Coordination Development Level of EES System Based on Coupling Coordination Model in Hebei Province

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Abstract: This study aims to measure the coupling coordination degree and identity main influencing factors in Hebei province. This study used the coupling coordination model to calculate the comprehensive index, coupling degree and coupling coordination degree and the grey relational model for main influencing factors of the EES system in Hebei province from 2010 to 2018. The results show that: (1) The ecological index and economic index of Hebei province show a u-shaped curve, the social index is on the rise, and the development level of each system is in a low level of fluctuation. (2) The coupling level of the three subsystems is relatively high, but the coupling coordination is still a low level of coordinated development. (3) The order of the coupling coordination degree affected by the index of the system layer is social > ecological > economy, and there is a strong correlation among them.

1. Introduction

The generalized ecosystem is a complex system composed of the Ecology-Economy-Society system (hereinafter referred to as the EES system) [1]. Only when ecological protection, economic development and social progress developed in a coordinated way, can the efficient use of materials, energy and information be realized, so as to achieve ecological security. At present, there are few studies on ecology, economy and society as three parts of a complex system, and even fewer studies on analyzing the trend of coupling and coordination of complex system and finding influencing factors on the time scale [2-3].

To form the spatial pattern of ecological security in the Beijing-Tianjin-Hebei region, the ecological security of Hebei province must be guaranteed. However, the current research on the ecological security of Hebei province focuses on land ecological security, and there is no research on the coordinated development level of the ecological, economic and social systems from the overall perspective, let alone the influencing factors [4-5]. Therefore, after analyzing the coupling coordination level and characteristics of the EES system in Hebei province and finding out its influencing factors, suggestions can be put forward to promote the sustainable development of ecology, economy, and society.

In this paper, taking Hebei province as the research object, after constructing the coupling coordination degree evaluation index system of the EES system in Hebei province, use the coupling coordination model to judge the coupling coordination level and characteristics, and find out the influence factors of the coupling coordination degree by using grey correlation model measuring indicators at various levels and grey correlation degree.

2. Research Methods and Data Sources

2.1 Research Area and Data Sources

Hebei province, located on the north China plain, is surrounded by Beijing and adjacent to Tianjin in the east. The original data comes from Statistical yearbook of China, Statistical yearbook of Hebei

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province, State of ecological environment bulletin of Hebei province and Bulletin on the national economic and social development of Hebei province from 2010 to 2019.

2.2 Index System and Weight

The index system consists of 34 indicators, which summarize the status of the ecosystem, economic system and social system from 9 dimensions (Table 1), and the entropy method was used to determine the weight of all levels of indexes (Table 1).

Table 1 Evaluation index system of the EES system in Hebei province.

The target layer	System layer(Weight)	Rule layer	Weight	Index layer	Weight
EES system	Ecology system A （0.311）	Ecological status A1	0.125	Urban population density	0.020
				Water resources per capita	0.027
				Forest coverage rate	0.048
				urban green coverage rate	0.030
		Ecological problems A2	0.089	PM_{10} concentration	0.021
				SO_2 concentration	0.021
				NO_2 concentration	0.023
				Urban environmental noise	0.025
		Governance measures A3	0.097	The proportion of environmental protection investment	0.044
				Days with air quality better than level 2	0.027
				Per capita urban road area	0.026
	Economy system B （0.377）	Economic aggregate B1	0.103	Total GDP	0.023
				Fiscal revenue	0.026
				Industrial added value	0.020
				The growth rate of total retail sales of consumer goods	0.035
		Economic quality B2	0.145	Per capita GDP	0.023
				GDP growth rate	0.052
				The growth rate of the added value of tertiary industry	0.033
				Growth rate of industrial output value	0.037
		Economic vitality B3	0.128	The proportion of tertiary industry	0.037
				Number of ten thousand college students	0.030
				Investment intensity of R&D	0.027
				The growth rate of fixed assets investment	0.034
	Society system C （0.312）	Life quality C1	0.117	Urban residents' income	0.028
				Rural residents' income	0.027
				Residents' consumption level	0.026
				Urban residents' household Engel coefficient	0.036
		Social development C2	0.118	Per capita book ownership	0.035
				The number of public transportation owned by 10,000 people	0.027
				The number of public toilets per 10,000 people	0.027
				The ratio of teachers to students in colleges and universities	0.029

	Social stability C3	0.077	The urban unemployment rate	0.027
			The ratio of urban and rural residents' income	0.022
			The number of medical and health beds for 1,000 people	0.029

2.3 Coupling Coordination Model

The coupling degree measures the influence degree of the internal elements of the composite system on each other's interactions. The coupling degree (C) formula of the three-dimensional composite system is as follows:

$$C= [(A\times B\times C)/ ((A+B+C)/3) ^3] ^ (1/3) \quad (1)$$

In type (1): C is the coupling degree, A, B and C are the development indexes of three subsystems, and the value of C is between 0 and 1. The closer to 1, the higher the coupling degree. The coupling degree and corresponding coupling type of EES system are divided into 4 classes (Table 2) [6].

