Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 16, No. 1, 2024

Characteristics of the Evolution of Resource and Environmental Carrying Capacity in Shaanxi Province

Penghui Dai

College of Xi'an International Studies University, Xi'an, China

Abstract: This paper constructs a resource and environmental carrying capacity index system based on the DPSIR model, and adopts the entropy weight TOPSIS method to analyze the resource and environmental carrying capacity of Shaanxi Province in terms of time series and spatial distribution. The results show that from 2010 to 2020, the resource environmental carrying capacity of Shaanxi Province in general shows a fluctuating upward trend, and on the whole there is a small decrease in 2017 compared with 2016 and 2020 compared with 2019, and an increase in 2019 compared with 2018; in terms of the characterization value of the resource environmental carrying capacity of each city, Yan'an City is in the first place for a long period of time, and it is stable in the top three with Yulin and Xi'an; each The resource environmental carrying capacity of each city shows a gradual convergence state, indicating that the difference between their carrying capacity gradually decreases. Finally, this paper makes corresponding suggestions for the improvement of the resource and environmental carrying capacity of Shaanxi Province from five aspects: economic development, low-carbon development, resource and environmental load reduction, population growth, and environmental infrastructure construction.

Keywords: Resource and environmental carrying capacity, DPSIR model, Entropy weight TOPSIS, Shaanxi Province.

1. Introduction

Evaluation of resource and environmental carrying capacity can comprehensively reflect regional resource and environmental endowment and support capacity, and is also one of the core contents of territorial spatial planning [1]. With the acceleration of China's industrialization and urbanization, the contradictions between economy and society, resources and environment have gradually come to the fore, such as insufficient space for land resources, scarcity of water resources, and degradation of ecological service functions [2-3]. How to deal with the contradiction between resource and environmental support and economic and social development, and strengthen the healthy, coordinated and sustainable development of land space has gradually become a hotspot of concern for all walks of life [4-6]. In 2016, 13 ministries and commissions, including the National Development and Reform Commission (NDRC) and the State Oceanic Administration (SOA), jointly issued the “Technical Method for Monitoring and Early Warning on Resource and Environmental Carrying Capacity (for Trial Implementation)”, and in 2019, the Ministry of Natural Resources (MNR) issued the “Circular on Comprehensively Carrying Out Territorial Notice on Comprehensively Carrying Out the Work of Spatial Planning [7], which fully illustrates the important theoretical significance and the necessity of practical exploration of scientific research on the evaluation of regional resource and environmental carrying capacity [8].

Current research on the evaluation of regional resource and environmental carrying capacity mainly focuses on the evaluation index system and the selection of research methods. Due to the different resource endowment and location conditions of different regions, there are differences in the definition of the connotation of resource and environmental carrying capacity, and there are also differences in the construction of the evaluation index system. In 1985, the United Nations defined the concept of resource and environmental carrying capacity, put forward a series of quantitative methods, and was gradually popularized [9-10]. The research of foreign scholars on resource and environmental carrying capacity is mainly based on the theory of sustainable development, such as: Graymore et al [11] based on the system theory model to empirically analyze the resource and environmental carrying capacity of Southeast Queensland, Australia; Brasher et al [12] used multi-stage sampling to estimate the energy carrying capacity of active and passive management of wetlands in the U.S. state of Ohio; Hansen et al [13] used biophysical predictor variables to infer species richness (SK) across North America, and concluded that species richness carrying capacity is highly correlated with biodiversity conservation; Brown et al [14] assessed the carrying capacity of tourism and local economic, social, ecological, and other resources and environments in Mexico and Papua New Guinea based on the regional environmental resource energy value method; Lorenz et al [15] calculated the carrying capacity of a sustainable boating tourism river section based on water quality protection and proposed management measures to integrate social, tourism and ecological aspects. Domestic research on the carrying capacity of resources and environment is relatively late, such as: Cheng Yuguang [16] used the state-space method to study the carrying capacity of resources and environment in Jiangxi Province; Miao Junxia et al. [3] constructed an evaluation index system of the carrying capacity of resources and environment of counties in the Loess Plateau at the levels of natural resources, ecological environment, and geologic environment; Song Chulin et al. Response” model to construct a resource and environmental carrying capacity evaluation index system for restricted development areas in Jilin Province; Yang Lina et al [5] constructed a resource and environmental carrying capacity evaluation index system for Chongqing Municipality from six aspects: economy, society, nature, water resources, land resources, and ecology; Zhao Dongsheng et al [17] constructed a resource and environmental carrying capacity evaluation index system for

