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Comprehensive Evaluation and Improvement Strategy for the Carrying Capacity of Resource Environment in Shandong Province, China

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ABSTRACT

Crises, such as resource shortage, environmental pollution, and ecological damage, restrict the sustainability of regional economic and social development. A comprehensive evaluation on the carrying capacity of resource environment (CCRE) based on a scientific system is beneficial to determining the background, constraints, and potentials of the carrying capacity of regional resource environments, comprehending economic and social development, and realizing harmonious development between ecological civilization and economic society. For deeply understanding the carrying capacity level of regional resource environment and mastering its variation trend accurately, an evaluation system was constructed in this study based on Shandong Province in China. This system covered 11 indexes of economic, resource, and environment subsystems. CCRE in Shandong Province from 2005 to 2016 were evaluated and estimated comprehensively through the TOPSIS model based on entropy rights. Results showed that the general CCRE in Shandong Province increased significantly from 2005 to 2016, with an annual average growth rate of 5.23%. The development level of the economic subsystem was increased yearly, which basically conformed to the variation trend of CCRE. The economic development laid a solid economic foundation for improving CCRE in Shandong Province. The overall levels of resource and environment subsystems increased yearly, which showed annual growth rates of 4.15% and 2.15%, respectively. Specific countermeasures, including reasonable development and utilization of natural resources, improving the regional ecological environment, and accelerating the technological development and construction of conservation-minded society were proposed. Research conclusions can provide certain references for constructing a long-term evaluation mechanism of CCRE, formulating spatial planning of resource utilization, and strengthening ecological civilization construction.

INTRODUCTION

The rapid economic development provides humans with not only rich material products but also a series of environmental problems, thus intensifying conflicts among resources, environment, economy, and society. The resource and environmental problems are becoming major restraints of economic development in countries and cities. Solving conflict between economic development and ecological damage, facilitating the harmonious development of resources and environment with social and economic development, and realizing sound social and economic development are problems that deserve considerable attention and proper solutions worldwide. With the significant increase in social productivity and the continuous technological progress, China has achieved outstanding growth in economic strength and comprehensive national strength since the reform and opening-up, accompanied with accelerating urbanization. However, these phenomena have caused increasing pressure over resources, environment, and society. Under such severe situations, people have realized that resource environment is of scarcity rather than inexhaustible. Such scarcity becomes increasingly prominent with the economic development. The traditional production mode and consumption pattern in the past must be changed in consideration of the increasingly serious resource environmental problems at present. The construction of resource-saving and environment-friendly production mode and consumption pattern must be accelerated to strengthen the sustainable development of resource environment for increasing the sustainable development capability of the society and improving the ecological civilization construction. In the urbanization process, implementing people-oriented conservation of land and resources and protecting environment should be insisted. These conditions enable to determine the boundaries for urban development reasonably, adjust the structures of construction lands, prevent excessive urban expansion, and increase the comprehensive carrying capacity of cities.

As a key industrial province in China, Shandong Province has a significantly vulnerable ecological environment, although it has achieved breakthroughs in economic aggregates. In Fig.1, urban population density and the production of household have sharply increased as a result of the accelerating urbanization. Moreover, the industrial development in Shandong Province has presented a typical extensive growth of "high consumption, high pollution, and low benefits." In the industrialization process, conflicts, such as between low industrial benefits and sustainable development of resource-based industries, between high-input and high-consumption mode and construction of a resource-conserving society, between high pollutant emission and ecological environmental protection, and between single industrial structure and accelerating industrialization, have occurred. With the continuous urban expansion to suburbs, urban expansion occupies the cultivated lands. The continuous concentration of urban population leads to water resource shortage and production of abundant pollutants in cities, thus deteriorating ecological environment in urban areas continuously. The environmental damage causes a series of environmental pollution problems, such as threats to human health. In particular, environmental pollution and resource consumption are further intensified. The decreasing carrying capacity of resource environment (CCRE) in Shandong Province has become a major restraint of development. Therefore, studying CCRE in Shandong Province facing with low energy utilization and serious environmental pollution is important.

