Analysis of Sustainable Development Capacity of Ecosystem in Tangshan Based on Entropy Method

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Abstract: Since the concept of sustainable development was put forward, China has paid more and more attention to the construction of ecological civilization and has placed greater emphasis on ecological environmental protection. Based on the entropy method, this paper combines entropy change analysis and information entropy to evaluate the sustainable development capability of the ecosystem in Tangshan City. The results of the study indicate that the ecological carrying capacity of Tangshan City has increased to some extent between 2011 and 2016, but the pressure on the ecosystem of Tangshan City is also increasing. The pressure caused by human activities on the environment is gradually decreasing, and the ecological environment has been improved. During the study period, the ecosystem of Tangshan City developed in an orderly and healthy direction. The decline in raw coal production, the increase in industrial electricity consumption and the increase in population are not conducive to alleviating the pressure on the ecological environment in Tangshan City. The comprehensive utilization of industrial solid waste needs to be improved. Based on the above results, proposals were made to increase the output of raw coal, increase energy efficiency, and further increase the overall utilization rate of general industrial solid waste.

1. Introduction

In 1987, the World Commission on Environment and Development formally proposed the concept of sustainable development in its report “Our Common Future”. Sustainable development refers to the ability to meet the needs of the present without compromising the ability of future generations to meet their needs. The essence of development is the coordinated symbiosis between man and nature. In China, the country is paying more and more attention to the construction of ecological civilization. General Secretary Xi Jinping stressed at the National Ecological Environmental Protection Conference held in Beijing from May 18 to 19, 2018, “The construction of ecological civilization is a fundamental plan for the sustainable development of the Chinese nation.”

To make sustainable development work, we need to scientifically quantify the use of resources by humans. Humans are constantly exploring ways to quantify the sustainability of a country or region. Among them, the construction of the evaluation index system is indispensable. As a sub-central city in the northeast of the Beijing-Tianjin-Hebei urban agglomeration, Tangshan City is particularly well known for its rapid development in the steel industry and energy industry. Therefore, it is necessary to conduct research on sustainable development in Tangshan City [1].

The research results of Tangshan's sustainable development ability evaluation can be roughly divided into the following three categories: the application of emergy theory and ecological footprint theory in Tangshan's sustainable development capability evaluation, and the entropy method in Tangshan's sustainable development capability evaluation. Application and evaluation of sustainable development capacity of Tangshan City based on urban ecology. Throughout the literature, the evaluation of sustainable development capacity of Tangshan City based on urban ecology is the research trend [2]. However, the existing research results do not comprehensively analyze its structure, function and evolution mechanism from the perspective of urban complex ecosystem. Based on the entropy method, this paper combines entropy change analysis and information entropy to evaluate the sustainable development ability of Tangshan ecosystem, in order to enrich and improve the research method of Tangshan sustainable development, and to

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develop sustainable development in Tangshan City. Play a certain theoretical support [3].

2. Theoretical Basis

2.1. Environmental scarcity theory

The supply of environmental resources was able to meet human needs until the 1960s. However, environmental problems have gradually emerged as the degree of impact of human activities on the environment has grown. Humans realize that the rate of resource regeneration is much lower than the speed at which people can request environmental resources. Therefore, environmental scarcity theory has emerged, and the understanding of limited resources is a prerequisite for the development of sustainable development theory [4].

2.2. Environmental value theory

The use value, potential value and existence value constitute the environmental value. Use value means that the environment can provide various resources for human beings; potential value means that the environment can provide choice for our children and grandchildren; the existence of value is the right of the environment to be independent of human needs. Environmental value theory is one of the theoretical foundations of sustainable development.

2.3. Regional-level sustainable development concept of “time and space fairness”

There are also differences in sustainability standards for countries with different levels of development. Developed countries can expand and develop, medium-level countries respond to sustainable development, and developing countries respond to deteriorating development. The difference standard not only reflects the multiple fairness, but also the development of the goal of time and space coupling and time and space fairness [5].

2.4. The concept of sustainable use of resources

From the perspective of sustainable development, natural resources can be divided into ten categories: land resources, water resources, forest resources, grassland resources, mineral resources, energy resources, marine resources, species resources, climate resources and tourism resources. Sustainable development of the concept of resources refers to the sustainable use of resources. Through rational development and utilization of resources, pollution control and environmental protection, maintain the dynamic balance of ecosystems and achieve sustainable development.

