

A Study on the Coordinated Development of Ecological Environment, Urbanization and High-quality Economy in the Yellow River Basin

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Abstract: The protection of the ecological environment and high-quality development in the Yellow River Basin is a major national strategy. Urbanization is also important and should be promoted more efficiency in China. The ecological environment of the Yellow River Basin has been destroyed, further affecting the process of urbanization. The difficulty of sustainable economic development has increased. Therefore, China needs high-quality economic development. In this context, the coordinated development of the ecological environment, urbanization and high-quality economy in the Yellow River Basin deserve more attention. Based on the time-series data of the Yellow River Basin from 2010 to 2020, this paper analyzes the trend and characteristics of the development of the ecological environment subsystem, urbanization subsystem and high-quality economy subsystem by building a comprehensive evaluation system of the three subsystems, using entropy method and coupling coordination degree model. The results show that: from 2010 to 2020, the comprehensive level show an obvious upward trend; the story of urbanization and high-quality economic growth is higher than the level of ecological environment. Urbanization and economic development show the spatial difference of environmental carrying capacity; the coupling degree has been at a high level, and the coordination degree has changed significantly. We can conclude that the system coordination degree is in a steady upward trend. And, as a whole, it is shifting to order from disorder and getting to the level of coordination. It is helpful to guide the strategy formulation of the coordinated development among the ecological environment, urbanization and high-quality economy in the Yellow River Basin.

Keywords: Ecological Environment, Urbanization, High-quality Economic Development, Coupling and Coordination, The Yellow River Basin

1. Introduction

The Yellow River Basin is the birthplace of China, and it is also the center of the country's important economic development. With the economic development and expansion of human activities, the ecological environment of the Yellow River Basin has been destroyed. This has resulted in soil erosion, water pollution, and flood threats. It has restricted the process of urbanization; it has a deleterious effect on the sustainable development of society and the economy. The 19th National Congress put forward that urbanization should promote more

efficiently in China. And it is emphasized that both high-quality economic development and ecological, environmental protection are significant. The urbanization and economic development of the areas along the Yellow River should be quality and based on the principle of green and low-carbon. It became the focus of theoretical research on ensuring a collaborative relationship among ecological environment, urbanization and high-quality economy in the Yellow River Basin. Therefore, this paper aims to solve the problem and analyze its temporal and spatial evolution mechanism.

There is a complex relationship between the ecological

environment and high-quality economic development. Promotion and restriction exist at the same time. It results from that natural resources are limited and economic growth is endless. The limitation of natural resources is not sufficient to ensure economic development. Meanwhile, economic development can provide ample financial support for ecological environment protection. Maintaining coordination between the environmental environment and high-quality economic growth is crucial [1]. Furthermore, China's urbanization is developing rapidly, leading to the explosion of development and putting pressure on environmental protection. The proposal of new urbanization brings greater difficulties to achieving harmony. It is urgent to research the cooperative relationship among urbanization, ecological environment and high-quality economic development [2].

There are some research progresses with regard to the ecological environment and economy. Researchers mainly studied the relationship between environmental environment and economic development judging from the time series and spatial differentiation. On the one hand, researchers found the collaborative relationship between the ecological environment and economic development in a certain period [3]. On this basis, a regional ecological-economic coordinated development model has been constructed to analyze the coordination of regional economic development. On the other hand, from spatial differentiation, exploratory spatial data analysis and geographic detector methods were used to analyze the "coordinated development between the environment and economy" of the regional areas [4-6]. The analysis of its coordination degree aims to promote coordinated regional development and put forward development strategies tailored to local conditions [7, 8].

People pay more and more attention to the collaborative relationship between urban development and the ecological environment and realize the harmonious and long-term existence of man and nature. In the urbanization process, problems such as the relative lack of natural resources and the destruction of the ecological environment have become increasingly prominent [9]. In the process of new urbanization, the concept of ecological civilization should be integrated, and the theme of environmental protection should be linked to improving people's quality of life [10, 11]. The collaborative development of urbanization and the ecological environment is conducive to solving outstanding economic and social development problems, better optimizing the allocation of social resources, and achieving sustainable economic and social action [12, 13].

