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Comprehensive Evaluation of the Eco-Environmental Carrying Capacity of Beijing-Tianjin-Hebei Urban Agglomeration

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Comprehensive Evaluation of the Eco-Environmental Carrying Capacity of Beijing-Tianjin-Hebei Urban Agglomeration

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Abstract. In order to study the eco-environmental carrying capacity of Beijing-Tianjin-Hebei urban agglomeration, this paper constructed the evaluation indexes system of the urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei based on the DPSIR concept model, determined the weights of indexes by entropy method, evaluated the urban eco-environmental carrying capacity combined with TOPSIS method, and analyzed the urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei in 2012-2016 through horizontal comparison and longitudinal analysis. The results show that the spatial differences of Beijing-Tianjin-Hebei city's eco-environmental carrying capacity are obvious, showing the characteristics of "strong in the middle north and weak in the south". Since 2014, the eco-environmental carrying capacity of 13 cities in Beijing-Tianjin-Hebei has been significantly improved, and the effect of eco-environmental governance is remarkable.

1. Introduction

Eco-environmental protection is one of the key areas that need to be broken through first in the coordinated development of Beijing-Tianjin-Hebei region. The Beijing-Tianjin-Hebei urban agglomeration should play an exemplary role in promoting high-quality development through eco-environmental protection. However, eco-environmental deterioration, resource constraints and unbalanced regional ecological development are the main problems in the process of Beijing-Tianjin-Hebei regional eco-environment collaborative governance. It is very important to analyze the development trend of the eco-environmental carrying capacity of the Beijing-Tianjin-Hebei urban agglomeration in order to solve the problem of coordinated eco-environmental management.

2. Literature Review

The eco-environmental carrying capacity is the supporting capacity of the eco-environmental system to human social and economic activities in a certain period. Scholars at home and abroad have done many researches on bearing capacity. Fu Yunpeng [1] took 15 sub-provincial cities in China as an example, constructed a comprehensive evaluation index system of urban resource and environmental carrying capacity, and evaluated urban resource and environment. Based on the P-S-R model, Wang Kuifeng [2] and Yu Huixin [3] analyzed the eco-environmental carrying capacity of six cities in the Shandong peninsula and the Beijing-Tianjin-Hebei region, providing a reference for regional environmental governance. In combination with foreign research results, Repar [4] pointed out that



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ecological carrying capacity is a prerequisite for sustainable development, and Tehrani [5] stressed that in order to cope with non-linear, sudden and severe environmental responses, the urban ecosystem carrying capacity should be dynamically monitored on a regular basis.

The paper selects Beijing-Tianjin-Hebei region 13 cities as the research object, using the DPSIR model constructing evaluation index system of urban eco-environmental carrying capacity, combined with the eco-environmental carrying capacity evaluation model based on entropy and TOPSIS, spatial difference and development level of Beijing-Tianjin-Hebei urban eco-environmental carrying capacity is analyzed, and put forward corresponding countermeasures and suggestions, in order to provide reference for Beijing-Tianjin-Hebei urban eco-environmental governance together.

3. Research Method

Table 1. The evaluation indexes system of urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei

