ANALYSIS ON THE COUPLING CHARACTERISTICS OF URBAN ECOLOGICAL STRUCTURE AND LOCAL ECONOMY IN THE YELLOW RIVER BASIN

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ABSTRACT

The Yellow River Basin is an important part of China's ecological protection areas, but the stable development of the Yellow River Basin cannot be guaranteed due to the unreasonable setting of the local ecological structure and the slow pace of economic development. Many scholars at home and abroad have researched the ecological structure and urbanization level of the Yellow River Basin, but there is still a lack of work to analyze the coupling characteristics of the two. In this paper, the entropy weight method is used to study the coupling characteristics of economic development and ecological structure in the Yellow River Basin. The ecological environment, urbanization evaluation system and the ecological environment and urbanization coupling coordination characteristic evaluation system are constructed. The results show that the comprehensive evaluation coefficient of urbanization has increased by 276.2% from 2011 to 2020. The annual average increase of the comprehensive evaluation index of the ecological environment is over 35%. The degree of matching between the level of urban modernization and the ecological environment is basically above 95%.

KEYWORDS

Yellow River Basin; ecological architecture; urbanization; economic development; coupled and coordinated characteristics

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1. INTRODUCTION

China's economic development has accelerated the process of urbanization, which is the most important way to achieve industrialization and modernization and is given great attention by governments everywhere. From the birth of New China in 1949 to the period of reform and opening up in 1978, the level of urbanization in China has increased by about 50% [1-3]. After entering the 21st century, China's urbanization rate ranks relatively high in the world. Among them, the Yellow River Basin, as an ecological reserve in China, plays an important role in ensuring national ecological security and promoting economic development [4-6]. Before 1949, due to the conflict between natural resource development and economic development, the ecological structure of the Yellow River Basin could not be kept in balance. After that, the state intensified efforts to control the ecological environment in the Yellow River region, and the ecological structure was improved to a certain extent. Despite the obvious effect, the stable and sustainable economic development of the Yellow River Basin is still constrained by the ecological structure and economic scale. [7-11]. Therefore, it is necessary to adjust the ecological structure of the Yellow River Basin to promote the economic development of the Yellow River Basin.

In 2020, China proposed the key task of integrating new urbanization construction and urban and rural development, which clearly proposed to promote a high-quality new urbanization development strategy. As an important ecological sphere in China, improving the level of urbanization in the Yellow River Basin is an important means to ensure high-quality economic development [12-14]. One of the important factors affecting the economic development of cities in the Yellow River Basin cities is the ecological architecture of urbanization. The destruction of natural resources and their unbalanced use has led to the ecological structure of urbanization in an unstable state. The instability of the ecological structure of urbanization will in turn lead to an uncoordinated rate of economic development, which will result in lagging development. There are many advanced technologies available for surveying the distribution and exploitation of natural resources in the Yellow River Basin, which can help workers to obtain timely information data and take political measures [15-22]. The relationship between the level of urbanization and the regional economy is closely related, and there are many studies on the relationship between the two at home and abroad. The main focus is on the following three aspects. The first is the study of basic theory. The theoretical research mainly focuses on the complex model of urban ecological structure and economic development from the perspective of the "human-land" relationship. The second is the evolution pattern of the ecological structure of urbanization, exploring the dynamic pattern between the level of economic development and the ecological structure of urbanization. The third is to construct a coupled coordination model between urbanization ecological structure and economic development and analyze the influence of urbanization ecological factors on the speed and scale of economic development. The third type of these studies is a more intuitive way to grasp the coordinated development relationship between the two, and a number of scholars have conducted related studies [23-25].