STATE OF THE ART

Research on carrying capacity in foreign developed countries has been reported since the 1920s. Developed countries have discussed the concept of carrying capacity continuously and applied carrying capacity into management practices and environmental planning gradually. Key research attentions have shifted from static analysis to dynamic analysis and from department model to the integrated model under ecological environment-social economy combined system conditions. Relevant studies have interpreted diversity, dynamics, nonlinearity, and multiple feedbacks of carrying capacity problems. Arrow et al. (1996) discussed the relationship between economic growth and environmental quality, as well as the relations of economic activities with carrying capacity and restoration capacity of environment. Thapa et al. (2000) believed that under the underdeveloped economy in Nepal, land deterioration caused by traditional agriculture is a serious problem. The research results demonstrated that vulnerability of land resources would influence the sustainability and productivity of these resources. Chen (2006) developed a framework to test the dynamic response of a society-economic system to continuous exhaustion of natural resources provided by the environmental system. This framework could be used as a guideline in constructing indexes for measuring environmental system and social economic system to support makers of appropriate environmental policies. Slesser (2007) proposed to construct the ECCO system dynamic model by using energy as the transformation standard and analyzed the elastic relation between population and CCRE under different development strategies. On this basis, standards for selecting the optimal region for long-term development could be formulated. Fang et al. (2010) constructed a System Dynamics Model of CCRE in an urban agglomeration

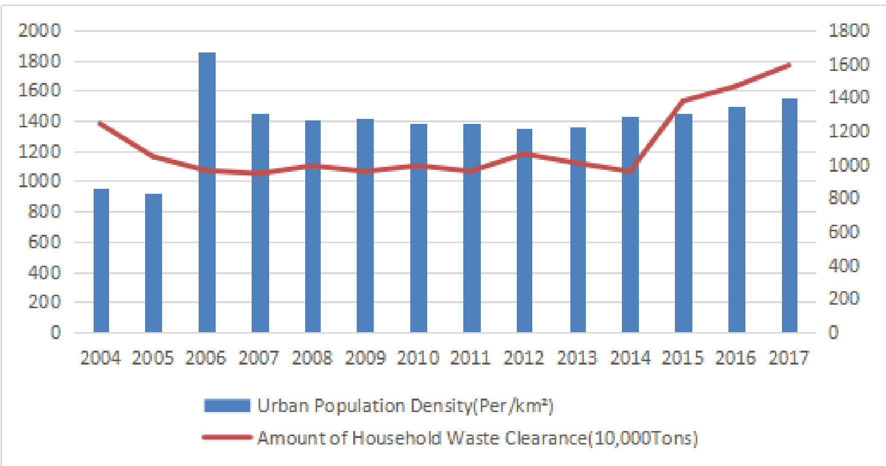

Fig.1: Population density and amount of household waste clearance in cities in Shandong Province from 2006 to 2017. (Data source: China National Statistical Database: http://data.stats.gov.cn/).