Rule layer	Index layer	Unit	Index code	Index properties
Driving forces	GDP per capita	yuan	D ₁	(+)
	Per capita consumption expenditure of urban residents	yuan	D ₂	(+)
	Per capita disposable income of urban residents	yuan	D ₃	(+)
	Natural rate of population growth	%	D ₄	(-)
	Urbanization level	%	D ₅	(+)
	Registered urban unemployment rate	%	D ₆	(-)
Pressure	The population density	person•km ⁻²	P ₁	(-)
	Water consumption per ten thousand yuan of GDP	m ³	P ₂	(-)
	Energy consumption per ten thousand yuan of GDP	t	P ₃	(-)
	Industrial SO ₂ emissions per ten thousand yuan of GDP	t	P ₄	(-)
	Industrial wastewater discharge per ten thousand yuan of GDP	t	P ₅	(-)
	Industrial smoke emission per ten thousand yuan of GDP	t	P ₆	(-)
State	Water resources per capita	m ³	S ₁	(+)
	Land resources per capita	m ² •person ⁻¹	S ₂	(+)
	Park green space per capita	m ² •person ⁻¹	S ₃	(+)
	Mean annual concentration of SO ₂	μg•m ⁻³	S ₄	(-)
	Mean annual concentration of NO ₂	μg•m ⁻³	S ₅	(-)
	Mean annual concentration of PM10	μg•m ⁻³	S ₆	(-)
Impact	Ambient air quality good rate	%	I ₁	(+)
	City SO ₂ mean compliance rate	%	I ₂	(+)
	City NO ₂ mean compliance rate	%	I ₃	(+)
	City PM10 mean compliance rate	%	I ₄	(+)
	The output value of the secondary industry accounts for a proportion of GDP	%	I ₅	(-)
	The output value of the tertiary industry accounts for a proportion of GDP	%	I ₆	(+)
Responses	Forest coverage	%	R ₁	(+)
	Green coverage of the built-up area	%	R ₂	(+)
	Comprehensive utilization rate of industrial solid waste	%	R ₃	(+)
	Centralized treatment rate of urban sewage treatment plants	%	R ₄	(+)
	Harmless disposal rate of municipal solid waste	%	R ₅	(+)
	Proportion of investment in water conservancy, environment and public facilities management	%	R ₆	(+)

DPSIR model is a framework model based on causal relationship organization information, developed to measure the indicator system of environment and sustainable development, and to study the causal framework of the interaction between society and environment. Based on the DPSIR model framework and in combination with the current situation of eco-environmental development and collaborative governance of Beijing-Tianjin-Hebei urban agglomeration, 30 evaluation indexes were selected from five subsystems of driving force, pressure, state, impact and response to construct the evaluation index system of urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei (Table 1).

3.1. Eco-environmental carrying capacity evaluation model based on entropy weight and TOPSIS

3.1.1. *Weight of evaluation index.* The specific calculation is shown in formula (1).

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

Among them, $H_i = (1/\ln n) \sum_{i=1}^n f_{ij} \ln f_{ij}$ called information entropy; $f_{ij} = y_{ij} / \sum_{j=1}^n y_{ij}$ called the characteristic weight of the index, $\ln 0 = 0$.

3.1.2. *Construction of evaluation matrix.* The specific calculation is shown in formula (2).

$$R = [r_{ij}]_{mn} = [y_{ij} \cdot w_i]_{mn} \quad (2)$$

3.1.3. *Positive and negative ideal solutions.* R^+ and R^- are called positive and negative ideal values, and the specific calculation is shown in formula (3) and formula (4).

$$R^+ = \left\{ \max_{1 \leq i \leq m} r_{ij} \mid i=1, 2, \dots, m \right\} = \{r_1^+, r_2^+, \dots, r_m^+\} \quad (3)$$

$$R^- = \left\{ \min_{1 \leq i \leq m} r_{ij} \mid i=1, 2, \dots, m \right\} = \{r_1^-, r_2^-, \dots, r_m^-\} \quad (4)$$

3.1.4. *Distance calculation.* The Euclidean distance formula is adopted, and the specific calculation is shown in formula (5) and formula (6).

$$D_j^+ = \sqrt{\sum_{i=1}^m (r_i^+ - r_{ij})^2} \quad (5)$$

$$D_j^- = \sqrt{\sum_{i=1}^m (r_{ij} - r_i^-)^2} \quad (6)$$

3.1.5. *Calculate relative closeness.* Let C_j be the degree to which the eco-environmental carrying capacity is close to the ideal value, called relative closeness, $C_j \in [0, 1]$. The larger C_j is, the closer the city's eco-environmental carrying capacity is to the optimal level. In this paper, C_j is used to judge the eco-environmental carrying capacity and the specific calculation is shown in formula (7).

