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Analyzing the coupled and coordinated development relationship of the Yellow River Basin from the perspective of population-economy-ecology-environment system

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Abstract: Based on entropy weight method and coupling coordination degree model, the development index and coupling coordination degree of the three systems in the Yellow River Basin were measured from 2012 to 2021, and explored in both time and space dimensions. The results show that the population development index of the Yellow River Basin is the highest, the economic development index rises more, and the ecological environment development index is the lowest and shows a decreasing trend; the coupling coordination degree rises as a whole, and the regional differences are significant, so the construction of ecological environmental protection should be emphasized to promote the high-quality development of the Yellow River Basin.

Keywords: Coupled Coordination Degree; Entropy Weight Method; Population-Economy-Ecological Environment; Yellow River Basin

1. Introduction

High-quality development of the Yellow River Basin is a major development strategy, and at the same time, the Yellow River is also an important ecological security barrier in China, an important area for population activities and economic development, and has a pivotal strategic position in the overall situation of the country's development and socialist modernization, so it is very necessary to protect the Yellow River Basin and achieve high-quality development of the population, the economy, and the ecological environment.

At present, scholars at home and abroad have made certain achievements in the research on the coupling and coordination of population, economy and ecological environment, and have constructed a reasonable indicator system with different methods, including TOPSIS model[1], factor analysis[2], gray correlation model[3], coupling and coordination model[4-5], as well as various mathematical methods. The research objects are Chinese provincial regions[6] and provincial urban agglomerations [7-11]. However, there is a gap in the research on the coordinated development of population, economy and ecological environment in the Yellow River Basin. Based on this, this paper applies the entropy method and the coupled coordination model to analyze the coupled population-economy-ecology-environment system coordination relationship in the Yellow River Basin from 2012 to 2021, in order to promote the high-quality development of the Yellow River Basin.

2. Research design

2.1 Construction of the indicator system and data sources

2.1.1 Construction of the indicator system

Following the principles of systematicity, rationality and scientificity of the selected indicators, referring to the relevant research results and combining with the actual situation of the study area, the statistical yearbooks of nine provinces (autonomous regions), such as Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shanxi, Shaanxi, Henan and Shandong, were collected, and linear interpolation was utilized to supplement the few missing data. A coupled and coordinated evaluation index system of population, economy and ecological environment in the Yellow River Basin was constructed (Table 1).

Table 1 Comprehensive evaluation index system of population-economy-ecological environment tri-system in the Yellow River basin

system level	Dimension of measurement	Evaluation indicators	Type of indicator
Population subsys-tem	Size of population	Year-end resident population	-
		Urban population density	-
	population structure	sex ratio	-
		Aging coefficient	-
	quality of population	Percentage of students enrolled in higher education	+
		Percentage of urban population	+
Economic subsys-tem	economic level	GDP per capita	+
		Investment in fixed assets per capita	+
		Fiscal revenue per capita	+
	economic structure	Primary sector as a share of GDP	+
		Tertiary sector as a share of GDP	+
		External trade dependence	+
ecosystem	Resource elements	Forests per capita	+
		Cultivated land area per capita	+
		Water resources per capita	+
	ecological pollution	Industrial emissions	-
		Domestic waste emissions	-
		Industrial solid waste emissions	-
	Environmental protection and construction	Urban sewage treatment rate	+
		Disposal rate of non-hazardous urban waste	+
		Industrial solid waste utilization	+
		forest cover	+
		Public green space per capita	+
		Environmental investment as a share of GDP	+

2.2 Data processing

2.2.1 Entropy weight method

First determine the weights of the indicators. Calculate the information entropy under each metric , i.e:

$$E_j = -K\sum_{i=1}^{m} P_{ij} \ln P_{ij} \qquad (3)$$

included among these，$K = \frac{1}{\ln m}$，$P_{ij} = \frac{x_{ij}^{o}}{\sum_{i=1}^{m} x_{ij}^{o}}$。

The entropy weight W_j is given by:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \qquad (4)$$