As to the ecological environment, urbanization and high-quality economy, on the one hand, researchers has so far paid attention to the two out of three. There is a lack of discussion about the three systems concurrently. On the other hand, given that most studies focus on the whole country or a small local area, the scope along Yellow River Basin is in between, and research on Yellow River Basin should be more profound and improved as it is an important economic center in China. Moreover, China government think highly of developing quality instead of speed. Therefore, following

previous works, this paper analyses the coordination of the three systems in the first place, then discusses the temporal and spatial evolution mechanism of the whole system.

2. Research Methods and Data Sources

2.1. Data Sources

To calculate the coordination degree of the ecological environment, urbanization, and high-quality economic development of the Yellow River Basin, nine provinces were selected, including Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia Shaanxi, Shanxi, Henan and Shandong. The data came from China Statistical Yearbook, China Urban Statistical Yearbook, China Environmental Statistics Yearbook, and other statistical databases from 2010 to 2020. Some of the data were comprehensively calculated by multiple basic data.

To overcome the problem caused by the difference in the indicators and the inconsistencies of data units and magnitude, the original data were standardized, meeting the needs of model calculation, making sure the result was reliable. Suppose there are m ($i=1, 2, \dots, m$) research objects, n ($j=1, 2, \dots, n$) indicators, x_{ij} is the j^{th} indicator's value of object I , y_{ij} is the standardization of x_{ij} . The calculation formulas are as follows:

$$y_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, \text{ when } x_{ij} \text{ is positive vector} \quad (1)$$

$$y_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, \text{ when } x_{ij} \text{ is negative vector} \quad (2)$$

2.2. Research Methods

2.2.1. Index Weight Determination Method

Based on the analytic hierarchy process, we build a comprehensive evaluation index system to measure the system situations consisting of ecological environment, urbanization and high-quality economic development. The environmental environment subsystem is assessed by three factors, including level, pressure, and protection [14]. The urbanization subsystem is evaluated by four elements: population, economic, social, and spatial [15]. The high-quality economic development subsystem is assessed by four factors: innovative economy, coordinated economy, green economy, and open economy. And each element is measured with multiple indicators based on previous research. The entropy method is used to assign weights to each index. The calculation process is shown as follows, and the indexes and the weights are shown in Table 1.

The proportion of each evaluating indicator:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^m y_{ij}} \quad (3)$$

Entropy value of indicator:

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^m p_{ij} \ln(p_{ij}) \quad (4)$$

Information utility value of indicator:

$$g_j = 1 - e_j \quad (5)$$

Entropy weight of indicator:

$$w_j = \frac{g_j}{\sum_{j=1}^n g_j} \quad (6)$$

Comprehensive score of indicator:

$$s_j = \sum_{i=1}^m w_j y_{ij} \quad (7)$$

Table 1. Evaluation system of ecological environment, urbanization and high-quality economic development in the Yellow River Basin.

System	Factor	Indicator	j	w _j
Ecological environment subsystem	Ecological environment level	Forest cover rate	j=1	0.032308
		Water resources per capita	j=2	0.016315
		Cultivated land area per capita	j=3	0.033489
		Proportion of nature reserves in jurisdiction	j=4	0.027996
	Ecological environment pressure	Wastewater discharge per capita	j=5	0.03228
		Industrial so ₂ emissions per capita	j=6	0.021634
		Solid waste removal and transportation volume per capita	j=7	0.029952
		Industrial solid waste generation per capita	j=8	0.03261
	Ecological environment protection	Total environmental pollution investment	j=9	0.030331
		Afforestation area per capita	j=10	0.029923
		Industrial solid waste utilization rate	j=11	0.033982
		Park green area per capita	j=12	0.032659
Urbanization subsystem	Population	Proportion of urban population	j=13	0.035578
		Urban unemployment rate	j=14	0.03578
		GDP per capita	j=15	0.034655
		Disposable income per capita	j=16	0.036027
	Economic	The proportion of tertiary industry in GDP	j=17	0.03552
		Gas penetration rate	j=18	0.035755
		Number of college students per 100,000 people	j=19	0.034553
		Number of hospital beds	j=20	0.035988
	Spatial	Built-up area per capita	j=21	0.031559
		Road area per capita	j=22	0.031886
		Urban population density	j=23	0.032741
		Technology market turnover	j=24	0.027541
High-quality economic development subsystem	Innovative economy	R&D expenditure input intensity	j=25	0.032906
		Industrial advanced	j=26	0.034579
	Coordinated economy	Consumption expenditure per capita	j=27	0.035678
		Electricity consumption per capita	j=28	0.031324
	Green economy	Green coverage rate in built-up area	j=29	0.035397
		Every 100,000 people own public transportation vehicles	j=30	0.032618
	Open economy	Average salary of employed persons in urban units	j=31	0.036436