$$C_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad (7)$$

4. Results and analysis

Based on the statistical data of the Beijing-Tianjin-Hebei region from 2012 to 2016, the calculation was carried out by formula (1) - (7). By horizontal comparison, the relative closeness of the eco-environmental carrying capacity of 13 cities in the Beijing-Tianjin-Hebei region from 2012 to 2016 was calculated and its mean value was taken to analyze the spatial difference of the urban eco-environmental carrying capacity in the Beijing-Tianjin-Hebei region. By longitudinal analysis, taking single city as the research object, analyzes the dynamic change trend of each city's eco-environmental carrying capacity.

4.1. Spatial difference of eco-environmental carrying capacity of the Beijing-Tianjin-Hebei urban agglomeration

Through horizontal comparison, the comprehensive ranking of the relative closeness of the eco-environmental carrying capacity of Beijing-Tianjin-Hebei city is obtained (Table 2). According to the results, the overall eco-environmental carrying capacity of the Beijing-Tianjin-Hebei region is in a weak position, and the highest relative closeness is 0.5901. The eco-environmental carrying capacity of the Beijing-Tianjin-Hebei region is obviously different. Beijing, Chengde and Qinhuangdao rank the top three, while Handan, Hengshui and Xingtai rank the last three. The eco-environmental carrying capacity is the strongest and weakest in Beijing and Xingtai respectively, and the corresponding relative closeness is 0.5901 and 0.1628, which is nearly four times of that in Beijing. According to the calculation results of relative past-schedule in Table 2, the spatial difference distribution map of eco-environmental carrying capacity of beijing-tianjin-hebei urban agglomeration is drawn (figure 1). From the perspective of spatial distribution, the eco-environmental carrying capacity of the Beijing-Tianjin-Hebei urban agglomeration is "strong in the middle north and weak in the south".

Table 2. The comprehensive ranking of the urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei

Rank	City	C_i	Rank	City	C_i
1	Beijing	0.590	8	Cangzhou	0.307
2	Chengde	0.473	9	Shijiazhuang	0.250
3	Qinhuangdao	0.438	10	Baoding	0.228
4	Zhangjiakou	0.425	11	Handan	0.223
5	Tianjin	0.416	12	Hengshui	0.222
6	Langfang	0.390	13	Xingtai	0.163
7	Tangshan	0.308			

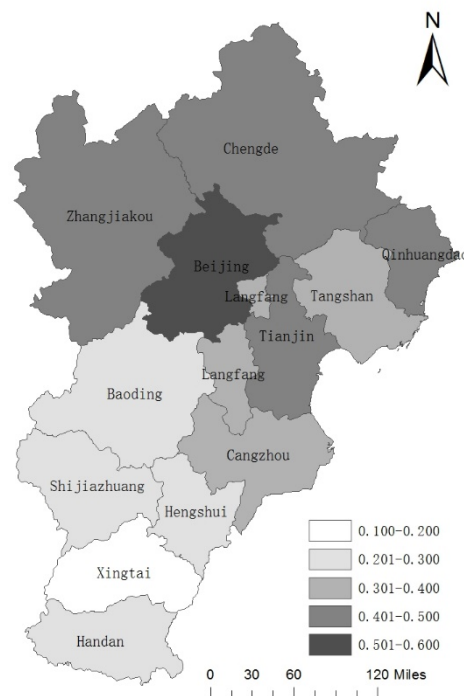


Figure 1. The spatial differences of urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei

4.2. Regional characteristics of eco-environmental carrying capacity of Beijing-Tianjin-Hebei urban agglomeration

Vertical analysis and calculation of the relative closeness of the eco-environmental carrying capacity of 13 cities in the Beijing-Tianjin-Hebei region from 2012 to 2016 (Figure 2). Overall, the carrying capacity of each city's ecological environment has fluctuated greatly in the past five years. The carrying capacity of Beijing and Tianjin decreased from 2012 to 2014 and reached the lowest value during the research period in 2014. The other 11 cities showed a downward trend from 2012 to 2013 and reached the lowest value during the research period in 2013. From 2014 to 2016, there were 12 cities in a continuous rising trend, and only Zhangjiakou city's eco-environmental carrying capacity in 2016 was in a declining state compared with 2015. Compared with 2012, Xingtai, Baoding and Chengde had the largest growth, with 1.49%, 1.32% and 1.21% respectively.

