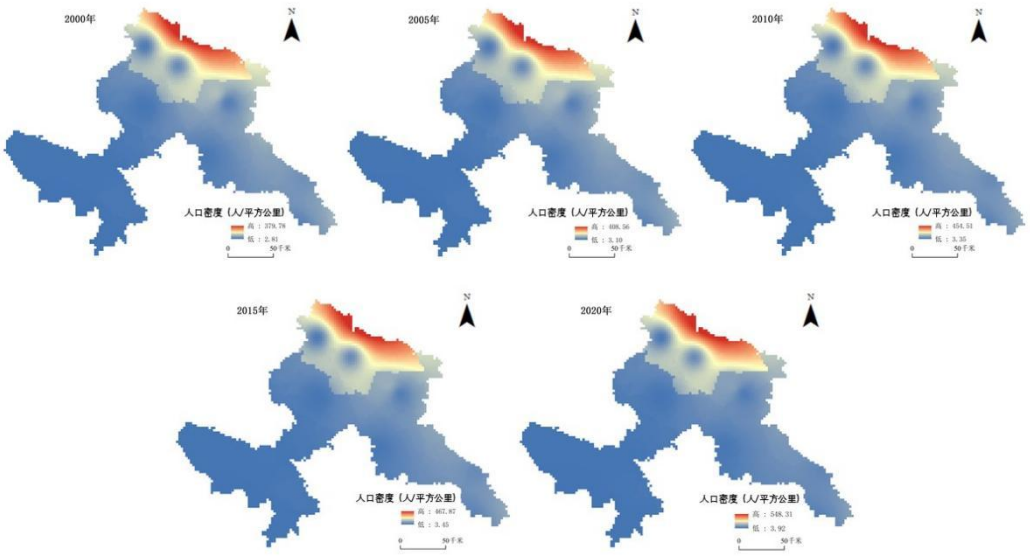

Figure 3 Grading Chart of Population Density Sensitivity

The center-of-gravity of per capita GDP in the research area gradually shifts from south to north (see Figure 4).