If both subsystems are less developed and they are at the same level, the value of C is also close to 1, it is called "pseudo-coordination", so we introduce the coupling coordination degree model. The coupling coordination degree can measure the overall effect of the coupling coordination development of the composite system under the coupling development of each subsystem, that is, the overall efficiency and synergistic effect. The formula of coupling coordination degree (D) is as follows:

$$D=(C\times T) ^ (1/2) \quad (2)$$

$$T=a' \times A +b' \times B +c' \times C \quad (3)$$

In type (2) and (3): T is the coordinated development index of the composite system. a', b' and c' are undetermined coefficients, which reflect the influence degree of economic, ecological and social subsystems on the EES system. In this paper, the weight of the specific indicator layer is added to obtain the weight of the superior system (table 1): a'=0.311, b'=0.377, c'=0.312.

Referring to the classification method of the coupling coordination type of [7], the development status of the coupling coordination of the EES system is divided into four categories (Table 2).

Table 2 Type division of coupling coordination and coupling coordination.

Number	Section	Type of coupling	Section.	Type of coupling coordination
1	0<C<0.30	Mutual exclusion	0<D<0.30	Disordered state of decline
2	0.30<C<0.50	Antagonism Hang	0.30<D<0.50	Barely coordination
3	0.50<C<0.80	Run-in optimization level	0.50<D<0.80	Moderate coordination
4	0.80<C<1	Fusion State	0.80<D<1	High coordinated

2.4 Grey Relational Model

The correlation degree is an important index to measure the strength, size and order of the relations among factors. The grey correlation degree model determines the difference and similarity among the sequences by analyzing the correlation degree between the reference sequence and the comparison sequence points.

After averaging the correlation degree of the indicator layer and obtaining the correlation degree of the superior indicator, the correlation level can be determined and sorted according to the classification interval of the correlation degree (Table 3), and the influence degree of each indicator on the coupling and coordinated development can be obtained.

Table 3 Classification interval of correlation degree.

Section	[0,0.35]	[0.35,0.65]	[0.65,0.85]	[0.85,1.0]
Correlation degree	Weak correlation	Similar correlation	Medium correlation	Strong correlation

3. Results Analysis

According to the above method, the development index, the coupling degree and the coupling coordination degree of the EES system in Hebei province from 2010 to 2018 are obtained (Fig.1, Table 4-5). The following analysis is made according to the results.

3.1 Evaluation of the EES System Development Index in Hebei Province

As can be seen from Fig.1, from 2010 to 2018, the ecological index and economic index of Hebei province showed a u-shaped curve, reaching the lowest points in 2013 and 2014 respectively. The ecological environment recovered and the economic structure was constantly optimized with the promotion of the 13th five-year plan. The social index is on the rise, which is closely related to the implementation of various livelihood measures in Hebei province and the increase of investment in science, education, culture and health. Besides, the index of each system is lower than 0.3, indicating that the development level of each system is at a low level of fluctuation.

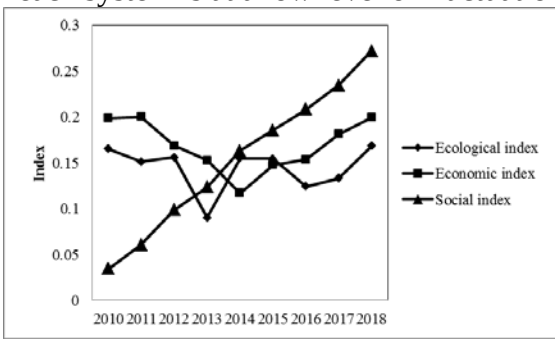

Figure 1 Index trend chart of the EES system in Hebei province from 2010 to 2018.

3.2 Evaluation of the Coupling Level of the EES System in Hebei Province

It can be seen from Table 4 that from 2010 to 2018, the coupling degree of EES system in Hebei province showed an increasing trend, and the coordination degree between the systems realized the transformation from "Mutual exclusion" to" Fusion State ". In 2010, with the development of the economy and the restoration of the ecological environment, it entered a state of benign coupling. Since 2012, the coupling degree has been higher than 0.95, indicating the orderly development of ecology, economy and society, and the coupling level of the three subsystems is relatively high.