Chongqing Municipality from the aspects of biological population, ecosystem environmental stress, natural resource supply, natural environment, socio-economic development, and social and economic development; Li Hongmei et al [18] constructed a resource and environmental carrying capacity evaluation index system along the Yangtze River (Yichang-Jingzhou section) based on economy and society, resources, and the environment; Song Chulin et al [4] utilized a BP network model to study the spatial and temporal characteristics of the ecological carrying capacity of the urban agglomeration of the Rim of Chang-Zhu-Tan City; Song Zeming et al [19] used the DPSIR- TOPSIS model to study the carrying capacity of marine resources and environment and obstacle factors in 11 coastal provinces in China; Li Long et al [20] constructed an index system from three aspects of ecology, agriculture and construction to evaluate the spatio-temporal characteristics of resource and environmental carrying capacity of Ningyuan County, Hunan Province; Liu Jinhua et al [21] constructed an evaluation of the resource and environmental carrying capacity of Jinan City from four aspects of resources, ecology and environment, and economic and social index system, and analyzed the agglomeration effect based on the village and town scale. In summary, the resource environment system is a composite system covering resources, environment, economic and social, scholars around the resources, environment, economic and social aspects of these three aspects of the selection of evaluation indicators to carry out more research [22-23]. Common evaluation methods used by scholars at home and abroad include energy value method [14, 24], TOPSIS [19], principal component analysis method [25], ecological footprint method [26], entropy weight method [27], fuzzy comprehensive evaluation [28], system dynamics [29], and damping coefficient method [30]. From the viewpoint of the study area, there are fewer studies on the evaluation of resource and environmental carrying capacity of ecologically fragile regions.

Shaanxi Province is located in the arid and semi-arid region in the west of China, and is an important economic development zone and ecologically fragile area in the west of China, as well as an important ecological barrier construction in China and the core area for the implementation of the national "One Belt, One Road" initiative. In recent years, with the economic and social development, the problem of ecological and environmental damage and the contradiction of coordinated development of human-land relations have become prominent. In order to completely reverse the situation of resource and environmental constraints on the development of Shaanxi Province, and to promote the high-quality development of the region, the study of the level of resource and environmental carrying capacity and its spatial and temporal evolution in Shaanxi Province is of strategic significance for realizing the coordinated development of the region in Shaanxi Province. Based on this, this paper constructs the index system of resource and environmental carrying capacity of Shaanxi Province based on the DPSIR model, and screens a targeted and relatively unified evaluation index system based on the panel data from 2010 to 2020. The entropy weight method TOPSIS method is used for comprehensive evaluation, in order to reflect more objectively the level of resource and environmental carrying capacity of Shaanxi Province and its temporal and spatial evolution, with a view to providing theoretical references for improving the level of spatial planning and policy making in Shaanxi Province.

2. General Situation and Data Source of The Research Area

2.1. Overview of the Research Area

Shaanxi Province is located in the northwest of China, in the middle reaches of the Yellow River, neighboring Shanxi and Henan in the east, Ningxia and Gansu in the west, Sichuan, Chongqing and Hubei in the south, and Inner Mongolia in the north, between the longitude of 105°29'-111°15' east and the latitude of 31°42'-39°35' north, and the landforms of the province are from south to north, including the Qinba Mountain Range, the Guanzhong Plain and the northern Shaanxi plateau. As an important hub connecting east and central China, northwest and southwest China, Shaanxi Province is of great significance to the economic development of the western region of China. However, the region is a typical ecologically fragile and complex area because of its high and low elevation fluctuations, diverse ecological types, fragile ecological environment, and other conditions [31].

2.2. Data Sources

The data for this study come from the 2011-2021 edition of the China Urban Statistical Yearbook, the Shaanxi Provincial Statistical Yearbook, and the Shaanxi Provincial Water Resources Bulletin 2010-2020, as well as data from the National Economic and Social Development Statistical Bulletin of the corresponding cities for the corresponding years.

