Vulnerability Assessment of Resource-based Cities Based on Entropy Weight-topsis Model: A Case Study of Karamay, Xinjiang, China

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Vulnerability assessment of resource-based cities based on Entropy Weight-TOPSIS model: a case study of Karamay, Xinjiang, China

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The vulnerability of a city is an important index to evaluate the healthy development of a city, and also an important guide to the harmonious and sustainable development of resource-based cities. This paper constructs the vulnerability assessment system of resource-based cities from four dimensions of resources, ecology, society and economy, and puts forward the Entropy Weight-TOPSIS model to study the dynamic changes of urban vulnerability in the resource-based city—Karamay. The research results show that the urban vulnerability score of Karamay rose steadily from 2008 to 2017, but the overall vulnerability score was always between 0.1 and 0.2, indicating that the urban vulnerability of Karamay has not significantly improved and is still in the stage of extremely fragile economic and social comprehensive development. The ecological vulnerability, social vulnerability and economic vulnerability of Karamay show a good trend of improvement, and social development contributes the most to the comprehensive vulnerability of the city, while the score of resource vulnerability shows a significant decline. Resource development and utilization is still the key to determine the healthy and sustainable development of Karamay.

Urban vulnerability is mainly used to evaluate the level of sustainable and healthy development of a city, and it is an important index in the evaluation of urban security[0]. The Human Factors of Global Environmental Change (IHDP) has taken the study of urban vulnerability as a key research content and put forward many guiding viewpoints. At the same time, IHDP also pointed out that the comprehensive study and evaluation of the vulnerability of typical cities has very important theoretical and practical significance[0]. Vulnerability was first applied in the study of natural disasters and other issues. With the development of economy and society and the broadening of cognition, the study of vulnerability has gradually developed from the field of natural science to the field of social science[0]. White G F, Timmernan P, Dow K and other early scholars successively defined the concept of vulnerability and clearly explained the concept of vulnerability. Since the beginning of the 21st century, the study of vulnerability has been characterized by the blossoming of a hundred flowers and a number of landmark achievements have been formed[4-6].

As an important type of city, resource-based cities have distinct characteristics of resource-oriented economic structure, and their vulnerability is generally high[0]. At present, researches on vulnerability of resource-based cities are constantly increasing. For the evaluation of vulnerability of resource-based cities, common methods mainly include coupling degree evaluation method, comprehensive index method, packet analysis method, etc[0]. Coupling degree analysis is to determine the degree of coupling among systems or elements by studying the interaction and influence among various systems or elements, and to evaluate the different influences and dynamic trends of different elements on urban vulnerability. The comprehensive index method can unify the standardized treatment of a number of complex indicators without unified measurement standards, and then convert them into a comprehensive index, which can be used to accurately evaluate the comprehensive situation of an evaluation object. Packet analysis mainly analyzes and studies the input and output of different evaluation units through the establishment of CCR model. This method can be relatively objective without determining the weight of each index, but it ignores the difference between each decision unit, and the accuracy of the model also needs to be improved.

Integrated the advantages and disadvantages of the above research methods, this paper combining with the characteristics of Karamay, joined in the index system of oil production, its self-sufficiency rate of energy and resources comprehensive exploitation and utilization of resources cities such as technology innovation ability related parameters of the actual, put forward the Entropy-TOPSIS model for evaluation of the resources city, mainly through objectively the entropy weight method to determine index weight, and comprehensive evaluation combined with TOPSIS model, avoids the influence of subjective factors, make the evaluation results more objective and scientific, It also tries to make a comprehensive evaluation of the development of Karamay in the past 10 years through a scientific index system and a reasonable evaluation method, so as to facilitate the transformation and healthy development of Karamay and provide experience for other similar resource-based cities in China for their coordinated and sustainable development.

Methodology

Background. In 2013, the State Council issued a notice on the National Sustainable Development Plan for Resource-based Cities (2013-2020), proposing that resource-based cities are an important base for China's energy security and strategic security, as well as an important support for the coordinated and sustainable development of the national economy. Promoting the coordinated and sustainable development of resource-based cities is an inevitable requirement for accelerating the transformation of the traditional mode of economic development and achieving the two centenary goals. It is also an inevitable demand for promoting the coordinated and sustainable development of regions, promoting the new type of industrialization and urbanization, maintaining social harmony and stability, and building a beautiful China. With the coming of the year 2020, the construction effect of 262 resource-based cities in China needs to be tested urgently.

Study area. Karamay City (80°44′ E-86°1′ E, 44°7′ N-46°8′ N) is located Located in the western Junggar Basin, China (Fig. 1). It has four districts, covering an area of 7733km^2 with over 0.46 million urban residents. Karamay city landform is mostly gobi desert, the terrain is inclined strip,

north and south long, east and west narrow. The region is characterised by a Temperate continental climate with an average annual precipitation of 108.9 mm, annual average temperature of 8.6 °C. Its characteristic is: cold and heat difference is great, dry little rain, spring and autumn monsoon is much, winter and summer temperature difference is big. The snow is thin, evaporates quickly, and the frozen soil is deep. Disasters such as high winds, cold waves, hail and mountain torrents occur frequently. In the four seasons, winter and summer are long, and the temperature difference is large, spring and autumn are the transitional period, the change of seasons is not obvious.

Oil and natural gas are the most important mineral resources in Karamay. Since 2002, the crude oil output of Karamay has been more than 10 million tons, making outstanding contributions to the regional economic development and national economic construction of Xinjiang. At present, Karamay continues to strengthen resources exploration and development efforts, committed to build a complete industrial chain of high-end energy and chemical industry highland. However, with the arrival of the new century, Karamay is facing the difficult problem of coordinated and sustainable development. Karamay, located in the northwest margin of Xinjiang Junggar Basin, is a modern regional central city on the Silk Road Economic belt, as well as a national key petroleum and petrochemical base and a new type of industrial city. The urban population is about 450,000. According to 2018 data, Karamay's GDP reached 89.81 billion yuan, an increase of 6.7%. Among them, the added value of the primary industry reached 500 million yuan, an increase of 0.3% over the previous year. The added value of the secondary industry was 65.47 billion yuan, down 1.1% from the previous year. The added value of the tertiary industry reached 23.84 billion yuan, an increase of 23.1% over the previous year. Since the 12th Five-Year Plan period, Karamay has made steady progress in its economic construction and strengthened its economic strength. Both regional and per capita GDP rank among the top in Xinjiang. However, there are still some problems, such as a relatively single economic structure, poor anti-risk capability, insufficient extension of industrial chain, and economic vitality to be improved. By 2020, the public information shows that the proportion of the secondary industry in Karamay is as high as 70%, with prominent contradiction in

industrial structure and obvious vulnerability of the city.

Data and Method. All data in this paper are from the Karamay Statistical Yearbook (2008-2017), Statistical Bulletin of The National Economy and Social Development of Karamay (2008-2017), China Energy Statistical Yearbook and government work reports and public information published on the official website of the Karamay Municipal Government. For the missing individual year data, the sliding smoothing method or trend extrapolation method is used to obtain. A total of 36 evaluation indicators were collected and sorted out in the past 10 years, and the Entropy Weight-TOPSIS model was used for empirical analysis and research. According to the analysis results, feasible guidance and Suggestions were provided for the road of harmonious and sustainable development of Karamay.