in Central China by using the system dynamic method. He found that facilitating the social and economic development under resource environmental protection is the best mode to promote harmonious development of resources, environment, society, and economy in urban agglomeration. Zhu et al. (2010) believed that evaluating the carrying capacity of ecological environment related to water is the key to control the excessive use of water resources and solve ecological problems. He determined the ecological economic aggregates in different ecological environmental regions in the Haihe Basin by using time series and multiobjective optimization method. Byron et al. (2011) analyzed aquaculture in Narragansett Bay of Rhode Island, USA by using the environmental carrying capacity model and found that this ecosystem had high primary productivity and abundant energy consumption. Liu et al. (2011) proposed a comprehensive evaluation system based on natural resource capacity, environmental assimilation capacity, and service capacity and social support capability of ecosystem. The corresponding measurable indexes were designed by using the residual ratio model and residual ratio vector of carrying capacity to assess the carrying capacity of environment (CCE). Dang et al. (2012) tested the environmental resource base in the Yanggou Basin in Loess hilly region in China through energy synthesis method. Evaluation results implied that the environmental condition in the Yanggou Basin was improved during the study period after the implementation of ecological restoration program, which indicated that the ecological restoration program relieved ecological deterioration. Berck et al. (2012) deemed that changes in environmental quality influence the carrying capacity of the Earth and that nonoptimal changed environmental problems interact with carrying capacity, thereby leading to a unique internal stable state of the world environment and human population along the oscillation process. Wen et al. (2016) proposed a new index system that performs a comprehensive evaluation by using ecotope stress index model and state space method. On the basis of this index system, they conducted a comprehensive evaluation on current ecological carrying capacity, resource utilization, and pollution emission in the temperate continental climate zone in northwest China. Li et al. (2016) analyzed industrial structural optimization based on the carrying capacity of water environment in the Huaihe Basin in Shandong Province by using the inaccurate random multiobjective planning method that combined random planning, interval linear planning, and multiobjective planning. Results demonstrated that coal, paper-making, and food-processing industries had high risks of water pollution, although they were traditional pillar industries. Yang et al. (2016) evaluated affordable population, agricultural, and economic scales of water resources in karst region in Guizhou Province, China. Results showed that the actual population and cultivated land area in China from 1999 to 2012 were significantly higher than the agricultural comprehensive index in China, which reflected the overload of population and agriculture in China. Fan et al. (2017) proposed a theoretical model to predict risks of regional sustainable development in China and performed the first empirical evaluation. Research results presented that extensive industrialization caused environmental pollution and made the largest contributions to alarming state, followed by special coupling of scarcity and low utilization of natural water resources. Qian et al. (2018) established an evaluation system involving 20 indexes based on the driving-pressure-state-impact-response-management (DPSIRM) framework and constructed a coupling simulation anneal projection pursuit model to evaluate the carrying capacity of atmosphere environment in the region. Results reflected that driving force and pressure subsystems play a dominant role in the entire system, and attention should be paid to economic development, urbanization, population growth, and pollutant emission. Yuan et al. (2018) assessed the relationship between comprehensive carrying capacity (UCC) and economic growth in the Yangtze River Economic Belt (YREB) by using a spatial econometric model based on data of 84 cities in the study area from 2006 to 2014. He found that the influences of UCC on economic growth presented a "U-shaped" variation trend. UCC development was a crucial support to the economic growth of YREB. Existing literature has shown that the concept of carrying capacity is endowed with different meanings in different development stages, which is related to resource shortage, environmental deterioration, and sharp population increase. The concept of carrying capacity has been extended from the initial physics into demographics, ecology, and economics. Many studies have been conducted on carrying capacity in the world, through which abundant research achievements were gained. All of these research achievements have certain references to this study. Nevertheless, existing studies on carrying capacity are relatively single and mainly focus on land, water, traffic, urbanization scale, and ecosystem. With the economic growth and occurrence of resource and environmental problems, people have begun to realize that economic development should not be achieved at the cost of resources and environment. Economic growth must be coordinated with CCRE. In the present study, key attentions were paid to the construction of the index system and the evaluation method of CCRE in Shandong Province based on previous studies. This study is conducive to realizing a scientific and objective assessment of CCRE. Reasonable suggestions for the development and construction of Shandong Province are provided.

BRIEF INTRODUCTION TO THE MODEL AND DATA SPECIFICATION

Brief introduction to the model: The concept of entropy indicates that decision accuracy can be increased by depending on the decision-making information content. Entropy is an ideal scale in multiobjective decision and evaluation. After original data of index evaluation are collected and mastered, the weight of these original data is determined, which can reflect implicit information in index data objectively and truly. As a result, the resolution of indexes can be increased, and selection bias caused by too small index difference could be avoided, thus enabling to reflect index information comprehensively. Entropy weight represents the relative intensity of index competition. Entropy weight is generally low when the entropy of index is large, which indicates the minimal importance of the index. The technique for order of preference by similarity to ideal solution (TOPSIS) model is the decision-making technique commonly used in system engineering, and it is mainly used to solve the multiobjective decision problem of limited programs. TOPSIS is a comprehensive evaluation method that uses distance as the evaluation standard. The degree of the target close to or deviated from positive and negative ideal solutions can be calculated by defining a certain measurement in the objective space. The TOPSIS model can evaluate regional CCRE and reflect the dynamic and variation trends of regional CCRE comprehensively and objectively. In this study, the TOPSIS model based on entropy weight was applied to evaluate and analyze CCRE in Shandong Province.