3. Overview of Research Sites

Tangshan City is located in the eastern part of Hebei Province, adjacent to Beijing and Tianjin. It is the throat of the North China and Northeast Passages. It is the central city of the Beijing-Tianjin-Tang Industrial Base and the sub-central city of the northeast of the Beijing-Tianjin-Hebei urban agglomeration [6]. The total area of Tangshan City is 13,472 square kilometers. In 2016, the annual GDP of the region was 635.49 billion yuan. Among them, the added value of the primary industry was 59.9 billion yuan, the added value of the secondary industry was 349.99 billion yuan, and the added value of the tertiary industry was 225.6 billion yuan, accounting for 3.5%, 5.1% and 10.2% respectively [7]. Calculated according to the resident population, the per capita GDP of the whole year is 80,617 yuan.

In agriculture, in 2016, the annual grain sown area was 479,000 hectares and the grain output was 3.055 million tons. The total output of oil (mainly peanut) is 321,000 tons. The total output of dried fresh fruit is 2.69 million tons, of which the chestnut output is 92,000 tons. The total output of meat was 758,000 tons, of which the pork output was 516,000 tons.

In terms of industry, the top five leading industries in Tangshan are: steel industry, energy industry, chemical industry, building materials industry, and equipment manufacturing industry. It is a typical resource-based city that starts from coal and is made up of steel. Steel, energy and other industries have played a major role in the development of Tangshan City [8]. In 2016, the output of

pig iron in Tangshan City was 88.95 million tons, the output of crude steel was 88.31 million tons, the output of steel was 118.37 million tons, and the power generation was 48.2 billion kWh. The steel industry and building materials industry realized profits of 11.97 billion yuan and 1.21 billion yuan respectively.

In recent years, the rapid development of Tangshan City, especially its industrial structure dominated by the secondary industry, has caused serious damage to the water environment and the atmospheric environment. To this end, Tangshan City continued to increase the disposal of environmental pollution, increased financial support for environmental governance, and achieved certain results. In 2016, the annual ambient air quality level was 2 days and the second-class days were 200 days. The annual average concentration of inhalable particulate matter decreased by 9.9%. The total emissions of chemical oxygen demand, ammonia nitrogen, sulfur dioxide and nitrogen oxides were 41,400 tons, 0.85 million tons, 161,800 tons and 181,100 tons, respectively.

4. Empirical Analysis

4.1. Entropy method

The entropy method is an objective weighting method that determines the weight of an indicator based on the size of the information provided by the observations of each indicator. The concept of entropy stems from thermodynamics and is a measure of system state uncertainty. In information theory, entropy is a measure of uncertainty. The larger the amount of information, the smaller the uncertainty and the smaller the entropy; the smaller the amount of information, the greater the uncertainty and the greater the entropy. According to the characteristics of entropy, the randomness and degree of disorder of a scheme can be judged by calculating the entropy value. The degree of dispersion of an index can also be judged by the entropy value. The greater the degree of dispersion of the index, the influence of the index on the comprehensive evaluation. The bigger.

Urban ecosystems not only exchange material, information and energy with the external environment, but also occur in succession and change over time in the constantly changing internal and external environment. This change is simply a continuous process in which the old structure is continuously decomposed and the new structure is continuously formed. Since the entropy value can judge the degree of randomness and disorder, this process can be expressed by the system entropy change. The process of urban ecosystem state changing with time is equivalent to the development process of entropy.

Studies have shown that there are striking similarities between thermodynamic systems and geographic systems. Therefore, it is feasible to study the urban ecosystem that is both an ecosystem and a complex geographic system from the perspective of entropy. This paper uses entropy method to quantitatively judge the development direction of urban ecosystem, and analyzes the sustainable development ability of urban ecosystem from the perspective of development trend.

Urban ecosystem is a multi-level, multi-functional and multi-factor dynamic artificial ecosystem composed of nature, society and economy. Its structure includes many subsystems. The relationship between them is complex, mutual restraint and interdependent development, forming a chain structure. Urban ecosystems have four basic elements of ecosystem formation: producers, consumers, decomposers and abiotic environments; three basic functions: production function, social consumption function and restoration function. From a systemic ecology perspective, these three basic functions are accomplished through the exchange of matter, information, and energy.

Researchers usually use the three indicators of “entropy flow”, “entropy production” and “total entropy change” to measure urban ecosystems. Entropy flow mainly reflects the carrying capacity of urban ecosystems, which can be used to reflect the coordination of urban ecosystems; entropy production reflects the restoration and regeneration capacity of urban ecosystems, which can be used to reflect the vitality of urban ecosystems; total entropy changes reflect urban ecosystems Order and health.