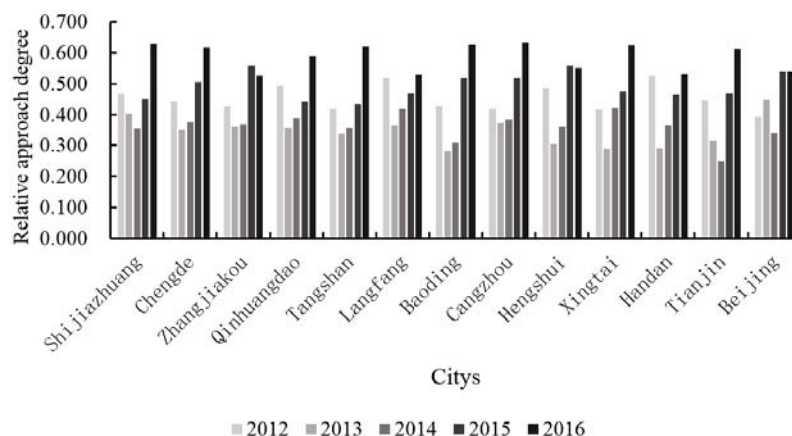


Figure 2. The relative approach degree of urban eco-environmental carrying capacity of Beijing-Tianjin-Hebei (2012-2016)

5. Conclusion

Based on relevant research results at home and abroad, combined with the current situation of eco-environmental development and collaborative governance in the Beijing-Tianjin-Hebei region, this paper constructs an evaluation index system of urban eco-environmental carrying capacity based on the DPSIR theoretical framework, and evaluates it with the TOPSIS method based on entropy weight. The conclusions are drawn as follows:

(1) The Beijing-Tianjin-Hebei urban eco-environmental carrying capacity is generally in a weak state, and there are serious spatial differences, showing the pattern of "strong in the middle north and weak in the south", Beijing, Chengde and Qinhuangdao ranked the top three, but Handan, Hengshui and Xingtai in the last three, the calculation results basically reflect the ecological status quo.

(2) During the research period, the eco-environmental carrying capacity of Beijing and Tianjin decreased from 2012 to 2014 and reached the lowest value in 2014, while that of the other 11 cities decreased from 2012 to 2013 and reached the lowest value in the research period in 2013. From 2014 to 2016, there were 12 cities in a continuous upward trend, and only Zhangjiakou saw a slight decrease in its ecological environment carrying capacity in 2016 compared with 2015. Remarkable progress has been made in coordinated ecological and environmental governance in the Beijing-Tianjin-Hebei region.

Based on the current policies and the research and analysis in this paper, the following suggestions are put forward for further promoting the coordinated eco-environmental governance in Beijing-Tianjin-Hebei urban agglomeration:

In order to solve the current situation of the spatial difference of the eco-environmental carrying capacity between Beijing-Tianjin-Hebei urban agglomeration, it is necessary to solve the imbalance of economic development between Beijing-Tianjin-Hebei urban agglomeration, seize the opportunity of the major national strategy of coordinated development between Beijing, Tianjin and Hebei and the non-capital function of Beijing, actively implement the guidance of industrial transfer between Beijing, Tianjin and Hebei, and promote the coordinated economic development of Beijing-Tianjin-Hebei urban agglomeration. We will promote regional development through urban development and build world-class urban agglomerations. Among them, the central and southern Hebei province as the Beijing-Tianjin-Hebei urban agglomeration of the eco-environmental carrying capacity of the depression, to strengthen its governance.

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