***Construction of standardized evaluation matrix*:** The original evaluation index matrix of regional CCRE in Shandong Province is expressed as

$$V=\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}. \quad ...(1)$$

The original data are normalized to acquire the standardized evaluation matrix. v_{mn} is the original data of the index m in year n. Processing of benefit (the higher the better) indexes is shown in Eq. (2), and processing of cost (the lower the better) indexes is shown in Eq. (3). v_{ij} is the index $i(i=1,2,3,\ldots,m)$ among the evaluation data in year $j(j=1,2,3,\ldots,n)$. The standardized evaluation matrix according to calculation is expressed in Eq. (4).

$$r_{ij}=\frac{v_{ij}-\min(v_{ij})}{\max(v_{ij})-\min(v_{ij})} \quad ...(2)$$

$$r_{ij}=\frac{\max(v_{ij})-v_{ij}}{\max(v_{ij})-\min(v_{ij})} \quad ...(3)$$

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad ...(4)$$

***Determination of index weights*:** The entropy weight can be calculated as

$$w_i=\frac{1-H_i}{m-\sum_{i=1}^{m}H_i}, \quad ...(5)$$

Where, $H_i=-\frac{1}{\ln n}\sum_{j=1}^{n} f_{ij}\ln f_{ij}$, which is called the information entropy. $f_{ij}=\frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}$, which is called the characteristic proportion of the index.

***Construction of the evaluation matrix based on entropy weight*:** A weighted standardized evaluation matrix (Y) was constructed by the weighting idea and entropy weight (w_i) to increase the objectivity of the regional CCRE evaluation matrix in Shandong Province. This matrix is expressed as

$$Y=\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix}=\begin{bmatrix} r_{11}\times w_1 & r_{12}\times w_1 & \cdots & r_{1n}\times w_1 \\ r_{21}\times w_2 & r_{22}\times w_2 & \cdots & r_{2n}\times w_2 \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1}\times w_m & r_{m2}\times w_m & \cdots & r_{mn}\times w_m \end{bmatrix}. \quad ...(6)$$

***Determination of positive and negative ideal solutions*:** Y^+ is the maximum of index *i* among the evaluation data in year *j*; it is the most preferred scheme or known as the positive ideal solution. Y^- is the minimum of index *i* among the evaluation data in year *j*; it is the most unfavorable scheme or known as the negative ideal solution. Calculation methods of Y^+ and Y^- are shown in Eqs. (7) and (8).

$$Y^+=\left\{\max_{1\le i\le m} y_{ij}\mid i=1,2,\cdots,m\right\}=\left\{y_1^+,y_2^+,\cdots,y_m^+\right\} \quad ...(7)$$

$$Y^-=\left\{\min_{1\le i\le m} y_{ij}\mid i=1,2,\cdots,m\right\}=\left\{y_1^-,y_2^-,\cdots,y_m^-\right\} \quad ...(8)$$

***Distance calculation*:** The calculation formula of euclidean distance was employed in the present study. D_j^+ be the distance between index i and y_i^+ and D_j^- be the distance between index *i* and y_i^-. D_j^+ and D_j^- can be calculated by

$$D_j^+=\sqrt{\sum_{i=1}^{m}(y_i^+-y_{ij})^2}, \quad ...(9)$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} (y_i^- - y_{ij})^2} . \quad ...(10)$$