3. Indicator System and Evaluation Model

3.1. Shaanxi Province Resource and Environmental Carrying Capacity Indicator System

In order to make Shaanxi Province's resource and environmental carrying capacity evaluation index system more targeted, scientific and rigorous, reference to the index system of the General Office of the Ministry of Natural Resources on the issuance of the "Guidelines for Evaluation of Resource and Environmental Carrying Capacity and Suitability of Territorial Spatial Development (for Trial Implementation)", the "Guidelines for Action on Development of Ecological Civilization Construction Standard System", the "Outline of Eco-county and Eco-municipality Construction Plan Preparation (for Trial Implementation)" and other official documents, prevailed, and based on the DPSIR conceptual model, a total of 18 indicators were selected from 5 levels of driving force, pressure, state, impact and response (Table 1). The attributes of the indicators are categorized into positive and negative: the larger the value of the positive indicators, the better the evaluation results, and the smaller the value of the negative indicators, the better the evaluation results.

Table 1. Shaanxi Province Resource and Environmental Carrying Capacity Indicator System

Level 1 Indicators	Level 2 Indicators	Level 3 Indicators	Nature of Indicator	Units
Environmental carrying capacity of resources	Driving	GDP per capita	+	yuan
		Natural population growth rate	+	‰
		Urbanization level	+	%
	Pressure	Municipal sewage discharges	-	10000 cubic meters
		population density	-	Persons/km^2
		Sulfur dioxide emissions	-	Dons
		Industrial fume (dust) emissions	-	Dons
	State	Building land area per capita	-	People/m^2
		Greening coverage in built-up areas	+	%
		Urban green space per capita	+	m^2
		Urban road space per capita	-	m^2
	Impact	Ambient air quality excellence rate	+	%
		Share of tertiary sector	+	%
		Hospital beds per 10,000 population	+	Sheets/10,000 persons
	Response	Centralized treatment rate of urban sewage treatment plants	+	%
		Non-hazardous treatment rate of domestic waste	+	%
		Comprehensive utilization rate of industrial solid waste	+	%
		Afforestation area per capita	+	m^2

3.2. DPSIR Model

The DPSIR model is evolved from the PSR model and is based on the evaluation of ecological, economic, social and other elements [32]. The concept of DPSIR was first proposed by the European Environment Agency (EEA) in 1998 to indicate the threat to the natural environment caused by human activities, and at the same time to reflect more accurately and comprehensively the relationship between human beings and the ecological environment that affects and interacts with each other [33]. In the DPSIR model, the Driving (D) is the support of economic activities in the regional society to the development of other regions; the Pressure (P) mainly refers to the consumption of regional production activities on the regional resources and ecological environment; the State (S) refers to the state of the resource and environmental carrying capacity presented under the dual role of the above driving force and pressure; the Impact (I) refers to the system state of the economic and social environment, the ecological brought about by the changes; the Response (R) refers to the positive and effective measures and countermeasures taken for the sustainable development of the region.

3.3. TOPSIS model of Entropy Weight

In this paper, the method of Chen Yu et al [31] for assessing the carrying capacity of resources and environment, this paper adopts the entropy weight TOPSIS method to evaluate the level of carrying capacity of resources and environment in Shaanxi Province. Different from the traditional TOPSIS evaluation method, the entropy weight TOPSIS method has the advantages of intuitive geometric significance, less information loss and flexible operation. The specific steps are as follows:

(1) Entropy weight method to determine the weights of standardized indicators, the formula is:

$$e_j = -k\sum_{i=1}^{m}\left[\left(\frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}\right)\bullet \ln\left(\frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}\right)\right],\ k = 1/\ln m \quad (1)$$

$$w_j = (1-e_j)/\sum_{j=1}^{n}(1-e_j) \quad (2)$$

Where: w_j is the weight of the jth indicator; e_j represents the information entropy of the jth indicator; m is the number of evaluation years; k is Boltzmann's constant.