Results

Vulnerability characteristics of Karamay. Characteristics of ecological environment vulnerability. Karamay is located in the Northern Slope of Tianshan Mountain, northwest margin of Junggar Basin and south foot of Gaill Mountain. It is a new modern industrial city in Xinjiang located in the central part of Eurasia continent and the hinterland of northwest China. Affected by geographical location and long-term water shortage and other factors, most areas are bare Gobi desert, with small woodland area, low forest coverage rate, serious salinization of land, little natural grassland area, and relatively fragile ecological environment. In recent decades the large-scale development of oil and gas resources, atmospheric environmental pollution, solid waste pollution and more and more serious problems such as soil salinity and land desertification, causing local species and quantity reduced, a great change of the natural ecological environment and even the destruction of the ecological environment governance, restoration and reconstruction of a difficult task. At the same time, due to the lack of sufficient macro environment and micro conditions, the new energy industry develops slowly and still needs a long process of adaptation and adjustment.

Characteristics of social development vulnerability. Affected by the shareholding reform of state-owned enterprises and the rigid industrial structure of resource-based cities, the improvement

of residents' living standards and the improvement of social security system in Karamay have become important factors hindering social construction. In addition, Karamay has a relatively dispersed urban distribution, with a narrow north-south distribution and a vast area. The government has insufficient resources for urban infrastructure construction, leading to a high degree of separation of urban geomorphological features. The duplication rate of urban infrastructure construction is relatively high and the amount of capital consumed is large. As a result, although the government's investment in infrastructure construction increases year by year, it is still difficult to improve the social development capacity.

Characteristics of economic construction vulnerability. Although the petroleum and petrochemical industries in Karamay have a good development momentum and the pressure of resource depletion and transformation has not been fully revealed, as a typical resource-based city, the industrial development is facing many problems of restriction. At present, petroleum and petrochemical industries still account for more than 70% of the total industry in Karamay, and the industrial structure is very single. In addition, due to the limited market demand for petrochemical products in Xinjiang, Karamay is far away from the main energy consumption market in eastern China and faces competition from surrounding areas, which restricts the expansion of its market scope. In addition, the investment of resources city itself is not strong, Karamay is typical of the city, "combining the enterprise" absolute proportion of large state-owned enterprises, mainly in the petrochemical industry, small and medium-sized enterprise development relative lag, big tail small enterprise structure, urban economic composition is single, the pull of residents living and employment is limited, lead to the local economic development is slow, economic growth momentum is insufficient, the slow development of non-public economy, and at the same time to maintain the security of fiscal expenditure is larger, the obvious contradiction between financial revenue and expenditure. In addition, under the background of the new round of tax reduction and reduction policy, Karamay's financial revenue even regressed, making the sensitivity of the economic subsystem increase continuously.

Characteristics of resource exploitation and utilization vulnerability. With the development of urban economy and society, the exploitation and utilization of oil resources, water resources and land resources in Karamay are increasing, and the disturbance degree of development activities to the resource subsystem also increases accordingly. Thanks to the discovery of the oilfield lake and the China university of petroleum (Beijing) Karamay campus settled in Karamay, Karamay oilfield presents the new development trend, energy production and processing technology to accelerate the progress, a certain amount of resources development and utilization of the vulnerability of relief, but as a typical resource-based city, Karamay resource vulnerability is still faced with serious challenges, transformation and sustainable development of the road is still a long way to go.

Construction of evaluation index system. The principle of evaluation index construction. (1)Principle of feasibility: The first consideration for the selection of indicators is that the indicators must be accessible. Of course, for some extremely important indicators, the requirements on the difficulty of data acquisition can be reduced. (2) Principle of comparability: Research should have the feasibility of horizontal comparison, so consistency of caliber and time should be paid attention to in the construction of indicators, so as to facilitate horizontal comparison with other resource-based cities. (3) Principle of representativeness: the indicators constructed can reflect the whole picture and essence of the objects to be evaluated. Therefore, it is necessary to pay attention to the problem focus, and try to make comprehensive and comprehensive selection of indicators to ensure that the indicators selected have a high degree of representativeness. (4) Scientific principle: The construction of urban vulnerability evaluation index system is a scientific process, which needs the guidance of corresponding scientific theories. The key point is to make the selected index system scientific, clear in scope, unified in scope, reasonable in unit, comprehensive in coverage and other characteristics. (5) Systematic principle: The construction of urban vulnerability index system is essentially the construction of a vulnerability system, in which there are four subsystems, namely, ecology, society, economy and resources. Therefore, attention should be paid to the internal relations among various indicators in the selection process to ensure the coordination and cooperation among

various indicators, so as to form an organic whole and thus enhance the credibility of the evaluation results.

Construction of evaluation index system. According to the actual situation of Karamay and features, built by the vulnerability of the vulnerability of ecological environment construction, social development, the vulnerability of economic development, resource exploitation and utilization of vulnerability 4 first-level indicators and 36 secondary indexes on the basis of the evaluation index system (Table 1), make the world for Karamay oil city, civilized and harmonious new industrial city to provide important reference for sustainable. Among them: the vulnerability evaluation of Karamay as the primary index (target layer), the vulnerability of the vulnerability of ecological environment construction, social development, the vulnerability of economic development, resource exploitation and utilization of vulnerability as secondary indexes (rule layer), covered under 36 specific indicators, including the added value of ten thousand yuan of industrial wastewater emissions intensity, such as sulfur dioxide emissions intensity, built up area green coverage rate as three-level index (index layer).

Table 1 Evaluation index system of urban vulnerability in Karamay

Target layer	Criterion layer	Index	Index layer / unit	Property	Weight
Urban vulnerability assessment	Ecological vulnerability	X1	Intensity of wastewater discharge per 10000 yuan of industrial added value / million tons	Negative	0.0144
		X2	Sulfur dioxide emission intensity / t	Negative	0.0322
		X3	Green coverage in built-up areas / %	Positive	0.0113
		X4	Comprehensive utilization rate of industrial solid waste / %	Positive	0.025
		X5	Disposal rate of industrial hazardous waste / %	Positive	0.0297
		X6	Centralized treatment rate of sewage treatment plant / %	Positive	0.0277
		X7	Harmless disposal rate of household garbage / %	Positive	0.0243
		X8	Per capita public green space area / square meter	Positive	0.0267
	Social vulnerability	X9	Per capita disposable income of urban residents / yuan	Positive	0.0332
		X10	The number of students in ten thousand ordinary middle schools / person	Positive	0.017
		X11	Ten thousand people have doctors / person	Positive	0.031
		X12	Millions have mobile phones	Positive	0.0303
		X13	Urban road area per capita / square meter	Positive	0.0247

	X14	Registered urban unemployment rate / %	Negative	0.0339
	X15	Ten thousand people have the number of buses	Positive	0.0191
	X16	Engel's coefficient for urban residents / %	Negative	0.0283
	X17	Natural population growth rate /‰	Positive	0.0371
	X18	Per capita living area of urban residents/(square meter / person)	Positive	0.0517
Economic vulnerability	X19	GDP growth/%	Positive	0.0314
	X20	The proportion of added value of tertiary industry /%	Positive	0.0286
	X21	Per capita GDP/yuan	Positive	0.0168
	X22	Fixed asset Investment density/(yuan/person)	Positive	0.0474
	X23	Local fiscal self-sufficiency rate /%	Positive	0.041
	X24	Per capita local fiscal revenue/yuan	Positive	0.0226
	X25	Industrial added value above designated size / 100 million yuan	Positive	0.0241
	X26	The proportion of science and technology spending in local government spending/per thousand	Positive	0.0275
Resources vulnerability	X27	Ability to foster and develop the new energy industry	Positive	0.0324
	X28	Crude output / million ton	Positive	0.0532
	X29	Urban per capita domestic water consumption / L	Negative	0.0261
	X30	Energy consumption per unit of GDP / (Tons of standard coal/ten thousand yuan）	Negative	0.0147
	X31	Water consumption per unit of GDP/(m^3 / ten thousand yuan)	Negative	0.0107
	X32	The popularity of the concept of sustainable energy consumption/%	Positive	0.0352
	X33	Clean energy utilization rate in living cities/%	Positive	0.0256
	X34	Energy consumption for industrial added value/(Tons of standard coal/ten thousand yuan）	Negative	0.0124
	X35	Energy self-sufficiency/%	Positive	0.0279
	X36	Technological innovation ability of comprehensive utilization of resources	Positive	0.0249