***Calculation proximity between evaluation object and ideal solutions*:** T_j is the proximity between CCRE in year *j* and the optimal level, ranging between [0,1]. High T_j reflects that the annual CCRE is significantly close to the optimal level. The CCRE reaches the highest when $T_j = 1$, whereas the CCRE is the lowest when $T_j = 0$. In this study, proximity refers to the level of CCRE. CCRE can be judged according to the annual value of T_j, thus enabling to determine the quality order of resource environment. The calculation formula of T_j is

$$T_j = \frac{D_j^-}{D_j^+ + D_j^-} . \quad ...(11)$$

Data specification: Many factors influence regional CCRE. Scholars have constructed evaluation index systems of regional CCRE and have gained certain research achievements. Chinese scholars paid a considerable attention to the perfection of the evaluation index systems of regional CCRE. "Regional CCRE" is a complicated concept that requires comprehensive consideration of carriers and carrying materials. In this study, an index system was constructed from economic development, resource, and environment subsystems. These subsystems were independent and correlated mutually, and they reflected the regional CCRE together. Regional economic strength, industrial structure, and people's living standard were investigated by the economic development subsystem, which constituted the economic resource basis of regional CCRE. Resource support to regional economic and social development and resource utilization and consumption by economic and social development were analyzed in the resource subsystem. Environmental pollution and management in the regional economic and social development were discussed in the environment subsystem. The specific index system is shown in Table 1. All data in this study came from the Statistical Yearbook of Shandong Province from 2005 to 2016 in consideration of the accessibility and scientificity of data.

RESULT ANALYSIS

An empirical study of the TOPSIS model based on entropy weight was conducted, which could explain the application values of the model and provide theoretical references and practice guidance to evaluate and increase CCRE in other provinces. The CCRE in Shandong Province from 2005 to 2016 was calculated from Eqs.(1) to (10). For deep analysis and description of the variation trend and causes of CCRE in Shandong Province, the CCRE of four subsystems was further calculated. On this basis, the characteristics and dynamic evolution trend of CCRE in Shandong Province and different subsystems were analyzed. The results are shown in Fig.2.

Fig. 2 depicts that from 2005 to 2016, CCRE in Shandong Province was generally increasing yearly. Specifically, CCRE in Shandong Province was stable but declined slightly from 2005 to 2012. The per capita hold of resource declined to some extent due to the increasingly prominent supply-demand conflict of resources in Shandong Province. For example, per capita cultivated area decreased yearly, and the per capita water resource decreased continuously, which caused significant negative impacts on CCRE. As a result, CCRE in Shandong Province decreased continuously but increased gradually after 2012 and reached a relatively high level. Technological progress in energy saving and emission reduction, pollution regulation, and waste utilization increased the comprehensive utilization of resources and relieved environmental pressure. Shandong Province released a series of energy-saving and emission reduction policies, which decreased the GDP per unit region in the province to different extents and achieved great breakthroughs and progresses in resource, environment, and economic social development. The economic development capacity was increased yearly. On the one hand, the economic development consumed considerable resources to cope with the accelerating economic and social development, which caused certain environmental pollution. While on the other hand, the economic development offered abundant economic resources for environmental improvement, pollution control, energy-saving, and emission reduction. The regional CCRE in Shandong Province was finally increased. Recently, the economic strength of Shandong Province was enhanced significantly, which provided rich economic resources for CCRE. Shandong Province was undertaking industrial transfer and eastward development. Industrial structure was optimized gradually, while industrialization and urbanization were promoted. Scientific technology was developing rapidly, thus shifting attention from pursuit of economic development scale to pursuit of economic development quality. Moreover, the urbanization level was improved yearly, accompanied with stable improvement of economic development capacity. The improving economic development in both quality and efficiency decreased resource waste, increased resource utilization, and relieved pressures over environment caused by economic activities to some extent.

Resource-carrying capacity was basically stable in the study period but presented a fast growth trend. The carrying capacity of the resource subsystem fluctuated due to the collaborative effect of three indexes, which also proved cer-

Table 1: Evaluation index system for regional CCRE.