(2) Determine the positive and negative ideal solutions and compute the Euclidean distance:

$$\text{Positive ideal solution } S_i^+ = \sqrt{\sum_{j=1}^{m}(f_{ij}-f_j^+)^2}\begin{pmatrix} i=1,2,\cdots,n \\ j=1,2,\cdots,m \end{pmatrix} \quad (3)$$

$$\text{Negative ideal solution } S_i^- = \sqrt{\sum_{j=1}^{m}(f_{ij}-f_j^-)^2}\begin{pmatrix} i=1,2,\cdots,n \\ j=1,2,\cdots,m \end{pmatrix} \quad (4)$$

(3) Calculate the C value of the closeness of each indicator to the ideal solution, Eq:

$$C_j = \frac{S_i^-}{S_i^- + S_i^+}\begin{pmatrix} i = 1,2,\cdots,n \\ j = 1,2,\cdots,m \end{pmatrix} \quad (5)$$

Where: C_j takes the value range of [0, 1], the larger its value, the higher the value of urban ecological resilience of the research unit, and vice versa, the lower.

4. Results & Analysis

4.1. Calculation Result

After assigning weights to the indicators through the entropy weight method, the TOPSIS model was applied to measure the carrying capacity of Shaanxi Province's resources and environment from 2010 to 2020 (Table 2).

Table 2. Shaanxi Province Resource Environmental Carrying Capacity Score Results (2010-2020)

Cities	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean value
Xi'an	0.463	0.466	0.469	0.452	0.462	0.467	0.465	0.477	0.463	0.480	0.460	0.466
Tongchuan	0.420	0.389	0.399	0.408	0.379	0.393	0.426	0.397	0.409	0.453	0.435	0.410
Baoji	0.329	0.346	0.349	0.349	0.341	0.344	0.375	0.360	0.372	0.389	0.379	0.358
Xianyang	0.330	0.333	0.349	0.353	0.345	0.366	0.387	0.366	0.366	0.419	0.392	0.364
Weinan	0.343	0.323	0.313	0.335	0.319	0.337	0.362	0.361	0.348	0.406	0.403	0.350
Yan'an	0.597	0.620	0.610	0.681	0.684	0.669	0.653	0.622	0.643	0.637	0.549	0.633
Hanzhong	0.369	0.370	0.372	0.376	0.373	0.371	0.390	0.342	0.367	0.401	0.370	0.373
Yulin	0.588	0.601	0.623	0.623	0.617	0.552	0.536	0.536	0.550	0.550	0.552	0.575
Ankang	0.396	0.389	0.414	0.424	0.430	0.424	0.461	0.476	0.464	0.461	0.439	0.434
Shangluo	0.348	0.337	0.332	0.347	0.351	0.348	0.404	0.387	0.388	0.454	0.438	0.376

4.2. Analysis of the Evolution of Resource and Environmental Carrying Capacity of Shaanxi Province

From 2010 to 2020, the carrying capacity of Shaanxi Province's resources and environment generally shows a fluctuating upward trend, and overall, there is a small decrease in 2017 compared to 2016 and in 2020 compared to 2019 (Fig. 1), which is mainly due to the decrease in the per capita afforestation area and the increase in the emission of industrial waste gas. The increase in 2019 compared to 2018 is due to the overall stable growth of the economy and the increasing urbanization level is increasing, etc., resulting from this. From the perspective of the characterization value of the resource and environmental carrying capacity of each city, Yan'an City has been in the first place for a long time, and Yulin and Xi'an are steadily in the top three; in the early period, Baoji (2010), Weinan (2011-2016) and the late period, Hanzhong (2017, 2020) have the lowest level of resource and environmental carrying capacity, and Weinan is constantly growing, and has been out of the latter three levels in 2020; the resource and environmental carrying capacity of each city is gradually converging The resource and environmental carrying capacity of each city is gradually converging, indicating that the difference between their carrying capacities is gradually decreasing; from an overall perspective, the resource and environmental carrying capacity of Shaanxi Province is at the intermediate level and above, and shows a trend of decreasing in the areas with low levels of resource and environmental carrying capacity.

The scores of resources environmental carrying capacity of some cities fluctuate greatly. Yan'an City and Yulin City have long been at the high-quality level of resource environmental carrying capacity, but generally show a fluctuating downward trend. Among them, Yan'an City rose significantly in 2013, mainly due to a significant decrease in industrial emissions and a significant increase in per capita afforestation area. Yulin City, on the other hand, experienced a significant decline in 2015, due to an increase in road area per capita and a decrease in afforestation area per capita as a result of urbanization.