The determination of evaluation index weight. C.E.Shannon put forward the concept of information entropy in 1984 and introduced the basic principle of information entropy in detail in her book Mathematical Theory of Communication. The information entropy of each index is calculated to reflect the importance of different indexes in the evaluation system. The value of information entropy is inversely proportional to the amount of information contained in the index, and then inversely proportional to the weight of the index. In other words, the greater the information entropy of an index is, the smaller the amount of information it contains and the smaller the weight it takes in the evaluation system. The entropy weight method gives weights to indicators. Its advantage is that entropy weight method is an objective weighting method, which can reduce the influence of human subjective factors in the weighting process. Moreover, the calculation process is relatively simple and has no special requirements on data.

The process is as follows:

Step 1: Standardize the data

Suppose the data of j years with i indicators are given, and it is denoted as X_{ij}

Assuming that the pair value of each indicator after standardization is Y_{ij},then:

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \tag{1}$$

Step2: Calculate the information entropy of each index

Determine the numerical weight of the ith index in the jth year:

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{2}$$

Determine the information entropy of the jth index:

$$E_j = -\frac{1}{ln\, n} \times \sum_{i=1}^{n} P_{ij}\, ln\, P_{ij} \tag{3}$$

Step3: Determine the weight of each index

According to the calculation formula of information entropy, the information entropy of each index is calculated $E_1, E_2, \dots, E_j$

Calculate the weight of each index through information entropy:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m} (1 - E_j)} \tag{4}$$

Construction of TOPSIS evaluation model. In 1981, C. L. Hwang et al proposed TOPSIS model, which can be understood as the distance method of Solution distance method for pros and cons. TOPSIS model is a commonly used evaluation model, which can make full use of the original data information without high requirements on the original data. Moreover, the evaluation results can accurately reflect the gap between various evaluation indexes and form relatively objective evaluation results.

The basic process of TOPSIS method is as follows: first, the original data matrix is generally processed forward to obtain the new normalized matrix; then, the matrix is standardized to obtain the normalized matrix. The optimal scheme and the worst scheme in the finite scheme are found from the standardized matrix by a certain method. Finally, the distance between each evaluation index and the optimal scheme and the worst scheme is calculated respectively to obtain the proximity degree between each evaluation index and the optimal scheme, and this is used as the basis for the evaluation. The specific steps are as follows:

(1) Construction of standardized evaluation matrix. Assume that the original evaluation matrix of vulnerability of resource-based cities is:

$$T = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \tag{5}$$

In Equation (5), T is the original evaluation matrix,X_{ij} is the original value of the ith index in the jth year,m is the evaluation index, and n is the evaluation year.

According to the different properties of the selected index, different standardization treatments are carried out. The indicators can be divided into three categories: positive indicators, negative indicators and median indicators. The formulas are as follows:

Positive indicators

$$y_{ij} = \frac{X_{ij} - \min_{1 \le i \le n}(X_{ij})}{\max_{1 \le i \le n}(X_{ij}) - \min_{1 \le i \le n}(X_{ij})} \tag{6}$$

Negative indicators

$$y_{ij} = \frac{\max_{1 \le i \le n}(X_{ij}) - X_{ij}}{\max_{1 \le i \le n}(X_{ij}) - \min_{1 \le i \le n}(X_{ij})} \tag{7}$$

Median indicators

$$y_{ij} = \begin{cases} 1 - \dfrac{p - X_{ij}}{\max_{1 \le i \le n}\left(p - \min_{1 \le i \le n}(X_{ij}),\ \max_{1 \le i \le n}(X_{ij}) - p\right)}, & X_{ij} < p \\ 1 - \dfrac{X_{ij} - p}{\max_{1 \le i \le n}\left(p - \min_{1 \le i \le n}(X_{ij}),\ \max_{1 \le i \le n}(X_{ij}) - p\right)}, & X_{ij} \ge p \end{cases} \tag{8}$$

In Equation(8),y_{ij} is the standard value of the index,X_{ij} is the initial value of the index,p represents the optimal

value of the median index in the evaluation area, and $\max_{1\le i\le n}(X_{ij})$、$\min_{1\le i\le n}(X_{ij})$ are the maximum and minimum values in the evaluation area of the index respectively. n is the year being evaluated.

The standardized matrix after processing is:

$$Y_{ij}=\begin{bmatrix}\beta_{11} & \beta_{12} & \cdots & \beta_{1n}\\ \beta_{21} & \beta_{22} & \cdots & \beta_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \beta_{m1} & \beta_{m2} & \cdots & \beta_{mn}\end{bmatrix} \tag{9}$$

In the formula,Y_{ij} is the standardized evaluation matrix, and β_{ij} represents the data standard value of the ith index in the jth year.

(2) Construct the evaluation matrix according to the determined entropy weight

$$V=\begin{bmatrix}v_{11} & v_{12} & \cdots & v_{1n}\\ v_{21} & v_{22} & \cdots & v_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ v_{m1} & v_{m2} & \cdots & v_{mn}\end{bmatrix}=\begin{bmatrix}\beta_{11}\cdot W_1 & \beta_{12}\cdot W_2 & \cdots & \beta_{1n}\cdot W_n\\ \beta_{21}\cdot W_1 & \beta_{22}\cdot W_2 & \cdots & \beta_{2n}\cdot W_n\\ \vdots & \vdots & \ddots & \vdots\\ \beta_{m1}\cdot W_1 & \beta_{m2}\cdot W_2 & \cdots & \beta_{mn}\cdot W_n\end{bmatrix} \tag{10}$$

(3) The TOPSIS model is used to determine the distance between positive and negative ideal solutions

The distance to the positive ideal solution:

$$D_j^+=\sqrt{\sum_{i=1}^{m}\left(v_i^+-v_{ij}\right)^2} \tag{11}$$

The distance to the negative ideal solution:

$$D_j^-=\sqrt{\sum_{i=1}^{m}\left(v_i^--v_{ij}\right)^2} \tag{12}$$

In Equations (11) and (12), v_i^+ is the maximum value of the evaluation index in the jth year,v_i^- is the minimum value of the evaluation index in the jth year. The two correspond to positive ideal solution and negative ideal solution respectively.

(1) Calculate the urban vulnerability assessment score m_j.

m_j represents the evaluation score of urban vulnerability in Karamay in year j ,and the value interval is (0,1). The closer to 0, the lower the evaluation score is and the more vulnerable the city is. The closer to 1, the higher the score and the healthier the city. The calculation formula is as follows:

$$m_j=\frac{D_j^-}{D_j^++D_j^-} \tag{13}$$

Data standardization and index weight determination. After the collection and sorting of the original data and the standardized processing, the entropy weight method was used to determine the information entropy of each index, and the objective weight of each index was determined accordingly (Table 1). Combined with the two, the standardized results of the index system of vulnerability assessment of Karamay based on the entropy weight method were obtained (Table 2).