Table 4 Coupling degree and types of EES system in Hebei province.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
C	0.78	0.89	0.97	0.98	0.99	0.99	0.98	0.97	0.98
Type	Mutual exclusion	Fusion State	Fusion State	Fusion State	Fusion State	Fusion State	Fusion State	Fusion State	Fusion State

3.3 Evaluation of Coupling and Coordinated Level of EES System in Hebei Province

It can be seen from Table 5 that the coupling coordination degree of the EES system in Hebei province showed a trend of slow rise from 2010 to 2018. On the whole, it belongs to the barely coordination type, and the mean coupling coordination degree (0.38) is significantly lower than the mean coupling coordination degree (0.95), which is still far from high coordinated development, indicating that the coupling coordination between various systems is still a relatively low level of coordinated development.

Specifically, from 2010 to 2014, the EES system in Hebei province was in the state of economic priority development. From 2015 to 2018, it is in a state of social priority development, and the ecological subsystem has been under great pressure of economic and social development.

Table 5 Coupling coordination degree and types of EES system in Hebei province.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
D	0.33	0.35	0.37	0.35	0.38	0.41	0.40	0.42	0.46
Type	Barely coordi	Barely coordi	Barely coordi	Barely coordi	Barely coordi	Barely coordi	Barely coordi	Barely coordi	Barely coordi-

	-nation	-nation	-nation	-nation	-nation	-nation	-nation	-nation	nation

4. Factors Influencing the Coordinated Development of EES System in Hebei Province

The influence factors of the coupling coordination degree of the EES system in Hebei province were calculated by the grey relational degree method. The calculation results (Table 6) show that:

(1)The order of the coupling coordination degree affected by the index of system layer is: social > ecological> economy, and they all have a strong correlation with it.

(2) The order of influence degree of factor level indicators is ecological environment problem> social stability> economic aggregate> ecological environment status> quality of life> social development> economic vitality> ecological management measures> economic quality. Besides, except for the medium correlation of economic quality, other factors have a strong correlation with it.

(3) The top five most affected by specific indicators are: industrial added value> SO_2 concentration> PM_{10} concentration> per capita GDP> urban and rural resident income ratio.

Table 6 Correlation degree and orders.

The target layer	System layer /The correlation degree /Order	The target layer / The correlation degree /Order	Index layer	The correlation degree	The order
EES system	Ecology system /0.768 /2	Ecological status /0.768 /4	Urban population density	0.818	7
			Water resources per capita	0.752	21
			Forest coverage rate	0.780	13
			urban green coverage rate	0.722	25
		Ecological problems /0.811 /1	PM_{10} concentration	0.845	3
			SO_2 concentration	0.872	2
			NO_2 concentration	0.788	12
			Urban environmental noise	0.737	23
		Governance measures /0.725 /8	The proportion of environmental protection investment	0.663	32
			Days with air quality better than level 2	0.718	26
			Per capita urban road area	0.793	10
	Economy system /0.741 /3	Economic aggregate /0.799 /3	Total GDP	0.829	6
			Fiscal revenue	0.806	9
			Industrial added value	0.889	1
			The growth rate of total retail sales of consumer goods	0.670	31
		Economic quality /0.699 /9	Per capita GDP	0.833	4
			GDP growth rate	0.608	34
			The growth rate of the added value of tertiary industry	0.728	24
			Growth rate of industrial output value	0.627	33
		Economic vitality /0.725 /7	The proportion of tertiary industry	0.690	29
			Number of ten thousand college students	0.768	18
			Investment intensity of R&D	0.770	17
			The growth rate of fixed assets investment	0.673	30
	Society system /0.770	Life quality /0.761 /5	Urban residents' income	0.777	15
			Rural residents' income	0.777	14
			Residents' consumption level	0.791	11

/1		Urban residents' household Engel coefficient	0.701	28
	Social development /0.747 /6	Per capita book ownership	0.739	22
		The number of public transportation owned by 10,000 people	0.765	20
		The number of public toilets per 10,000 people	0.715	27
		The ratio of teachers to students in colleges and universities	0.771	16
	Social stability /0.802 /2	The urban unemployment rate	0.807	8
		The ratio of urban and rural residents' income	0.832	5
		The number of medical and health beds for 1,000 people	0.766	19

5. Conclusion

By using the coupling coordination model, the development index, coupling degree and coupling coordination degree of the EES system in Hebei province are obtained. From 2010 to 2018, the ecological index and economic index of Hebei province showed a u-shaped curve, the social index is on the rise. Besides, the index of each system is lower than 0.3, indicating that the development level of each system is at a low level of fluctuation. The coupling level of the three subsystems is relatively high, but the coupling coordination is still a low level of coordinated development.

By using the grey relational degree model, the influence of each index layer on the coupling coordination level of the EES system in Hebei province and their orders are obtained. These results can be used to make rational planning of key indicators in comprehensive planning.

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