Systems	Indexes	Unit
Economic development subsystem	GDP per capita	10,000 (RMB)
	Urban per capita disposable income	10,000 (RMB)
	Urbanization rate	%
Resource subsystem	Per capita cultivated area	hm^2/per
	Per capita water resource amount	m^3/per
	GDP of a unit region	Tons of standard coal/ 10,000 persons
Environment subsystem	Water consumption for 10,000 RMB industrial added value	m^3/10,000 (RMB)
	Waste gas emission for unit industrial added value	m^3/10,000 (RMB)
	Comprehensive utilization of industrial solid wastes	%
	Investment amount for industrial pollution control	100 million (RMB)
	Forest coverage	%

tain effects of the energy-saving and emission reduction policies in Shandong Province. In the environment subsystem, the CCE was increasing yearly. Shandong Province not only paid considerable attention to ecological construction and environmental protection and implemented energy-saving projects successfully during the "11th Five-Year Plan" but also formulated and issued the energy-saving and emission reduction policies, which increased the CCE gradually.

SUGGESTIONS

Development and usage of natural resources reasonably and increasing resource utilization: In promoting urban construction in Shandong Province, regional environment is influenced significantly by the abundance of water resources. Attention should be given to strengthen education of water saving and public consciousness of environmental protection, introduce advanced environmental protection and water-saving technology into production and living, and advocate scientific, reasonable, economic, and sustainable water consumption mode to reduce environmental pressure caused by excessive consumption of water resources. In particular, Shandong Province is a traditional agricultural province and should perfect the irrigation system in agricultural regions to save irrigation water consumption. Moreover, water pollution control should be strengthened in rural regions of Shandong Province. In industrial regions, the development of water-saving industries and increase of water resource utilization should be encouraged. Key attention should be paid to strengthen wastewater emission control of industrial enterprises to increase the water environmental quality and protect water quality in the region. The government must develop its own functions to restrict occupation of cultivated lands by nonagricultural construction purposes strictly while protecting economic and agricultural development; formulate and adjust compensation and resettlement mechanism for land expropriation; and increase land utilization while protecting the quality of cultivated lands and basic farmland. Other suggestions are to regulate land use strictly and avoid wastes and pollution of land resources.

Improvement of regional ecological environment through scientific technologies: Shandong Province, which is undertaking accelerating industrialization and urbanization, proposes increasing demands for natural resources and development intensity. The local environment is going to bear strong pressure, and regional environmental problems will be developed gradually. Shandong Province must have a good ecological environment to realize a coordinated, sound, and sustainable social economic development. The province should adjust and optimize the industrial structure by centering at the ecological industrial transformation, change the high-input, high-consumption, and high-pollution economic growth mode, and strengthen the construction of ecological environment. On the basis of objective evaluation and scientific recognition of major ecological environmental problems in the region, Shandong Province should use resources reasonably by perfecting legal system, increase scientific input, and strengthen ecological construction, aiming to improve the ecological environment and promote sustainable economic social development. Additional suggestions are to implement comprehensive control, construction, and management throughout the province, optimize energy structures, and solve urban atmospheric pollution. The mutual compensation mechanism of urbanization region and water ecological zone, especially the long-term stable ecological compensation mechanism, should be established. According to the philosophy of circular economics and the goal of constructing a resource-saving and environment-friendly society, the source control of industrial pollution should be combined with terminal administration. High-pollution enterprises should be shut down or trans-

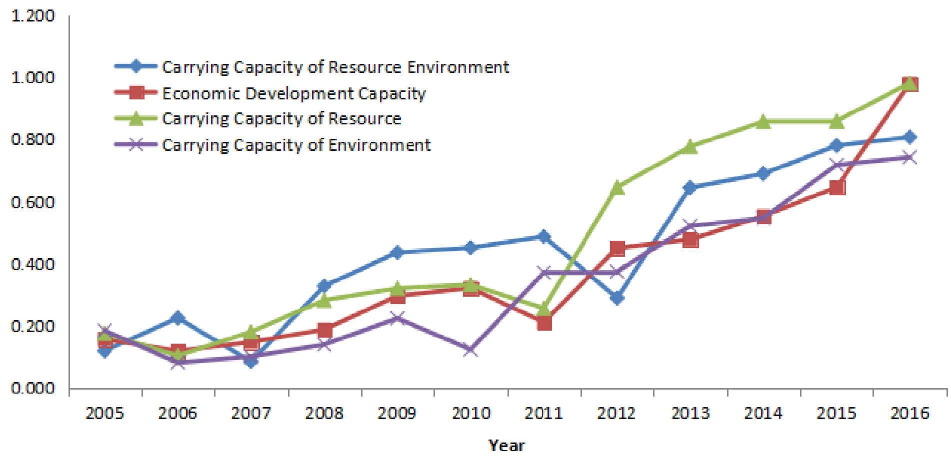

Fig. 2: Changes in CCRE in Shandong Province (2005-2016).