4.2. Construction of indicator system and evaluation model

Based on the principles of scientificity, pertinence and operability, this paper builds an evaluation index system for the sustainable development capability of urban ecosystems based on the following four aspects.

The supported input entropy index (producer) reflects the ecological carrying capacity of the city to a certain extent. The indicators mainly select the main material cycle in the ecosystem and the substances necessary for human life. In addition, the total value of imports and exports is selected as an indicator of the flow of material and energy between regions. The pressure-type output entropy index (consumer) reflects to some extent the pressure exerted by the economic and social activities in the city on the urban ecosystem.

Consumption metabolic entropy indicators mainly reflect the pressure of human activities on the environment and the ecological problems that need to be solved. The reductive metabolic entropy index mainly reflects the level of human governance of ecological and environmental problems.

According to the entropy method and the application in the evaluation of urban ecosystem sustainability, the evaluation model constructed is shown in Table 1.

Table 1 Evaluation model of urban ecosystem sustainable development ability

	Symbols and formulas	Representative meaning
Supported input entropy index	$\Delta_e S_1$	Degree of disorder
Pressure output entropy index	$\Delta_e S_2$	Degree of disorder
Consumption metabolite entropy index	$\Delta_i S_2$	Degree of disorder
Reductive metabolic entropy index	$\Delta_i S_1$	Degree of disorder
Entropy flow	$\Delta_e S_2 - \Delta_e S_1$	Ecosystem coordination
Entropy production	$\Delta_i S_2 - \Delta_i S_1$	Vitality of the ecosystem
Total entropy change	$(\Delta_e S_2 - \Delta_e S_1) + (\Delta_i S_2 - \Delta_i S_1)$	Ecosystem order and health

4.3. Empirical analysis

This paper collects relevant data from 2011 to 2016, and the data comes from the corresponding year “Tangshan Statistical Yearbook”.

The supported input entropy index and the reduced metabolism entropy index are positive indicators, and the pressure output entropy index and the consumption metabolism entropy index are negative indicators, so there is a difference in processing the data.

(1) Analysis of the sustainable development ability of Tangshan City's ecosystem

The evaluation results of the sustainable development ability of Tangshan ecosystem based on the entropy method are shown in Table 2.

Table 2 Evaluation results of Tangshan ecosystem sustainable development ability based on entropy method

	years					
	2011	2012	2013	2014	2015	2016
Supported input entropy index	0.2758	0.3052	0.4422	0.5119	0.5721	0.6600
Pressure output entropy index	0.7899	0.5545	0.3592	0.2200	0.5177	0.3818
Consumption metabolite entropy index	0.2937	0.3243	0.4125	0.5211	0.6775	0.7905
Reductive metabolic entropy index	0.4495	0.3446	0.5285	0.5282	0.5350	0.7205
Entropy flow	0.5141	0.2493	-0.0830	-0.2919	-0.0544	-0.2782
Entropy production	-0.1558	-0.0203	-0.1160	-0.0071	0.1425	0.0700
Total entropy change	0.3583	0.2290	-0.1991	-0.2990	0.0881	-0.2082

Supported input entropy indicators gradually increased in 2011~2016. The pressure-type output entropy index decreased first and then rose in 2014, and the overall trend showed a downward trend.

This shows that with the development of social economy, the diversity and complexity of ecosystems in Tangshan City continue to increase, and the degree of disorder of the system increases. The supported input entropy index is a positive indicator, showing an upward trend indicating that the ecological carrying capacity of Tangshan City has increased to a certain extent. The pressure-type output entropy index is a negative indicator, and the downward trend during the study period indicates that the pressure on the Tangshan ecosystem is increasing. This is in line with the status quo of Tangshan City, which is dominated by the steel industry and the energy industry. The continuous development of the steel industry and the energy industry has increased the speed of economic development to a certain extent, but the pressure on the ecosystem has also increased.

The consumption metabolic entropy index gradually increased in 2011~2016, which is a negative indicator. This shows that the pressure exerted by human activities on the environment is gradually decreasing. The reductive metabolic entropy index rose first and then rose in 2012, and the overall trend is an upward trend, which is a positive indicator. This shows that during the research period, the leader consciously carried out environmental protection work and achieved certain results, and the ecological environment has been improved.

The entropy flow gradually declined in 2011~2016. Entropy production fluctuated between 2011 and 2016. The total entropy change fluctuated between 2011 and 2016. This shows that the Tangshan ecosystem has developed in an orderly and healthy direction during the study period.