(w_j represent Entropy weight of indicator j)

2.2.2. Coupling Degree and Coupling Coordination Degree Model

The ecological environment subsystem, the urbanization subsystem and the high-quality economic development subsystem depend on each other, interact and influence each other. It gradually forms a relatively stable overall system [16]. The paper set up a model to calculate the coupling coordination degree of the three. The ecological environment subsystem is U₁, U₂ defines the urbanization subsystem, and U₃ represents the economic high-quality development subsystem. The calculation model is as follows:

Coupling degree model:

$$C = \left\{ \frac{U_1 * U_2 * U_3}{\left[\frac{1}{3} (U_1 + U_2 + U_3) \right]^3} \right\}^{\frac{1}{3}} \quad (8)$$

The value of the coupling degree C is [0, 1]. The larger C means the greater coupling and the stronger correlation of the system. Otherwise, the smaller C means the smaller coupling and the weaker correlation. That means when the C is closer at 0, there is no coupling degree, and each subsystem is in a state of being irrelevant.

Coupling coordination degree model:

$$D=\sqrt{CT} \tag{9}$$

$$T=\alpha U_1+\beta U_2+\delta U_3 \tag{10}$$

The value scope of the coupling coordination degree D is $[0, 1]$, T is the comprehensive evaluation index of the three subsystems. In this formula α , β , δ are undetermined coefficients, and $\alpha+\beta+\delta=1$. According to previous research, this article regards that the three subsystems are equally important, and this make the point that $\alpha=\beta=\delta=1/3$. Based on the model, the coordinated development is divided into 10 categories, as shown in Table 2.

Table 2. Types of coordinated development.

Type	Scope of D	Type	Scope of D
Extreme disorder	[0, 0.1)	barely coordination	[0.5, 0.6)
Serious disorder	[0.1, 0.2)	Primary coordination	[0.6, 0.7)
Moderate disorder	[0.2, 0.3)	Intermediate coordination	[0.7, 0.8)
Mild disorder	[0.3, 0.4)	Well coordination	[0.8, 0.9)
Verge disorder	[0.4, 0.5)	Wonderful coordination	[0.9, 1.0]

3. Results and Discuss

3.1. Overall Evaluation

The comprehensive evaluation index of the nine provinces along to the Yellow River Basin are as Figure 1, though the entropy method and coupling coordination mode 1.

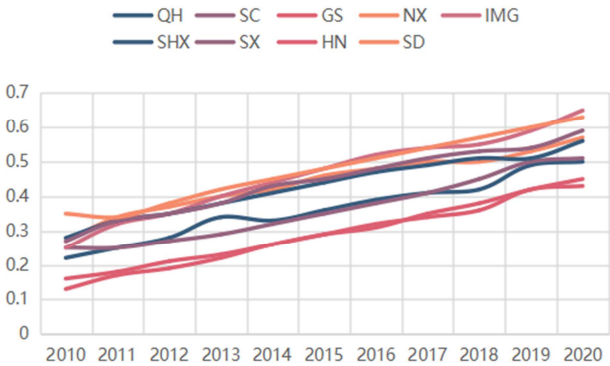


Figure 1. The comprehensive index.