formed. A batch of facilities for concentrated processing and comprehensive utilization of three industrial wastes should be constructed. Enterprises are encouraged to apply clean technologies and produce green products for realizing the goal of energy-saving and emission reduction.

Accelerating progresses in technological level and industrial updating: The continuous technological progress provides an important impetus for economic growth and development and becomes a major way to facilitate industrial updating and development toward high end of the value chain. Shandong Province has to optimize local talent structures continuously and promote the industry-university-research cooperation. With respect to talent training, suggestions are to further train different types of talents, expand channel for talent introduction, and increase the quantity and quality of talents through internal and external resources. Meanwhile, the province should increase technological inputs continuously, promote industrial updating through technological innovation, and create innovation industrial clusters and chains. With the continuous technological inputs, scientific technological progresses are achieved rapidly. Shandong Province should establish a source-monitoring and forecasting system to improve environmental management and monitoring ability continuously. The promotion of circulation, recycle, and comprehensive utilization technologies, cleaning production and comprehensive saving strategy, recycling, production and commercialization technologies of "three wastes" will promote and accelerate the transformation of environmental scientific research achievements into productivity, realize transformation of economic growth mode, and strengthen the sustainable competitiveness of the region.

Reasonable use resources and construction of a conservation-minded society: With the continuous progress of urbanization in Shandong Province, land shortage is intensified. Under this circumstance, considerable resources are wasted, and the land planning is unreasonable, thus resulting in serious land wastes. The land resource configuration must be optimized. On the one hand, great efforts should be made to protect existing agricultural lands, strengthen the monitoring and protection of farmland, and protect the total farmland area. On the basis of ecological safety, the urban land organization and planning must be perfected, and the overall urban development must be promoted to realize reasonable use of lands in Shandong Province. On the other hand, some land resources should be developed scientifically and effectively. As a result, some lands that are not used reasonably or idle land resources can be reused again, while wastelands and sloping lands could be developed. Moreover, the province should develop circular economics and insist in the sustainable development. The conflicts between population and various resources are intensifying gradually due to the large population in Shandong Province. Hence, sustainable development is the only way to solve conflicts. Increasing utilization of natural resources and advocating enterprises to make reforms of sustainable development are encouraged. Establishing and perfecting the scientific circulation economic system, increasing input to the tertiary industry, reducing pollutant emission to the maximum extent, and improving the living quality of life are suggested.

CONCLUSIONS

Sharp increasing of population, excessive consumption of resources, environmental pollution, and ecological damages are becoming prominent, which restrict the economic development and improvement of people's living quality. The resource shortage and vulnerable environment are facing with heavier pressure due to the large population bases and backward economy and technology. Major problems in regional development can be disclosed by scientific estimation of CCRE in regions. Feasible regulation policies to implement sustainable development of regional resource environment are provided. In this study, the evaluation index of regional CCRE was constructed first based on Shandong Province, China. CCRE in Shandong Province from 2005 to 2016 was then evaluated and estimated comprehensively by the TOPSIS model based on entropy weight. The research results demonstrated that the CCRE in Shandong Province was increasing gradually from 2005 to 2016, showing an average growth rate of 5.23%. The development level of economic subsystem was increasing gradually, which was basically consistent with the variation trend of CCRE and laid a solid economic basis for improving CCRE in Shandong Province. The annual average growth rates of resource and environment subsystems were 4.15% and 2.15%, respectively. Deep studies on enriching the evaluation system of CCRE, visual display of big data of current CCRE situations, combined evaluation based on multiple methods, and effects of technological progress on regional CCRE are still needed.

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