(2) Specific analysis of sustainable development ability of various parts of Tangshan ecosystem

The information entropy and entropy weights of the evaluation index of sustainable development capability of Tangshan City are shown in Table 5.

In the supported input entropy index, the top two rankings of entropy weight are soda ash and total import and export value. The lowest ranking of entropy weight is raw coal. The output of soda ash has risen sharply, and the total output value of imports and exports has risen sharply and then dropped sharply, showing an inverted U shape. Raw coal production showed a downward trend. This shows that the sharp increase in soda ash production and the sharp increase in the total value of imports and exports have the greatest impact on the development of supportive input systems in Tangshan City. The downward trend of raw coal production is not conducive to the development of supportive input systems in Tangshan City.

In the pressure output type entropy index, the entropy weight is ranked higher in industrial electricity consumption and natural population growth rate. The fluctuations in industrial electricity consumption are large, first fluctuating to the maximum, then gradually decreasing; the natural population growth rate fluctuates. The large increase in industrial electricity consumption and the high natural population growth rate indicate that during the research period, the pressure output system of Tangshan City was brought closer to the direction of pressure increase.

Among the consumption metabolic entropy indicators, the top five entropy weights are the annual average concentration of respirable particulate matter, ammonia nitrogen emissions from water environment, industrial nitrogen oxide emissions, industrial sulfur dioxide emissions, and chemical oxygen demand emissions from industrial wastewater. the amount. This shows that these five indicators have a greater impact on the consumption metabolism function of Tangshan City. The annual average concentration of respirable particulate matter, ammonia nitrogen emissions from water, industrial NOx emissions, industrial sulphur dioxide emissions, and chemical oxygen demand emissions from industrial wastewater were significantly reduced during the study period. This shows that Tangshan City has slightly improved the annual average concentration of respirable particulate matter, ammonia nitrogen emissions from water environment, industrial nitrogen oxide emissions, industrial sulfur dioxide emissions and chemical oxygen demand emissions from industrial wastewater, effectively alleviating environmental pressure.

Among the reductive metabolic entropy indicators, the highest entropy weight ranking is the centralized treatment rate of sewage. The centralized treatment rate of sewage increased during the study period. This indicates that the increase in the concentration of sewage treatment has played a greater role in enhancing the reductive function of Tangshan City. The general industrial solid waste comprehensive utilization rate, urban greening coverage area and urban park green area area have

lower entropy weight.

5. Conclusions and Recommendations

5.1. Conclusion

(1) The ecological carrying capacity of Tangshan City has increased to a certain extent, but the pressure on the ecosystem of Tangshan City is also increasing. The pressure caused by human activities to the environment is gradually decreasing. During the research period, the leaders consciously carried out environmental protection work and achieved certain effects, and the ecological environment has been improved. In general, the Tangshan ecosystem developed in an orderly and healthy direction during the study period.

(2) Among the supported input entropy indicators, the sharp increase in soda ash production and the sharp increase in the total value of imports and exports have the greatest impact on the development of supportive input systems in Tangshan City. The downward trend of raw coal production is not conducive to the development of supportive input systems in Tangshan City. In the pressure output type entropy index, the large increase in industrial electricity consumption and the high natural population growth rate indicate that the pressure output system of Tangshan City is approaching the direction of pressure increase to some extent during the research period.

(3) In the consumption metabolic entropy index, this shows that Tangshan City's annual average concentration of respirable particulate matter, ammonia nitrogen emissions from water environment, industrial nitrogen oxide emissions, industrial sulfur dioxide emissions, and chemical oxygen demand emissions from industrial wastewater are slightly observed. The results have effectively alleviated environmental pressures. Among the reductive metabolic entropy indicators, the increase of centralized treatment rate of sewage has played a greater role in enhancing the reductive function of Tangshan City. The general industrial solid waste comprehensive utilization rate, urban greening coverage area and urban park green area area have lower entropy weight.

5.2. Recommendations

(1) Tangshan City needs to increase the output of raw coal, so that the supporting input system of Tangshan City will further develop in the direction of enhanced support; pay attention to the electricity consumption of industrial enterprises, develop science and technology and clean energy, develop new energy sources and improve energy efficiency. Vigorously develop wind power; control population growth and reduce population pressure on urban ecosystems.

(2) Tangshan City should continue to strengthen the treatment of industrial wastewater and industrial waste gas; further improve the comprehensive utilization rate of general industrial solid waste, expand urban green coverage area and urban park green space.

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