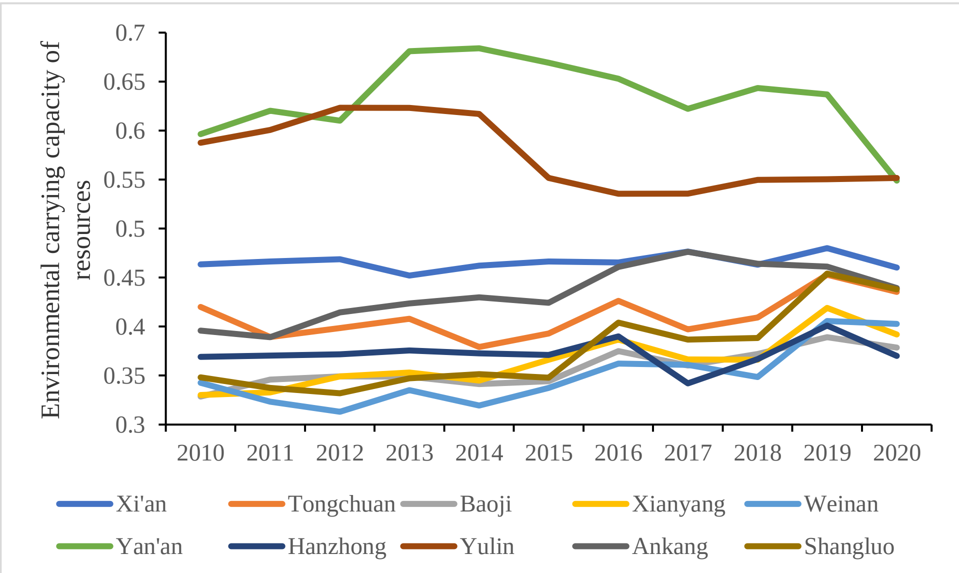

Figure 1. Evolution of Resource and Environmental Carrying Capacity of Cities in Shaanxi Province (2010-2020)

5. Conclusions and Recommendations

5.1. Concludes

This paper takes Shaanxi Province as an example, based on the DPSIR model, adopts the entropy weight method TOPSIS method to measure the level of resource and environmental carrying capacity from 2010 to 2020, and produces a map of the evolution of resource and environmental carrying capacity of each city from 2010 to 2020, and obtains the following conclusions of the study: from 2010 to 2020, the resource and environmental carrying capacity of Shaanxi Province in general shows a fluctuating upward trend, and on the whole There is a small decrease in 2017 compared with 2016 and 2020 compared with 2019, and an increase in 2019 compared with 2018; from the perspective of the characterization value of the resource and environmental carrying capacity of each city, Yan'an City has been in the first place for a long time, and it is steadily ranked in the top three with Yulin and Xi'an; the resource and environmental carrying capacity of each city is in a state of gradual convergence, which indicates that the difference between its carrying capacity is gradually decreasing.

5.2. Suggestion

During the period of 2010-2020, Shaanxi Province's resource and environmental carrying capacity has been improved as a whole, but it still belongs to a lower level, and the growth rate has gradually slowed down, indicating that Shaanxi Province's resource and environmental carrying capacity still has a large space for improvement, and that there is an urgent need to implement relevant measures to promote the steady improvement of the resource and environmental carrying capacity. The main recommendations are as follows:

(1) Economic development is closely related to the enhancement of the carrying capacity of resources and the environment. Economic development drives the improvement of the level of environmental governance, thus achieving the stable and balanced development of the economic-social-ecological complex system.

(2) Promote low-carbon development and balanced development. Strengthen the construction of regional integration in Shaanxi Province, strengthen the horizontal ecological compensation between regions, concentrate funds, technology and manpower to increase the protection of the environment, intensively and efficiently utilize resources, focus on promoting the balanced development of Shaanxi Province's regions, focus on energy conservation and emission reduction, reduce industrial pollution and actively adjust the industrial structure. Focus on industrial transformation and upgrading in each city, and increase the proportion of tertiary industry.

(3) Focus on resource and environmental “load reduction”. Should be from the social, economic industry, the environment, three aspects of the “load reduction”, reduce or limit the pollution of the industry, focus on industrial upgrading and improve industrial wastewater, exhaust emission standards, improve the relevant laws and regulations, strict control of pollution emissions and governance.