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Li et al [26] evaluated the coupled coordination degree (CCD) of PLES using temporal and spatial models and found that elevation, temperature, economy, and population were the main factors affecting CCD. By regulating these factors, land use can be effectively optimized and further ecological deterioration can be mitigated. Ma et al [27] constructed a long-term and short-term memory neural network model to explore the relationship between economic development and development intensity affecting the upper, middle and lower reaches of the Yellow River basin. The results showed that a 6.5% economic growth rate is more conducive to environmental protection compared to 7% and 6% economic growth rate development patterns, then the balance between ecological structure and economic development reaches the ideal state. Shi et al [28] used Graphab software to construct a holistic landscape heterogeneity analysis ecological network to analyze the ecological situation of the Yellow River basin, in which morphological spatial pattern analysis (MSPA) and structural equation modeling (SEM)) were used to identify ecological source areas and determine the resistance surface. The results indicate that the rational use of highly heterogeneous areas is an effective way to maintain the long-term stable development of the ecological structure of the Yellow River basin. Shi et al. [29] constructed a dynamic panel and a systematic generalized method of moments to predict the influencing factors of the urbanization level in the Yellow River Basin. The results show that while the urbanization of the Yellow River Basin is improving, the unreasonable economic development and urban scale layout still have an impact on the further development of urbanization. Wei et al [30] used an efficient data envelope method to determine the relationship between water use efficiency and urbanization level in the Yangtze River basin over a decade. The results showed that the level of economic development and the proportion of water resources can enhance water use efficiency. Chai [31] et al. used social network analysis to analyze the structure of the Yellow River basin based on a two-way "time distance" modified gravity model between cities. The results show that the relative strength of the linkages between cities in the Yellow River basin constrains economic development to some extent. It is possible to build a chain of urban centers by strengthening the linkages between subgroups to enhance economic exchange. Gong [32] constructed a spatial lag model and an error model with the objective of promoting high-quality development in the Yellow River basin. The relationship between economic growth, industrial structure and urbanization level and ecological structure layout of the Yellow River basin was analyzed. The results show that carbon emissions and economic growth rate in the Yellow River Basin show a "U" shaped KFC curve, and carbon emissions affect economic growth. Rong et al [33] investigated the relationship between economic index (EC) and environmental carbon emissions by analyzing the ecological structure and using the (STIRPAT) model. The results suggest that the ecological structure between Zhengzhou, Jinan, Zhoukou and Shangqiu is not reasonably coordinated, thus affecting the further development of the ecological economy.Solarin, SA [34] applied a new type of dynamic regression distribution lag model was used to predict, in which carbon dioxide emissions were selected as the research variable. The results show that the relationship between economic development and ecological structure is relatively complex. Economic growth will lead to environmental deterioration in a short

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period, but the development of urbanization will be less affected. From the perspective of development, promoting economic development can improve environmental quality after a certain period. As a whole the current research on economic development and ecological structure of towns by domestic and foreign scholars is multi-faceted. The content is relatively rich, but there is a lack of more systematic research. Moreover, most of the previous research work focused on the relationship between the economic development of the Yellow River Basin and various environmental factors and did not give the specific characteristics of the coupling between the economy and the environment. Moreover, the previous studies were relatively simple and did not discuss the relationship between the environment and the economy from multiple perspectives. The economic and environmental factors are interrelated and affect each other. Economic regression will lead to the decline of all aspects of the ecological environment, and eventually imbalance. The destruction of the ecological balance and the fragmentation of these ecological factors will lead to poor connections between various links of economic development and ultimately affect economic development. The analysis of the coupling characteristics helps to understand the development law between the two and has theoretical guidance for further economic improvement.

To sum up, this paper aims to promote the economic development of the Yellow River region and balance the ecological environment. Taking the evaluation of the relationship between the urbanization level and the ecological structure as the starting point, three evaluation indicators are constructed, which are the evaluation index of the ecological environment of the Yellow River Basin, the evaluation index of the local economy, and the evaluation index of the urbanization level and the coupling coordination characteristics of the regional economy. The coupled coordination relationship between urbanization and ecological environment subsystems in the Yellow River Basin is compared from two dimensions of time and space, and the economic development level of the Yellow River Basin is measured.

2. RESEARCH METHODOLOGY

2.1. ENTROPY METHOD

This paper chooses 2011-2020 as the time point to enumerate the ecological structure of urbanization in the Yellow River Basin as well as the economic development. The comprehensive ecological and environmental index, the urbanization index of the Yellow River basin and the analysis of the coupling and coordination characteristics of urbanization and environment are analyzed. Firstly, population, economic and urbanization indexes are selected to constitute a comprehensive evaluation system. Several indicators are selected to measure the interaction between the economy and the environment and the current situation of the ecological environment, and the weight of the indicators is determined by the entropy value method.