System level measurement. The integrated development index of the demographic-economic-ecological-environmental subsystem is calculated by the formula:

$$f(U_i) = \sum_{j=1}^{n} W_j x_{ij}^{o} \qquad (5)$$

2.2.2 Coupled Coordination Degree Models

Calculate the coupled coordination degree of the population-economy-ecological environment subsystem in the Yellow River Basin, Eq:

$$C = \left\{ \frac{f(x) \times g(x) \times h(x)}{\left[\left(f(x) \times g(x) \times h(x) / 3 \right) \right]^3} \right\}^{\frac{1}{3}} \quad (6)$$

$$T = \alpha_1 \times f(x) + \alpha_2 \times g(x) + \alpha_3 \times h(x) \quad (7)$$

$$D = \sqrt{C \times T} \quad (8)$$

In the formula: C denotes the coupling degree; T is the coordination index; α1, α2, α3 are the pending weights of the three subsystems, which are considered to be of the same degree of importance in the evaluation process, and α1, α2, α3=1/3; D is the degree of coupling coordination. The coupled coordination degree of population-economy-resource-environment system in the Yellow River Basin is divided into 10 types, as shown in Table 2.

Table 2. Discriminative criteria for coupling degree and division types

Negative coupling		Positive coupling	
D-value	typology	D-value	typology
0.00-0.09	Catastrophic decline	0.50-0.59	Barely coordinated development
0.10-0.19	serious dislocation and recession	0.60-0.69	Primary coordinated development
0.20-0.29	Moderately dysfunctional recession	0.70-0.79	Intermediate Coordinated Development
0.30-0.39	mildly disproportionate decline	0.80-0.89	Well-coordinated development
0.40-0.49	terminal decline	0.90-1.00	Quality and coordinated development

3. Results and analysis

3.1 Spatial and temporal characteristics of integrated population-economic-ecological development in the Yellow River basin

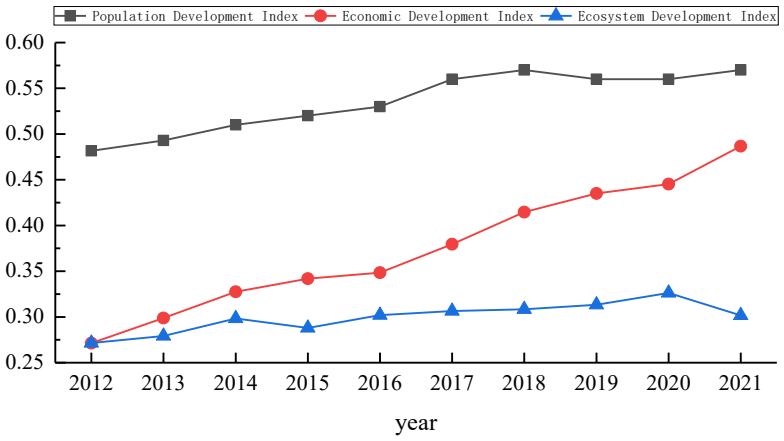

Fig 1 Changes in population-economy-ecological environment development index in the Yellow River Basin

From the comparison of the comprehensive development level of population-economy-ecological environment subsystems (Fig. 1), the Yellow River Basin has been in the stage of population dominance and ecological environment lagging behind. The population development index of the Yellow River Basin is high and continues to develop steadily, while the economic development index starts from a low point but

grows fast, showing a tailing trend, which indicates that with the continuous improvement of the economic development level, it attracts a large number of population and labor force influx, and the two complement each other and jointly promote their development. The up and down fluctuation of the ecological environment development index is obvious, and the development level is low, reflecting that the utilization of ecological environment resources in the Yellow River Basin is unreasonable, and the protection of ecological resources needs to be further improved.