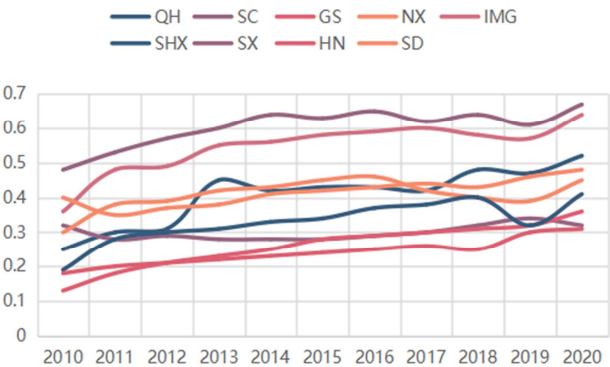


Figure 2. The ecological environment subsystem index.

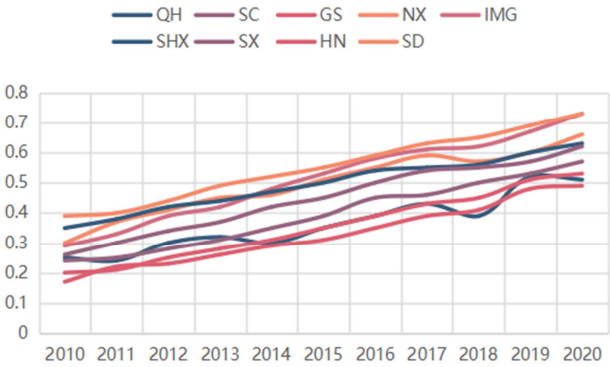


Figure 3. The urbanization subsystem index.

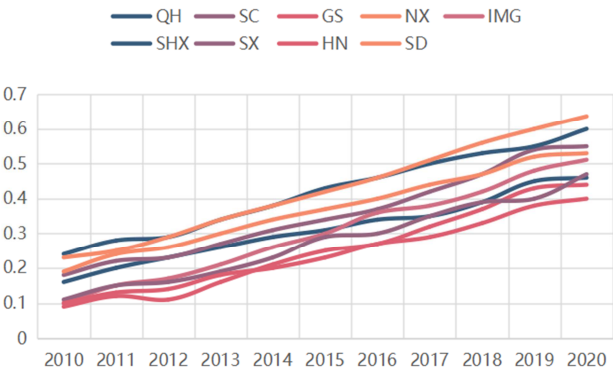


Figure 4. The high quality economic development subsystem index.

In the Figure 1, QH, SC, GS, NX, IMG, SHX, SX, HN, SD respectively represent Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong. From Figure 1, the comprehensive evaluation index of ecological environment, urbanization, and high-quality economic development of the nine provinces along to the Yellow River Basin has a steady trend up, which means the overall development is getting better. Specifically, there are many differences in the comprehensive evaluation index among the nine provinces. It is likely to be caused by the differences in aspects of the natural geographical environment and government policies. It displays as Shandong > Inner Mongolia > Shanxi > Ningxia > Shaanxi > Qinghai > Sichuan > Gansu > Henan. Shandong is located on the east coast of China, with convenient transportation and a high level of urbanization. Its comprehensive development evaluation index has always ranked first in the nine provinces. It achieves high-quality economic development by transforming old and new kinetic energy. In particular, Shandong Province prioritized sustainable development, implemented, and achieved high-quality economic development in recent years. As an important area under the Belt and Road initiative, Inner Mongolia has good development. Its comprehensive development index is close to Shandong province, with natural advantages such as the vast natural grassland and the rich natural resources. Four provinces also developed results by the Belt and Road initiative, including Ningxia, Shaanxi, Qinghai, and Gansu. And their comprehensive development index is on the rise. In

the inland area of China, Henan province is a largely agricultural province. The urbanization process is slow, the economy is underdeveloped, and its comprehensive development index is at the bottom. But nowadays, Henan has begun to digital economy strategy, which will lead to improvement.

Figure 2 shows the situation of ecological environment. The ecological index of the nine provinces along to the Yellow River at a low level but increasing year by year. Base on comparison, the index of Shanxi and Inner Mongolia is higher than the others. For Shanxi, known as a “coal sea” because of the richness of coal reserves, it has made great efforts to control the ecological environment in recent years, which has been proven effective. As for Inner Mongolia, it gets benefits from geographical location and natural resources. The index of Qinghai fluctuates widely. And the index of Sichuan is found a U-shaped. Besides, for Ningxia, Shandong, Shaanxi, Gansu, Henan, they have a less fluctuation rang.