(4) Population and resources are long-term and influential factors. The natural population growth rate is the subsequent driving force for development. In the long run, policies should be introduced to stimulate population growth, and emphasis should be placed on the promotion of re-employment of the residents and the rationalization of unemployment relief and re-employment training. Cities should focus on increasing forest coverage, the area of nature reserves, etc., with a view to enhancing the service function of Shaanxi Province's ecosystems; ensuring a steady increase in the carrying capacity of Shaanxi Province's resources and environment.

(5) Increase investment in environmental infrastructure construction. Strengthen ecological and environmental governance, build a multi-level, multi-principal grid-based coordinated governance organizational framework; improve the treatment capacity of manure and industrial and domestic garbage; increase the daily treatment capacity of various harmless treatment plants; and increase investment in environmental protection with a view to forming a synergistic socio-economic-ecosystem development situation.

References

[1] FENG Zhiming, YOU Zhen, YANG Yanzhao, et al. Comprehensive evaluation of resource and environmental carrying capacity of Tibet based on three-dimensional tetrahedral model [J]. Journal of Geography, 2021, 76(3):645-662.

[2] LIU Jiangyi, REN Wenzhen, SUN Yajing. Progress and outlook of research on resource and environmental carrying capacity evaluation in China [J]. Safety and Environmental Engineering, 2021, 28(6):230-236.

[3] MIAO Junxia, ZHENG Xu, SUN Pingping, et al. Evaluation of resource and environmental carrying capacity and coupling coordination in loess plateau counties: an example from Yanchuan County, Shaanxi Province [J]. Journal of Northwest Normal University (Natural Science Edition), 2021, 57(2):94-100.

[4] SONG Chulin, Shuai Hong. Spatial and temporal pattern of ecological carrying capacity and early warning research in the urban agglomeration around ChangZhuTan [J]. Journal of Central South Forestry University of Science and Technology (Social Science Edition), 2020, 14(3):45-55.

[5] YANG Lina, HE Xing, YAO Qiusheng, et al. Construction of resource and environmental carrying capacity evaluation index system and identification of dominant limiting factors in counties and districts [J]. Land Resources Science and Technology Management, 2020, 37(5):1-12.

[6] HONG Yang, YE Wenhu. Measurement of sustainable environmental carrying capacity and its application [J]. China Population-Resources and Environment, 1998, 8(3):54-58.

[7] SUN Lei, WANG Xiaohui, ZHANG Liu, et al. Analysis of ecological environmental protection in Anhui Province in the 14th Five-Year Plan [J]. Environmental Protection, 2022, 50(Z2):60-63.

[8] HUANG Xianjin, ZHOU Yan. An overview of research methods on resource and environmental carrying capacity [J]. China Environmental Management, 2018, 10(6):36-42, 54.

[9] UNESCO, FAO. Carrying capacity assessment with a pilot study of Kenya: a resource accounting methodology for sustainable development [R]. Rome: Food and Agriculture Organization of the United Nations, 1985: 115-121.

[10] HASTOYUANDO E, BRONTOWIYONO W, HASANAH N. Environmental carrying capacity analysis based on water resources (case study of eastsurabaya area) [J]. Civil and Environmental Engineering, 2020, 16(2): 229-237. DOI:10.2478/cee-2020-0022.

[11] GRAYMORE M L M, SIPE N G, RICKSON R E. Sustaining human carrying capacity: a tool for regional sustainability assessment [J]. Ecological Economics, 2010, 69(3): 459-468. DOI:10.1016/j.ecolecon.2009.08.016.

[12] BRASHER M G, STECKEL J D, GATES R J. Energetic carrying capacity of actively and passively managed wetlands for migrating ducks in Ohio [J]. The Journal of Wildlife Management, 2007, 71(8): 2532-2541. DOI:10.2307/4496373.

[13] HANSEN A J, PHILLIPS L B, FLATHER C H, et al. Carrying capacity for species richness as a context for conservation: a case study of North American breeding birds [J]. Global Ecology and Biogeography, 2011, 20(6): 817-831. DOI:10.1111/j.1466-8238.2011.00670.x.

[14] BROWN M T, LGIATI S. Emergy measures of carrying capacity to evaluate economic investments [J]. Population and Environment, 2001, 22(5): 471-501.

[15] LORENZ S, PUSCH M T. Estimating the recreational carrying capacity of a lowland river section [J]. Water Science and

Technology, 2012, 66(9): 2033-2039. DOI:10.2166/wst.2012.418.