Table 2 Results of standardization of vulnerability assessment index system of Karamay under entropy weight method

Index		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	The entropy of information
1	X1	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0144
2	X2	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0322
3	X3	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0113
4	X4	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.0250
5	X5	0.0000	0.0423	0.3069	0.2116	0.6032	0.7460	1.0000	0.9929	1.0000	1.0000	0.0297
6	X6	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0277
7	X7	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0243
8	X8	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0267

9	X9	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0332
10	X10	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.0170
11	X11	0.0000	0.0423	0.3069	0.2116	0.6032	0.7460	1.0000	0.9929	1.0000	1.0000	0.0310
12	X12	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0303
13	X13	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0247
14	X14	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0339
15	X15	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0191
16	X16	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.0283
17	X17	0.0000	0.0423	0.3069	0.2116	0.6032	0.746	1.0000	0.9929	1.0000	1.0000	0.0371
18	X18	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0517
19	X19	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0314
20	X20	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0286
21	X21	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0168
22	X22	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.0474
23	X23	0.0000	0.0423	0.3069	0.2116	0.6032	0.746	1.0000	0.9929	1.0000	1.0000	0.0410
24	X24	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0226
25	X25	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0241
26	X26	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0275
27	X27	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0324
28	X28	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.532
29	X29	0.0000	0.0423	0.3069	0.2116	0.6032	0.7460	1.0000	0.9929	1.0000	1.0000	0.0261
30	X30	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0147
31	X31	0.0000	0.3614	0.5543	1.0000	0.6277	0.6196	0.6114	0.5272	0.4103	0.6332	0.0107
32	X32	0.0000	0.2778	0.4237	0.1845	0.1911	0.1911	0.9882	0.9878	0.9826	1.0000	0.0352
33	X33	0.0000	0.6456	0.8101	0.8228	0.8354	0.8481	0.9873	1.0000	1.0000	0.9367	0.0256
34	X34	0.0965	0.0000	0.1598	0.9756	1.0000	0.7833	0.9787	0.6756	0.6252	0.8187	0.0124
35	X35	0.0000	0.0423	0.3069	0.2116	0.6032	0.7460	1.0000	0.9929	1.0000	1.0000	0.0279
36	X36	0.0000	0.2023	0.2727	0.2455	0.2455	0.6727	0.9500	0.9864	1.0000	0.9523	0.0249

Positive and negative ideal solutions and distance calculation. The above standardized matrix and Entropy Weight-TOPSIS model method are used to calculate the distance from the positive ideal solution and the negative ideal solution of the comprehensive vulnerability assessment score of Karamay from 2008 to 2017 and the vulnerability assessment score of each subsystem (Fig. 1).

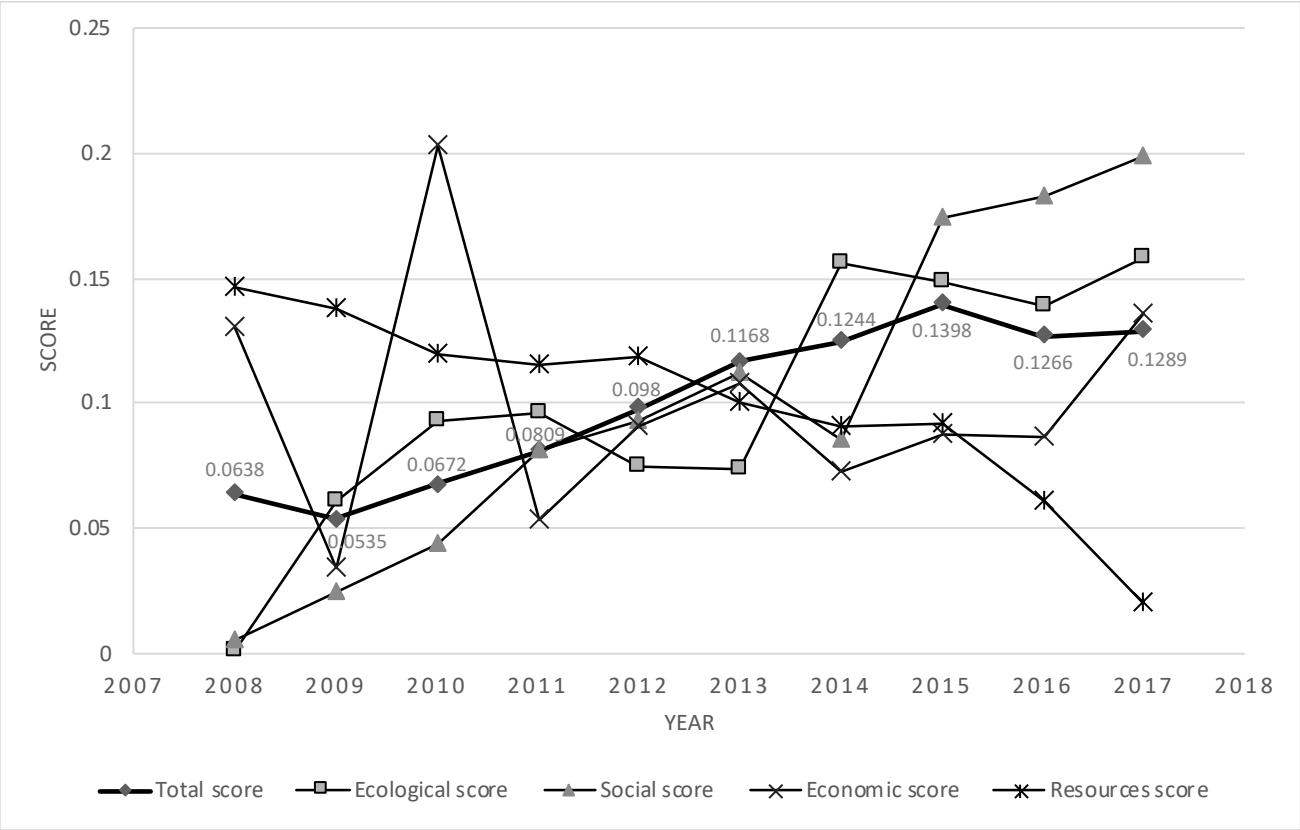

Figure 1 Vulnerability assessment results of Karamay from 2008 to 2017

On the whole, the score of urban vulnerability assessment in Karamay is stable, rising and falling, but generally low. The evaluation scores ranged from 0 to 0.2, all at a low level, indicating that the current urban vulnerability of Karamay is still at a high warning stage. The overall vulnerability score of Karamay showed a rising trend from 2008 to 2015 and a slight decline from 2016 to 2017. Among them, the level of urban vulnerability was low from 2008 to 2010, and the growth rate of urban vulnerability was slow from 2011 to 2015, but it kept steadily increasing. However, there was a downward trend of urban vulnerability after 2015.

Discussion

Ecological environment is fragile. In general, the ecological score of Karamay shows an upward trend (Fig. 2), among which, from 2008-2009, there was a large increase; in 2011, the growth slowed down; in 2013, there was a downward trend; in 2014, there was a significant increase; and then, until 2017, the ecological score of Karamay was in a very stable state. From the interior of the ecological vulnerability metrics, hazard-free treatment rate of green coverage, living garbage, sewage plants, concentration rate, industrial hazardous waste disposal rate, industrial solid waste comprehensive utilization of these five indexes have been optimized, the ecological vulnerability of the longitudinal level plays an important role in contribution, the added value of ten thousand yuan of industrial wastewater emissions intensity, the reverse of sulfur dioxide emissions intensity both indicators, the ecological fragility of transverse wave plays an adverse effect.