Figure 3 shows the situation of urbanization. The upward trend is obvious, and the level gap gradually narrows among these provinces. Topping that list is Shandong which is located on the east coast. For Inner Mongolia, it is following Shandong with a narrow gap. There is a similar uptrend between Ningxia and Qinghai. The urbanization process is promoting. The index of Shaanxi is lower than Inner Mongolia and Ningxia, caused by the slow process. The Shanxi, Sichuan and Henan index also shows an upward trend, although it is not high. Gansu is at the bottom, though the gap has narrowed significantly. In general, urbanization has achieved remarkable results, as the rural people move to cities, and agricultural labor has been transformed into non-agricultural work. People's living standards have been improved.

Figure 4 shows the situation of the economy. The index uptrends of these nine provinces are the same. The economic development of Shandong is at a relatively high level, and Shaanxi's economic growth is following Shandong's, with the steady raising. Sichuan is as same as Ningxia, and their economic development also has a similar uptrend and improved stability. There is a similar upwards trend between Inner Mongolia and Shanxi, with slow lifting speed. Qinghai and Gansu are in the middle of economic development, and they fluctuate very little. As for Henan, which is at the bottom, there is a wide gap with other provinces, although it is rising with low speed. In a word, the economic development of these nine provinces is creasing driven by innovation, and there is balanced economic development by realizing the upgrading and optimizing the industrial structure.

3.2. The Coupling Degree and Coordination Degree

According to the coupling degree model and coordination degree model, there is a gradual evolution of coupling degree and coordination degree among ecological environment subsystem, urbanization subsystem and economic development subsystem from 2010 to 2020.

With regard to coupling degree, which is shown in table 3, it is obtained that the result is fairly above 0.9. The relevance is strong among the three subsystems. That means all provinces in the Yellow River Basin should consider ecological environment protection and urbanization process while developing the economy with great effort. Qinghai is on the top of the list because the effort on the ecological environment has a good impact on the urbanization process and high-quality economic development. The biggest fluctuation is Inner Mongolia and Shanxi, increasing to 0.95 from the bottom 0.85 because they actively respond to green strategy when developing the economy and promoting urbanization. There is a consistent trend among Shaanxi, Henan and Gansu, which keep stable above 0.96 after 2009. As for Sichuan, the coupling degree is not steady on the contrary. It is under the influence of natural disasters, which further impacts economic development and the urbanization process. The coupling degree of Shandong and Ningxia is at a high level with increasing slowly; the three subsystems are mutual enhancement.

Table 3. The coupling and coordinated development of three subsystem in the Yellow River Basin.

Province	Comprehensive index value	Coupling degree	Coordination degree
Qinghai	0.496848	0.987652	0.60494
Sichuan	0.490933	0.968674	0.591327
Gansu	0.424224	0.961827	0.550423
Ningxia	0.533384	0.967706	0.616269
Inner Mongolia	0.596489	0.941058	0.659083
Shaanxi	0.51861	0.956632	0.600121
Shanxi	0.541071	0.938544	0.628961
Henan	0.421724	0.95094	0.545204
Shandong	0.605954	0.966356	0.65774

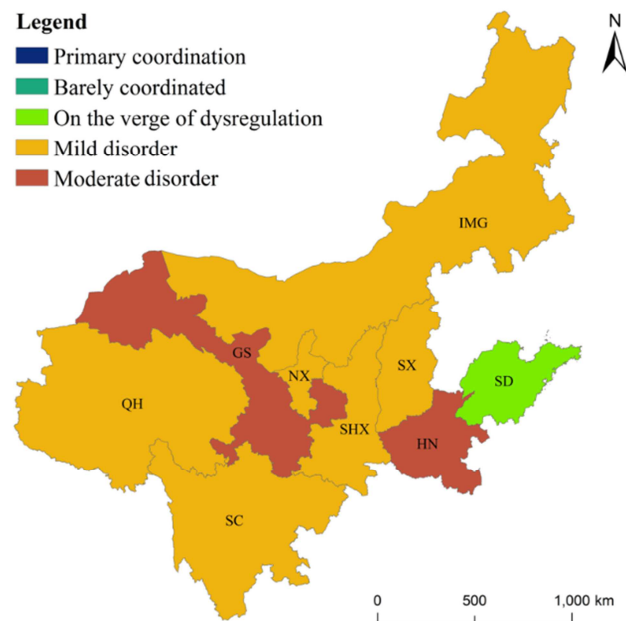


Figure 5. Coordination degree in 2010.