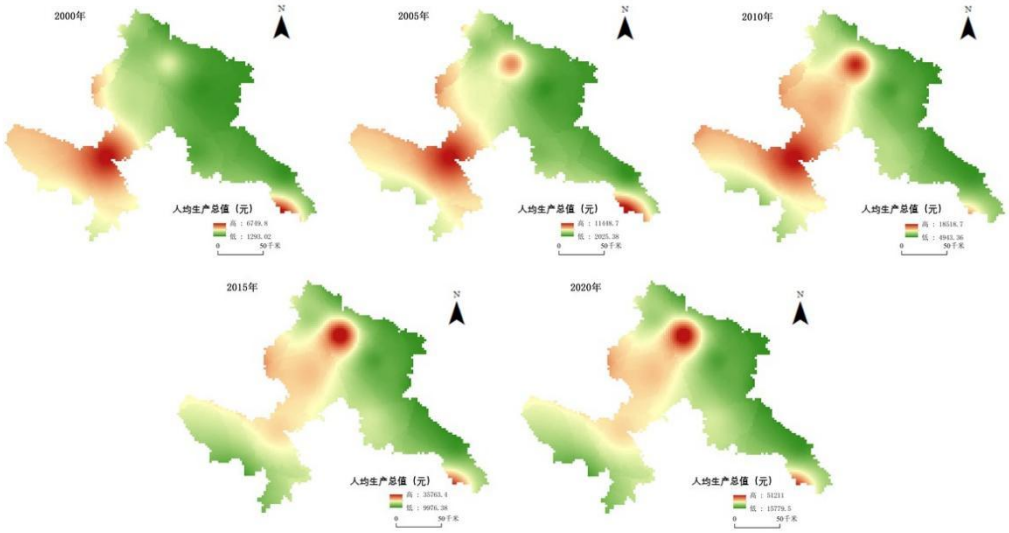

Figure 4 Grading Chart of per capita GDP Sensitivity

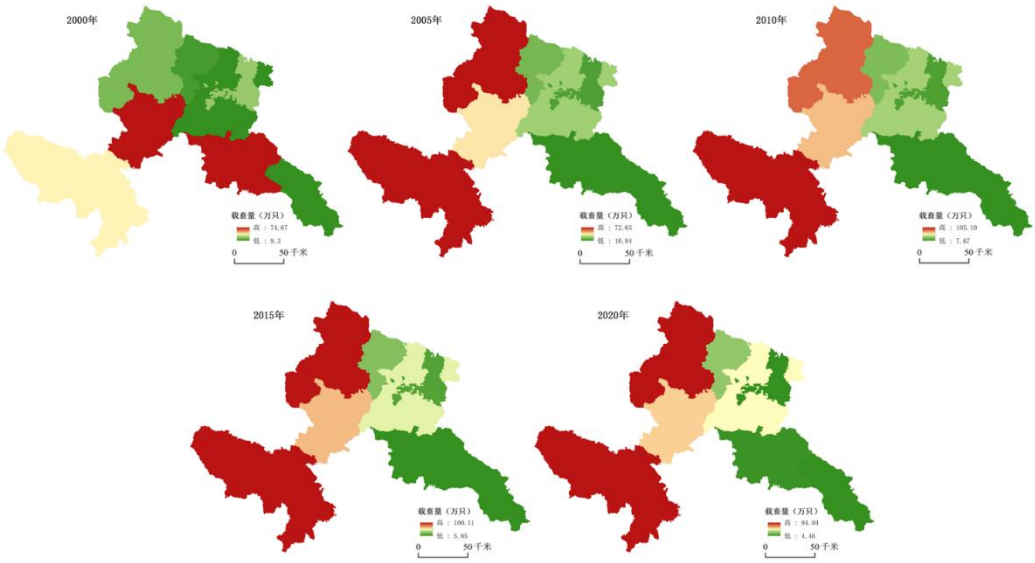

Figure 5 Grading Chart of Grazing Capacity Sensitivity

Areas with higher grazing capacity are susceptible to external influences and therefore have higher ecological sensitivity. The areas with higher grazing capacity sensitivity in the research area are located in Maqu County and northern Xiahe County (see Figure 5).

3.3 Comprehensive Evaluation of Ecological Sensitivity

Based on the above calculation results, a comprehensive ecological sensitivity evaluation model was calculated with the support of ArcGIS software to obtain the results of the comprehensive ecological sensitivity distribution in the research area from 2000 to 2020 (see Figure 6), which was classified into 5 levels using the natural breakpoint method, i.e., insensitive, mildly sensitive, moderately sensitive, highly sensitive and extremely sensitive[15].

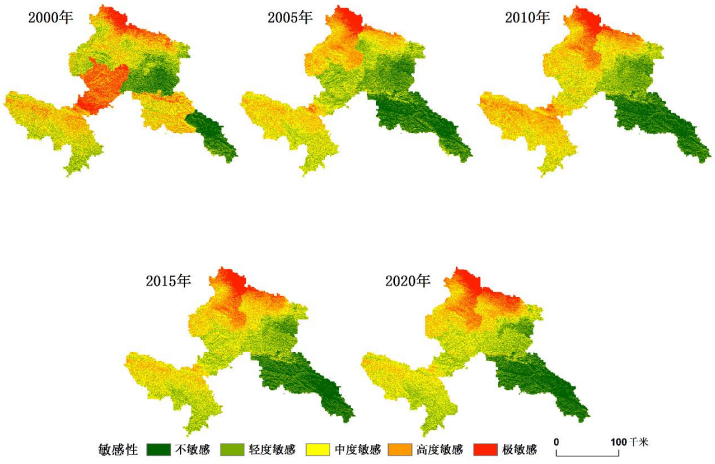

Figure 6 Comprehensive Ecological Sensitivity

sensitivity: insensitive, mildly sensitive, moderately sensitive, highly sensitive, extremely sensitive

Table 2 Zoning Area Statistics of Integrated Ecological Sensitivity in Gannan Tibetan Autonomous Prefecture

	2000	2005	2010	2015	2020

	Area/km^2	%	Area/km^2	%	Area/km^2	%	Area/km^2	%	Area/km^2	%
Insensitive	3817.31	10.78	6281.79	17.74	5719.61	16.16	5469.01	15.45	5567.53	15.73
Mildly Sensitive	8050.19	22.74	10344.98	29.22	7661.87	21.64	9895.68	27.95	9513.07	26.87
Moderately Sensitive	10636.29	30.04	10697.60	30.22	10776.00	30.44	11465.86	32.39	11858.87	33.50
Highly Sensitive	8929.01	25.22	6651.15	18.79	9175.80	25.92	6646.17	18.77	6180.21	17.46
Extremely Sensitive	3970.37	11.21	1427.65	4.03	2069.89	5.85	1926.45	5.44	2283.49	6.45

It was found that the ecological sensitivity of Gannan Prefecture showed a fluctuating trend of change during 2000-2020. The area of highly sensitive areas and extremely sensitive areas in the territory showed a decreasing trend, with a total area reduction of 4435.68 km^2.

The area of insensitive areas was 10.78% of the total area in 2000, increasing to 17.74% of the total area in 2005, decreasing to 15.45% of the total area in 2015 and floating to 15.73% in 2020. Insensitive areas increased by 1,750.22 km^2 in 20 years. Mildly sensitive areas accounted for 22.74% of the total area in 2000, decreasing to 26.87% in 2020. Moderately sensitive areas increased by 1,222.58 km^2 over 20 years. The area of highly sensitive areas accounted for 25.22% of the total area in 2000 and decreased to 17.46% in 2020. The area of mildly sensitive areas has been reduced by 2748.8 km^2 . The proportion of extremely sensitive areas to the total area decreased from 11.21% in 2000 and reached only 6.45% in 2020. Overall, the change in extremely sensitive areas from 2000 to 2020 generally showed a decreasing trend, and extremely sensitive areas decreased by a total of 1686.88 km^2 during the 20 years.