[16] Cheng Yuguang. Evaluation of regional resource and environmental carrying capacity of Jiangxi Province and its implications [D]. Nanchang: Nanchang University, 2007.

[17] ZHAO Dongsheng, ZHANG Xuemei, DENG Siqi, et al. Discussion on the evaluation theory and method of regional resources and environment carrying capacity [J]. Journal of Applied Ecology, 2022, 33(3):591-602.

[18] LI Hongmei, LIU Bo, YUAN Qin, et al. Evaluation index system and empirical research on resource and environmental carrying capacity along the Yangtze River (Yichang-Jingzhou section) [J]. Resource Environment and Engineering, 2020, 34(S2):78-82, 117.

[19] SONG Zeming, NING Ling. Evaluation of marine resources and environmental carrying capacity of China's coastal provinces based on DPSIR-TOPSIS model and study of obstacle factors [J]. Ecological Economy, 2020, 36(8):154-160, 212.

[20] LI Long, WU Dafang, LIU Yanyan, et al. Evaluation of resource and environmental carrying capacity of counties under multifunctional perspective:taking Ningyuan County of Hunan Province as an example [J]. Ecological Economy, 2020, 36(8):146-153.

[21] LIU Jinhua, LI Xiang, ZHENG Xinqi. Evaluation of resource and environmental carrying capacity and its spatial characterization under multi-scale perspective: taking Jinan City as an example [J]. Geographic Research and Development, 2019, 38(4):115-121.

[22] WANG Qin, LI Wei. Progress and outlook of research on evaluation of regional resource and environmental carrying capacity [J]. Journal of Ecological Environment, 2020, 29(7):1487-1498.

[23] WANG Ying, YU Yanghua, SUN Bo. Research on resource and environmental carrying capacity of Anshun City, Guizhou Province [J]. Environmental Science and Technology, 2019, 42(S1):253-260.

[24] SHEN Dan, ZHOU Dequan, FU Lian, et al. Research on the evaluation of resource and environmental carrying capacity based on PCA: Taking Zunyi City in Guizhou Province as an example [J]. Value Engineering, 2018, 37(34):191-193.

[25] FANG K, HEIJUNGS R, DE SNOO G R. Theoretical exploration for the combination of the ecological, energy, carbon, and water footprints: Overview of a footprint family [J]. Ecological Indicators, 2014, 36(jan.): 508-518. DOI:10.1016/j.ecolind.2013.08.017.

[26] Zeng Hao, Shen Jun, Jiang Jing. Study on the evaluation of resource and environmental carrying capacity and the evolution of spatial and temporal patterns in the Yangtze River Economic Belt [J]. South-to-North Water Diversion and Water Science and Technology, 2019, 17(3):89-96.

[27] Jiang Renwei. Research on the carrying capacity of mining geological environment in West Panzhi region [D]. Kunming: Yunnan University,2019.

[28] Lv Yizheng, Tian Jinping, Chen Lujun. Reflections on the green development of China's industrial parks based on human-land relationship [J]. China Environmental Management, 2021, 13(2):55-62.

[29] XU Wenhao, LU Tao, LIU Jiang. Evaluation of system dynamics of county resources and environmental carrying capacity [J]. Environmental Science and Technology, 2020, 43(8):192-199.

[30] XIA Haibin, LIU Min. Simulation and prediction of IPCC composite scenarios (SSPs-RCPs) for the Hu Huanyong Line based on an integrated geographic perspective [J]. Geography Research, 2021, 40(10):2838-2855.

[31] CHEN Yu, DING Ning, ZHAO Yunxia. Dynamic evaluation of resource and environmental carrying capacity of Northwest China based on entropy weight TOPSIS model [J]. Land Resources Science and Technology Management, 2022, 39(03):1-13.

[32] WANG Kueifeng, LI Na, YU Xuefeng, et al. Research on the evaluation index system of ecological environment carrying capacity based on P-S-R conceptual model-Taking Shandong Peninsula as an example [J]. Journal of Environmental Science, 2014, 34(8):2133-2139.

[33] TANG Jianxiong, ZENG Fang. Spatial and temporal evolution of the strength of ecological environment response to urbanization in the Yangtze River Economic Zone [J]. Journal of Central South Forestry University of Science and Technology (Social Science Edition) 2021, 15(4):43-52.