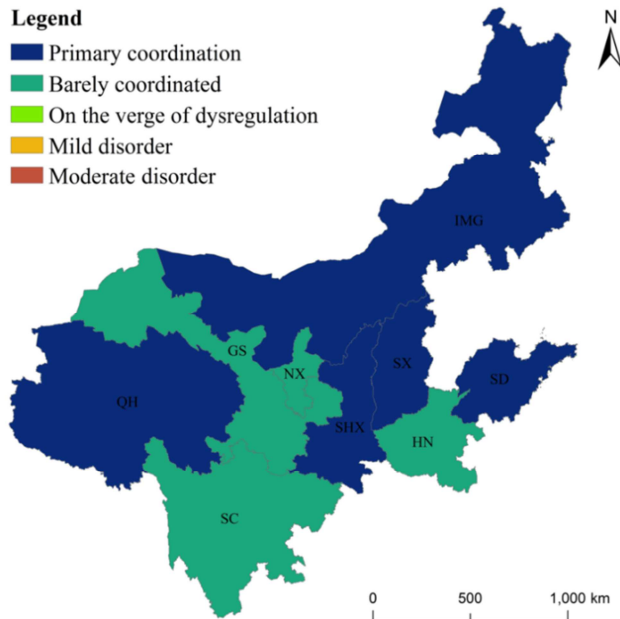


Figure 6. Coordination degree in 2020.

Concerning coupling coordination degree, the evolution map was established to show the coordination situation of the nine provinces classified the nine provinces from 2010-2020, using ArcGIS (Figure 5 and Figure 6). QH, SC, GS, NX, IMG, SHX, SX, HN, SD respectively represent Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong. In the beginning, the coupling coordination degree was disorder with widely difference, and it is getting coordinated after 10 years. Gansu and Henan has become barely coordination from Moderate disorder. It is Shandong that has minimal alteration, shifting to primary coordination from Verge disorder. And other provinces have also get into the stage of Primary coordination from a different beginning.

It is known from Table 3 that the coordination degree is between 0.5 and 0.65. Any hysteresis in ecological, urbanization and economic development negatively influence coordination. Across the board, the coordination degree is on an uptrend, and the environmental environment government is more effective. Urban infrastructure is being improved, and society is more energetic driven by innovation. The coordination degree of Shandong has been at the forefront for ten years because it has implemented the "five in one" and paid attention to ecological environment protection and public facilities construction during the economic development. The coordination degree of Gansu and Henan is on the rise, but the level of coordination degree is very low. The high-quality economic development subsystem level lags behind the ecological environment subsystem and urbanization subsystem. The coordination degree of Sichuan and Qinghai is at a low level. The ecological environment in Sichuan Province mainly inhibits the coordination degree level. It is imperative to strengthen the ecological environment protection. Qinghai is primarily affected by the economy and urbanization. Accelerating economic

development and promoting the process of urbanization is the primary task of Qinghai. The changing trend of system coordination degree in other provinces is the same, and the level of coordination degree has little difference, which is at the level of prior coordination.

4. Conclusion and Suggestion

Based on the 2010-2020 time-series data of the Yellow River Basin, this paper analyzes the changes in the ecological environment, urbanization and high-quality economic development by constructing a comprehensive evaluation index system using the entropy method and the coupling coordination degree model. The conclusions are as follows:

From 2010 to 2020, the total evaluation index value of the ecological environment, urbanization and high-quality economic development in the Yellow River Basin has been continuously improved. And the importance of the environmental index is significantly lower than the urbanization index and high-quality economic development index. The coupling degree is relatively high and shows a steady upward trend. The three subsystems are highly correlated and have strong interactions. According to the result of the coordination degree, we can conclude that the system coordination degree is in a steady upward trend. And, as a whole, it is shifting to order from disorder and getting to the level of coordination.