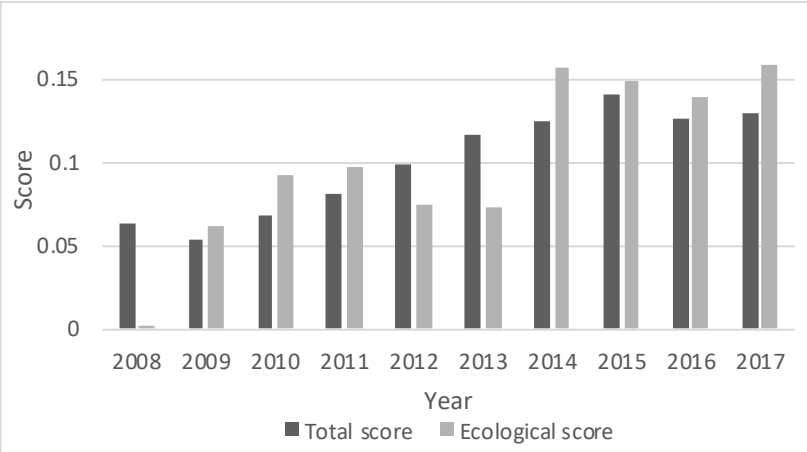

Figure 2 Vulnerability assessment results of ecological construction in Karamay from 2008 to 2017

Every year, the Karamay municipal government takes the ecological environment construction as the key work of the year and invests a lot of manpower, material resources and financial resources to improve the ecological environment of Karamay, and has been awarded the honorary title of "National Garden City". However, it can be seen from the evaluation results that although the ecological environment vulnerability of Karamay is constantly improving, the overall vulnerability index is still at a low level, and there is a strong contrast between the well-built urban ecological environment and the extremely fragile suburban and other regional ecological environment. Karamay still needs to further improve the quality and efficiency of ecological environment construction and focus on weak links. There is still a long way to go to improve the ecological environment.

Social development vulnerability. On the whole, the social score of Karamay shows an upward trend (Fig. 3). It showed an increasing trend from 2008 to 2013, and experienced a short period of decline in 2014, mainly because the registered urban unemployment rate and the unfavorable performance of urban residents' Engel coefficient in this stage dragged down the social score. After that, it rose steadily from 2015 to 2017. Through the analysis of the specific evaluation index data, found that over the past decade of Karamay urban per capita disposable income, urban per capita living area, urban per capita road area index data are rising steadily, such as one of the biggest changes is the urban per capita disposable income, rose from 14026.7 in 2008 yuan per person to 2017 RMB 39000 / person, up 2.5 times, the residents of Karamay's living standards continue to improve, the steady rise of happiness. Compared with the total score, the social development evaluation index of Karamay contributes a lot to the overall urban vulnerability evaluation of Karamay, indicating that Karamay attaches great importance to social development, infrastructure construction has been effectively improved, and various measures to guarantee and improve people's livelihood have been implemented.

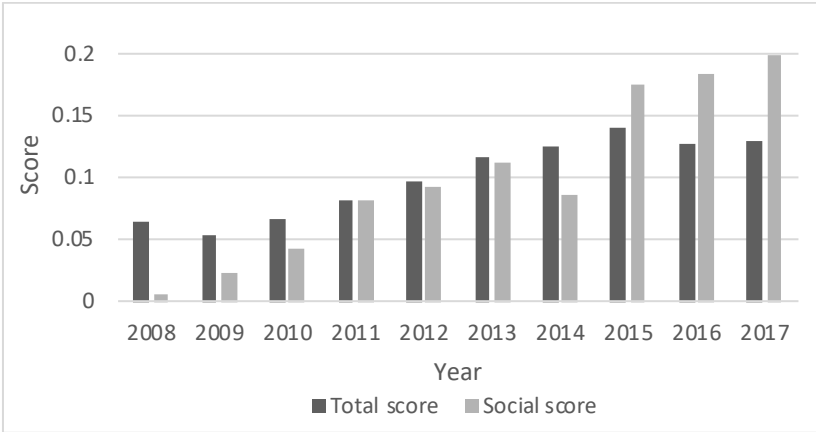

Figure 3 Evaluation results of social development vulnerability in Karamay from 2008 to 2017.

Fragility of economic development. The economic score of Karamay fluctuates greatly and presents a downward trend on the whole (Fig. 4). In 2008-2009, has experienced a sharp fall, followed up considerably, urban economy overly dependent on the oil industry, the economic score with global oil prices during the 2008-2009 financial crisis plunged and fell, and with the restorative oil prices rebounded in 2010-2013 and gradually restore the upward momentum, due

to late June 2004, the new round of oil prices continued to fall, the economic score suffer again, until 2007, when the production to make oil prices back above $50 a producer, rising economic scores got restorative. It can be seen from this that the economic development of Karamay is highly dependent on the oil industry, and the single industrial structure makes the economy of Karamay always maintain a high vulnerability. A slight shift in international oil prices is enough to stir the economic jitters in Karamay. In 2010, the urban vulnerability score of Karamay reached the highest point. Through the analysis of the evaluation index data, it was found that the most important index affecting the annual vulnerability score was GDP growth rate. In 2010, Karamay's GDP growth rate was 17.4%, compared with -1.2% in 2009. The great fluctuation of economic growth rate in Karamay makes this index have a higher evaluation weight under the entropy weight method, and become the most important index that affects the evaluation result of economic vulnerability in Karamay, and the economic transformation of Karamay is imminent.

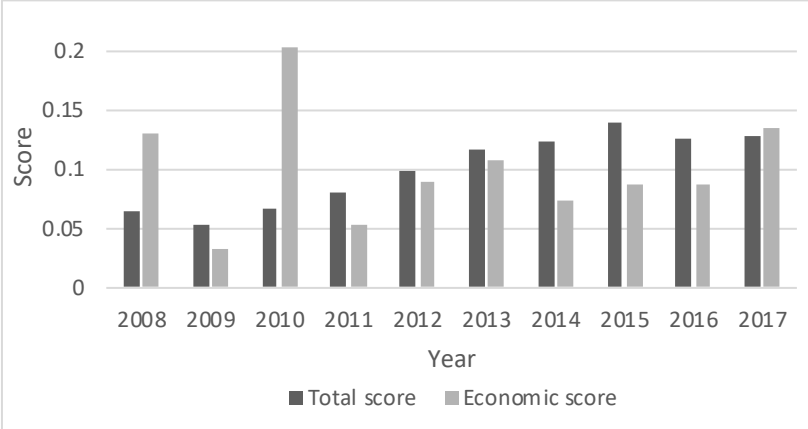

Figure 4 Vulnerability assessment results of economic construction in Karamay from 2008 to 2017

Vulnerability of resource development and utilization. On the whole, the resource score of Karamay showed a downward trend (Fig. 5). From 2008 to 2015, it decreased slowly, and then experienced two large drops, and gradually became the most adverse subsystem that affected the vulnerability assessment of Karamay. According to the internal indicators of resource vulnerability, the key indicators of urban per capita domestic water consumption, energy consumption per unit GDP, water consumption per unit GDP, and energy consumption per unit of industrial added value all show a significant decline. The energy consumption per unit GDP rose from 1.61 tons of standard coal / 10,000 yuan in 2008 to 2.05 tons of standard coal / 10,000 yuan in 2017, and the water consumption per unit GDP rose sharply from 16.81 tons / 10,000 yuan in 2008 to 61.77 tons / 10,000 yuan in 2017, more than tripling. Although Karamay has shown a steady rise in the ability of cultivating and developing new energy industry and the ability of technological innovation of comprehensive utilization of resources, its speed is slow. The overall score of urban resources is in a continuous downward process, which sounds an alarm for the steady development of Karamay and the benefit of the strategic development of petroleum and petrochemical resources. The utilization efficiency and sustainability of petroleum and petrochemical resources need to be paid more attention and strategic attention by the government.