The overall spatial distribution of ecological sensitivity shows a decreasing trend from north to south and from west to east. The areas with higher ecological sensitivity are mainly located in Xiahe and Lintan counties in the north of Gannan, Luqu County and Hezuo City in the central part, while the areas with lower ecological sensitivity are mainly located in the southeastern part with lower population density and higher vegetation coverage.

3.4 Analysis of the Change Trend of Ecological Sensitivity

The changes in ecological sensitivity from 2000 to 2020 were obtained by calculation, and the results were reclassified into three categories: volatility enhanced, constant volatility and volatility weakening (see Figure 7).

Table 3 Zoning Area Statistics of Integrated Ecological Sensitivity Changes in Gannan Tibetan Autonomous Prefecture

Zoning	Area/km^2	Proportion/%
Volatility Enhanced Zone	9155.64	25.86%
Constant Volatility Zone	13595.27	38.40%
Volatility Weakening Zone	12652.26	35.74%

The constant volatility area is mainly distributed in Zhouqu County and Maqu County in the south of the research area, the volatility enhanced area is mainly distributed in Xiahe County in the north, and the volatility weakening area is mainly distributed in Luqu County in the central part of the region. The ecological sensitivity change in the research area is mainly constant volatility, accounting for 38.40% of the total research area; the area of the volatility-enhanced zone accounts for 25.86% of the total research area, mainly distributed in the south of Xiahe County and the central part of Zhuoni County.

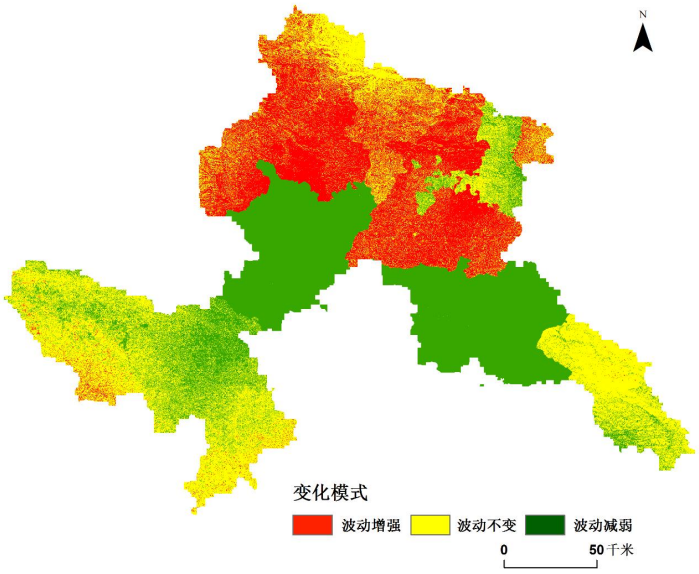

Figure 7 Change Results of Ecological Sensitivity

Change mode: volatility enhanced, constant volatility and volatility weakening

4. Conclusion and Discussion

4.1 Conclusion

Through the implementation of comprehensive closure protection, herding and grass restoration projects, the stability of the ecosystem has been significantly improved, and the ecological environment of the important water recharge ecological function area of the Yellow River in Gannan has been significantly improved.

(1) The research area is mainly highly sensitive, and the ecological sensitivity of Gannan Tibetan Autonomous Prefecture has improved in the past 20 years, with only 4435.68 km^2 of highly and extremely sensitive areas remaining. And the comprehensive ecological sensitivity shows a decreasing feature from north to south and from west to east in spatial distribution. The north and central areas of Gannan are densely populated and have faster economic development, so the ecological sensitivity is higher, while the southeast is less densely populated and has higher vegetation cover, so the sensitivity is relatively lower.

(2) The ecological sensitivity of Gannan Prefecture shows a fluctuating trend from 2000 to 2020, and the fluctuating enhancement area is mainly located in the south of Xiahe County and the central part of Zhuoni County, which accounts for 25.86% of the total area of the research area. The sensitivity of the central and southeastern parts of the research area gradually decreases, which accounts for 35.74% of the total area.

4.2 Discussion

Based on the summary of previous research results, this paper determines the weights of different index factors by the coefficient of variation method to construct a comprehensive ecological sensitivity model, and selects nine factors from both ecosystems and social systems to obtain the results of ecological sensitivity distribution and its time-space changes in the research area. Due to the complexity of the ecological environment in Gannan, it is impossible to comprehensively and accurately evaluate its ecological sensitivity by the existing factors. Therefore, the cumulative change model method has been used in this paper to study the ecological sensitivity changes in Gannan Prefecture. Such a method worthy of further

exploration and research provides a new perspective and idea for the subsequent research on the time-space changes of ecological sensitivity.

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