The Yellow River Basin and the Yangtze River Delta have different "ecological environment-urbanization-high economic quality" systems. As an advanced manufacturing base and national science and technology innovation center, the economic development of the Yangtze River Delta provides strong support for the sustainable development of society and the environment [5, 6]. The nine provinces in the Yellow River Basin face a damage of the environment, due to resource-based industries and traditional agriculture. It takes time to repair the damage, though the policy in promoting ecological protection has been raised and implemented.

Some papers in the Yellow River Basin mainly analyzed from the two-dimensional perspective of urbanization and ecological security. Researches showed that the rapid development of urbanization had brought about negative impacts such as the increase in wastewater discharge. Those take threats to the ecological security of the basin [9, 11]. Based on the important strategic position of the Yellow River Basin and the particularity of the ecological environment, this paper constructs a three-dimensional analysis system of "ecological environment-urbanization-high economic quality" system.

Based on the above research conclusions, this article combines the ecological environment, urbanization and high-quality economic development in the Yellow River Basin, and suggestions are as follows:

(1) Reasonably allocate resources and improve resource utilization. So far, the infrastructure of the Yellow River Basin is not sufficient, natural resources cannot meet the requirements of urbanization and high-quality economic

development, and the lagging of ecological, environmental protection restricts the process of urbanization and high-quality economic development. Therefore, it is necessary to increase ecological, environmental protection and promote environmental protection in the future. The development of a friendly society will enable the rational allocation of resources in the Yellow River Basin, improve the resource supply system, increase resource utilization, save energy, reduce emissions, and take the path of sustainable development. From 2010 to 2020, the coupling degree of the nine provinces is going up above 0.95 form below 0.9, and the gap is narrowing sharply.

(2) Reasonably plan the urban layout and improve the overall functions of the urban agglomeration. Sorting out the development planning layout of large and small cities, coordinating population development, infrastructure, public services, urban spatial structure and ecological environment, and other factors. Further, we can integrate regional urbanization development resources, support population agglomeration and industrial structure evolution, and improve the urban population security service system and infrastructure construction to inject vitality into promoting the construction of a new stable, healthy and green city. For example, Shandong Province has given full play to its coastal advantages, increased population carrying capacity, actively attracted foreign talents and cultivated outstanding enterprises. While bringing impetus to urban development, it also radiated other provinces in the Yellow River Basin and promoted the common development of the Yellow River Basin.

(3) Optimize the industrial structure and promote coordinated development. The provinces of the Yellow River Basin should gradually eliminate heavy industrial enterprises with high pollution, high energy consumption and high cost, improve human resource level, cultivate and introduce high-quality talents, increase investment in technological innovation, build a regional innovation system. In 2010, the coupling coordination degree was disorder with widely difference. Shandong is the region with the highest degree of coordination, up to 0.605954, and Henan is the region with the least degree of coordination, only 0.421724. It is getting coordinated after 10 years in the Yellow River Basin.

The government should strengthen the guidance of innovation and entrepreneurship. Cultivate the spirit of the regional invention. Promote the integrated development of various resources in the region, focusing on the development of modern service industries with high technology, high added value and low energy consumption, and fundamentally improve the ecological environment of the Yellow River Basin. While promoting the process of urbanization and accelerating high-quality economic development in the Yellow River Basin, it must also pay attention to ecological protection, increase environmental carrying capacity, and promote the coordinated development of ecology, urbanization, and economy.

(4) Continue to evaluate and reflect and establish a

multi-dimensional assessment system. In the coordinated development of the ecological environment, urbanization, and high-quality economic growth in the Yellow River Basin, the level of coupling and coordinated development should be repeatedly determined. The overall level of development of the Yellow River Basin should be judged according to the coordination degree. Its development advantages and disadvantages should be balanced to promote coordinated development. At the same time, a scientific leadership performance evaluation mechanism should be established. Based on measuring their economic growth, the evaluation of indicators such as population resources, infrastructure, ecological environment, and social security should be emphasized. It is necessary to pay attention to both the speed of development and the quality of the product.

Conflict of Interests

The authors declare that they have no competing interests.

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