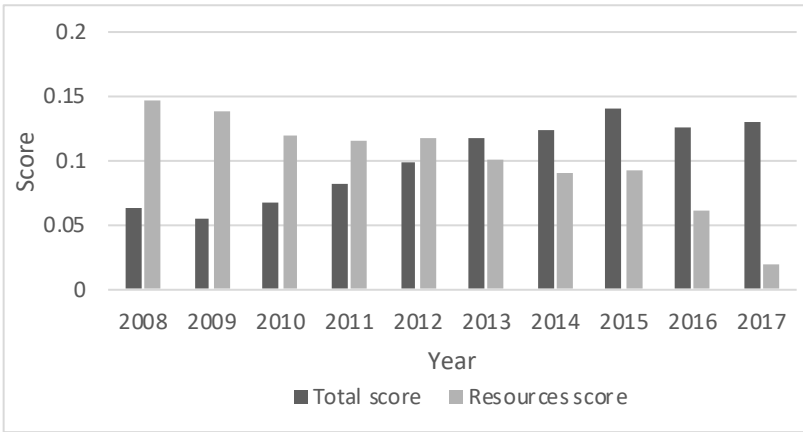

Figure 5 Vulnerability assessment results of resource development and utilization in Karamay from 2008 to 2017

Conclusions

(1) In recent years, at the same time of speeding up economic construction of Karamay, pay attention to create beautiful city civilization, strengthening pollution reduction, deepen the pollution prevention and control, promote the adjustment of industrial structure of rational, gradually improve the quality of ecological environment, improve the resource utilization efficiency, strengthen environmental protection, but the Karamay vulnerability remains on high alert phase. The urban vulnerability of Karamay is obviously dependent on the subsystem of economic development and fluctuates with the fluctuation of economic development vulnerability.

(2) The score of vulnerability of social system and environmental system in Karamay shows an upward trend, while the score of vulnerability of economic system shows an upward trend with a large fluctuation, while the score of vulnerability of resource system shows a downward trend. The main reason is that Karamay has formulated a specific "632" project to achieve the development strategic goal of "building a world oil city", with the main line of accelerating the transformation of industrial economy. Each subsystem has been promoted or weakened to different degrees, but the overall development is stable and positive.

(3) The main obstacles to the urban vulnerability of Karamay are: GDP growth rate, technological innovation ability of comprehensive utilization of resources and fixed asset investment density. At present, the factors that hinder the coordinated and sustainable development of Karamay are mainly in the aspects of economy and resources, which are manifested as the high instability and sensitivity of Karamay's economy and resources.

(4) It is suggested that Karamay, a resource-based city, should actively explore urban transformation and attach importance to not only the development of petroleum and petrochemical industry, but also comprehensive and diversified development; Strengthening innovation in new science and technology in resource utilization and exploration of petroleum resources; Promoting integrated regional development and reducing social vulnerability; We will implement a total pollutant control system and optimize urban environmental infrastructure. Promote the coordination and sustainable development among the four subsystems of ecological environment, economic development, resource development and utilization, and social development.