3.2 Analysis of coupled coordination relationships in the Yellow River Basin

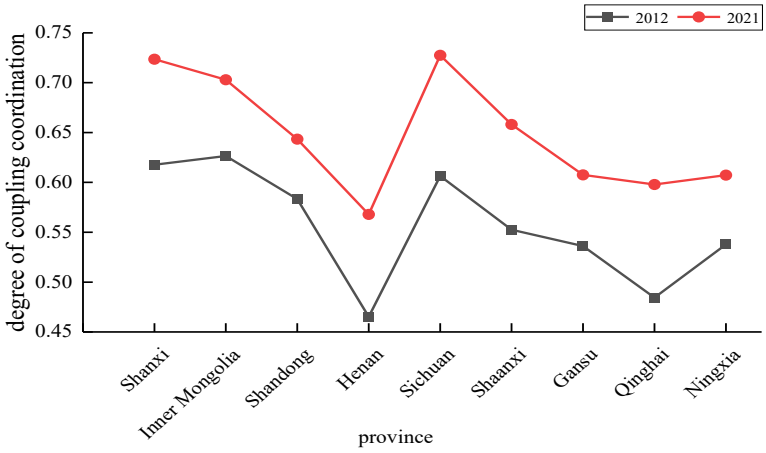

Fig. 2 Coupling harmonization degree in the Yellow River Basin

Figure 2 shows the coupling coordination level of the Yellow River Basin. From Figure 2, it can be seen that the coupling coordination development level of the Yellow River Basin generally moves from the barely coordinated development stage to the primary coordinated development stage. Among them, Sichuan has the highest level of coupled coordination, followed by Shanxi and Inner Mongolia, which are in the stage of medium coordinated development. Sichuan's population structure and economic structure continue to harmonize and improve, and the emphasis on ecological environmental protection gradually increases. Shandong, Shaanxi, Gansu, Qinghai and Ningxia are in the primary coordinated development stage. Shandong's rapid economic development and the transformation and upgrading of its economic structure have pushed up the degree of coupled coordination. Shaanxi, as an inland reform and opening-up highland, the province's rapid economic growth has attracted a large influx of talents. Qinghai and Ningxia have a higher level of comprehensive population development and a larger rise in the level of economic development, which is also an important reason for promoting the development of the degree of coupling coordination, but the emphasis on ecological environmental protection needs to be strengthened, and the weak foundation of ecological environmental protection leads to the slow development of the degree of coupling coordination. Henan has the lowest coupling coordination degree. Some industries in Henan still have low-end and high-energy-consumption problems, and the challenges of economic development, ecological environmental protection and governance, as well as the lack of policy implementation, have also constrained the development of coupling coordination.

4. Conclusions and recommendations

4.1 Conclusions

The comprehensive development level of population-economy-ecological environment subsystems in the Yellow River Basin from 2012 to 2021 generally shows a rising trend year by year. Among them, the development index of population subsystem is higher, the development of economic subsystem grows faster, and the development level of ecological environment subsystem shows a decreasing trend, which side by side reflects that the provinces pay less attention to ecological environment and the environmental protection mechanism is not perfect. The coupling and coordination degree of the Yellow River Basin has been increasing, and the whole has entered the primary coordi-

nated development stage from the barely coordinated development stage, and the increase is obvious, the coupling and coordination degree of the upper and middle reaches of the Yellow River is higher, Shanxi, Inner Mongolia and Sichuan have entered the intermediate coordinated development stage, and the coupling and coordination degree of Henan Province is the lowest. The ecological lagging problem of the Yellow River basin is more serious, and the ecological environment needs to be further upgraded.

4.2 Recommendations

We should adhere to the idea of vacating cage for birds and phoenix nirvana, promote the optimization and upgrading of industries in the Yellow River Basin, promote innovation-driven development, promote infrastructure upgrading, promote the construction of strong provinces, and promote the deepening of reform and opening up. The Yellow River Basin should focus on the construction of ecological environmental protection, comprehensive management, systematic management and source management of the ecological environment of the Yellow River Basin, integrated planning of ecological environmental protection and green low-carbon transformation of the Yellow River Basin, and comprehensively enhance the level of ecological environmental protection in the basin. Focusing on the coordinated development among population, economy and ecological environment of the Yellow River Basin, respecting the law of development, strengthening the construction of population, economy and ecological environment, and sounding the economic policies, improving the mechanism of capital investment and a series of other initiatives to promote the high-quality development of population-economy-ecological environment of the Yellow River Basin.

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