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Acknowledgements

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Figures

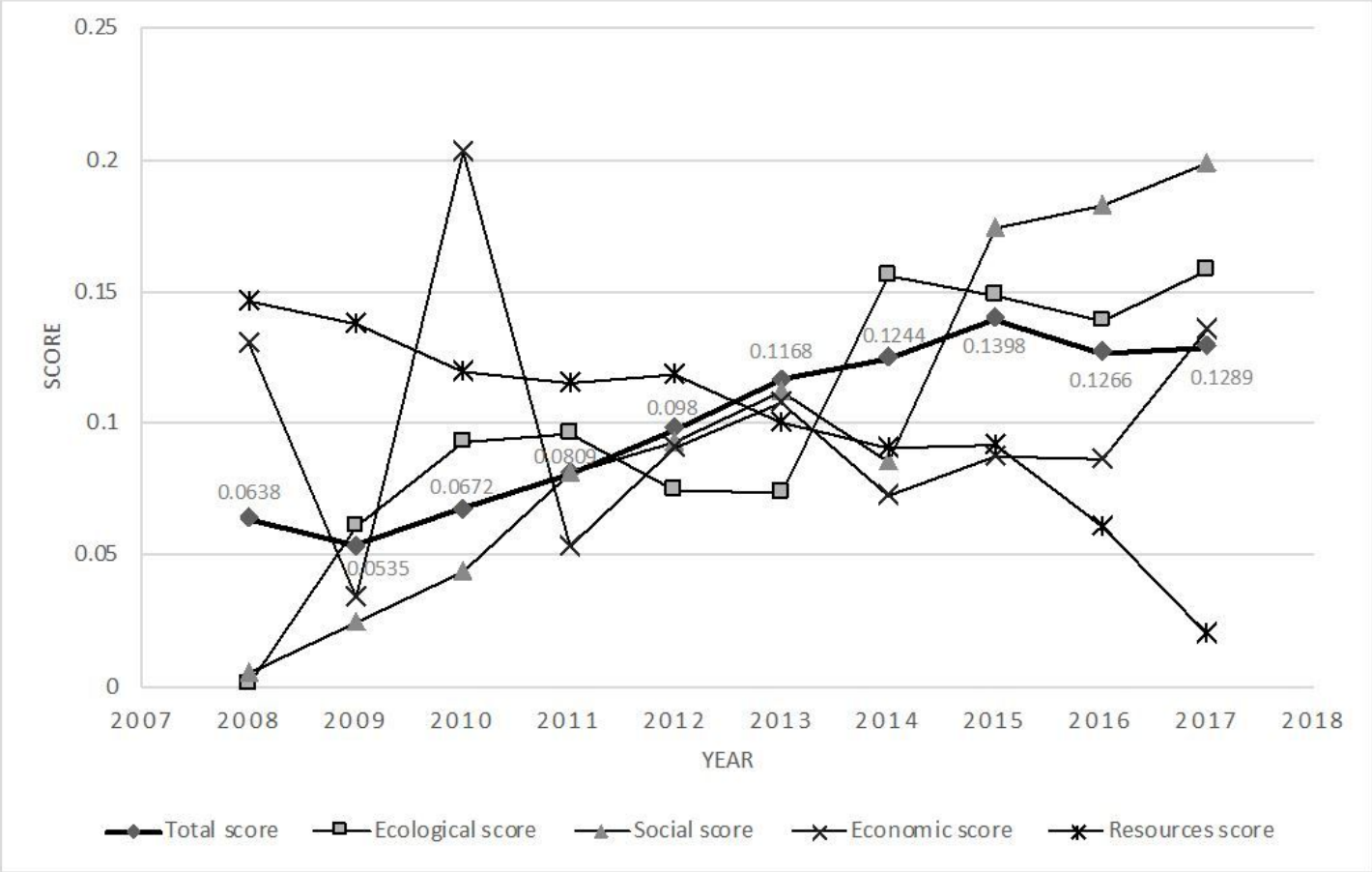

Figure 1

Vulnerability assessment results of Karamay from 2008 to 2017

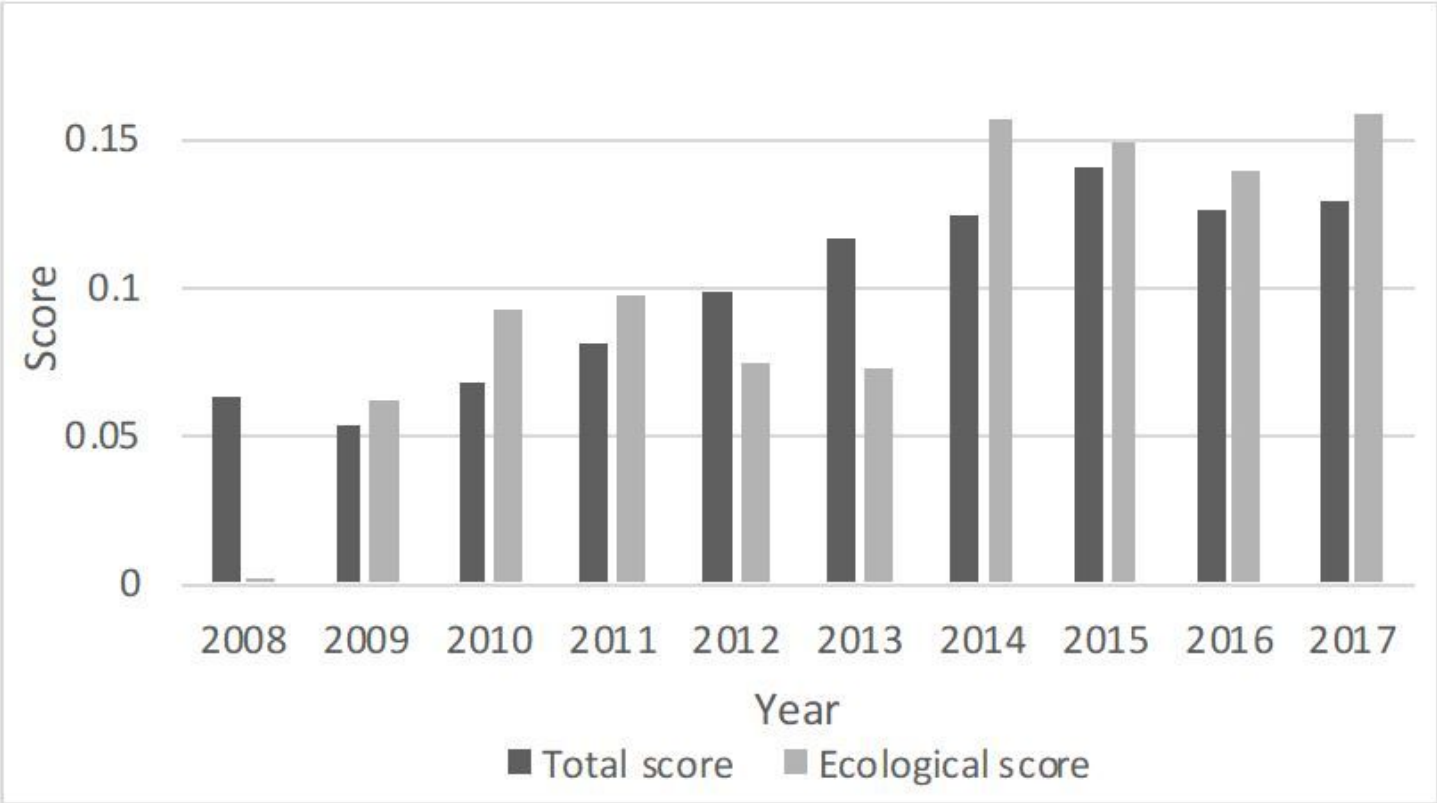

Figure 2

Vulnerability assessment results of ecological construction in Karamay from 2008 to 2017

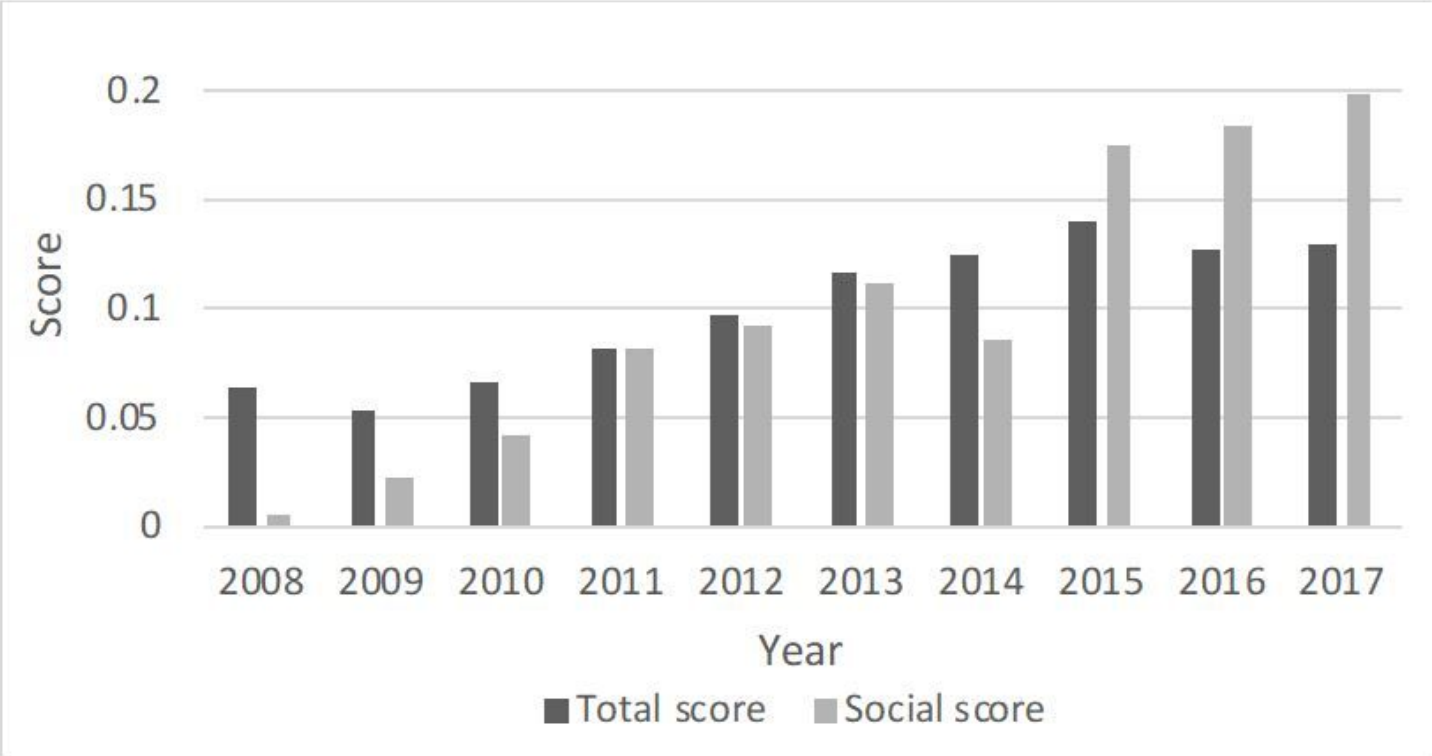

Figure 3

Evaluation results of social development vulnerability in Karamay from 2008 to 2017.

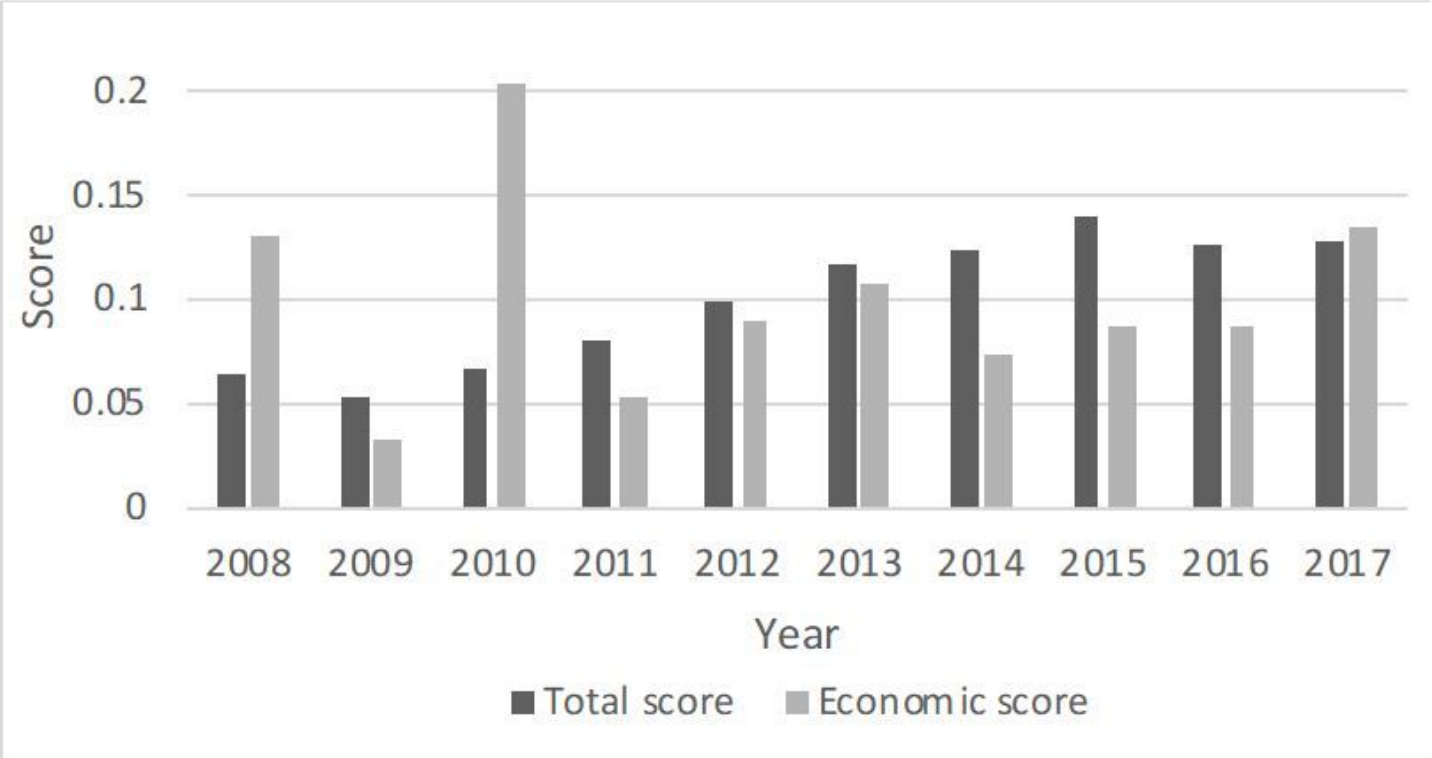

Figure 4

Vulnerability assessment results of economic construction in Karamay from 2008 to 2017

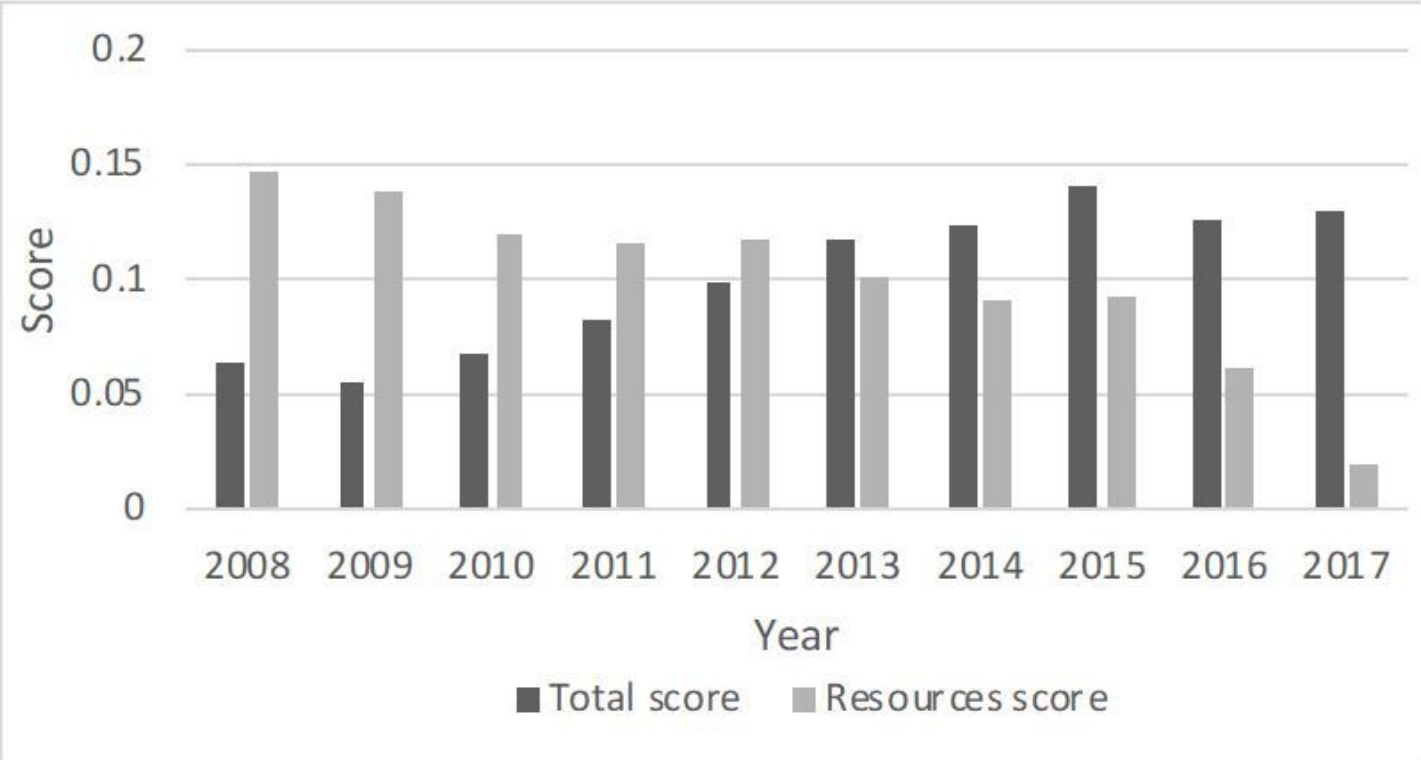

Figure 5

Vulnerability assessment results of resource development and utilization in Karamay from 2008 to 2017