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The entropy method used in this paper is relatively scientific and reasonable compared with the hierarchical analysis method and subjective assignment method, and it has been applied more often in academic research, especially in research related to regional economic development strategies. The entropy method was constructed in this paper to assign weights to the indicators of the factors influencing the level of urbanization development in the Yellow River Basin. In the analysis of the entropy method, it is necessary to have a clear understanding of the research object. How many indicators are in the urbanization index system constructed in this paper, how many of them are positive indicators and how many are negative indicators? Then the data needed for the study are dimensionless using the normalization method commonly used in mathematics. It is worth noting that zero values may appear in the process of dimensionless processing. At this point, the zero values are to be processed by shifting all the data to the right by one unit. The treatment of negative indicators is simply a matter of changing the sign in the numerator. The specific equation is shown below:

$$x_i = \frac{x_i - \min\{x_1, \ldots, x_n\}}{\max\{x_1, \ldots, x_n\} - \min\{x_1, \ldots, x_n\}} \tag{1}$$

where denotes the dimensionless parameter, $x_1, \ldots, x_n$ denotes the $1st, \ldots, n$ indicator.

$$p_i = \frac{x_i'}{\sum x_i'} \tag{2}$$

P_i represents the weight of the i data in the index. The entropy value of the i indicator is expressed as follows, where n denotes the number of samples.

$$e_j = -\frac{1}{\ln(n)} \sum P_i \times \ln\left(P_i\right) \tag{3}$$

The weights of each indicator are calculated as shown below, where G denotes the weight of each indicator.

$$W_j = \frac{G_j}{\sum G_j}, j = 1,2,\ldots\ldots, \mathrm{m} \tag{4}$$

Then a comprehensive evaluation index was constructed, and the expression of the evaluation index is shown below.

$$U_1 = \sum_{i=1}^{n} w_i y_{ij} \tag{5}$$

$$U_2 = \sum_{i=1}^{n} w_j y_{ij} \tag{6}$$

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Where W_{ij} denotes the weight of the index, and y_{ij} denotes the standardized index. U_1 denotes the comprehensive evaluation index of urbanization, and U_2 denotes the index of ecological environment structure.

2.2. PHYSICAL MODEL OF COHERENCE

Then a physical model of the degree of coordination between urbanization and ecological coupling is constructed. Coupling represents the phenomenon of interaction or interrelationship within a large system and between the system and the outside. The concept is often used in describing the relationship between variables. The Acuity Coordination Degree describes the degree of coupling between the level of urbanization in the Yellow River Basin and the relationship between local economic development. The formula for the degree of coupling is shown below.

$$C = 2 \times \left(\frac{U_1 \times U_2}{\left(U_1 + U_2\right)^2} \right)^{0.5} \tag{7}$$

$$D = \sqrt{C \times T}, T = \alpha U_1 + \beta U_2 \tag{8}$$

C is a dimensionless number representing the degree of interaction between the level of urbanization and the level of economic development in the Yellow River Basin and takes a value between 0 and 1. The larger the value of C, the more obvious the interaction between the two. T indicates the comprehensive evaluation index of urbanization level and economic development. α, β denotes the uncertainty coefficient. According to the index system constructed above, the results shown in Table 1 and Table 2 can be obtained. U_1 denotes the comprehensive evaluation index of urbanization, and U_2 denotes the index of ecological environment structure.

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Table 1. Evaluation index system of urbanization in the Yellow River Basin

Target layer	Criterion layer	Indicator layer	Attributes	Weights
Urbanization level	Population	Population density	+	56
		Population urbanization rate	+	75
		Population growth rate	+	183
		Unemployment rate	-	39
	Economy	GDP per capita	+	68
		Proportion of output value	+	44
		Total social consumption per capita	+	81
		GDP growth	+	72
	Society	Occupancy rate	+	46
		Urban per capita disposable income	+	75
		social security spending ratio	+	62
		Urban traffic level	+	78
	Integration	Ratio of urban and rural per capita disposable income	-	77
		Urban and rural per capita consumption expenditure ratio	-	65

Table 2. Ecological environment evaluation index system of the Yellow River basin

Target layer	Criterion layer	Indicator layer	Attributes	Weights
Ecosystem	Pressure	GDP energy consumption growth rate	-	105
		Industrial wastewater discharge per capita	-	146
		per capita sulfur dioxide emissions	-	179
		Tobacco powder emissions per capita	-	112
	State	Green coverage	+	58
		Per capita water resources	+	142
		Green area per capita	+	69
	Response	Sewage treatment rate	+	44
		Pollution-free treatment rate of garbage	+	57
		Green planting area	+	69
		Industrial waste utilization	+	55

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In the constructed index evaluation system, ecological environment and urbanization are viewed as having consistent importance. Therefore, the values of the uncertainty parameter α, β uncertainty parameter in this paper are taken as 0.5. According to the relationship between urbanization and economic development level, the paper classifies the coupled coordination degree of urbanization level and ecological environment in the Yellow River Basin into four categories, as shown in Table 3.

Table 3. Classification of types of coordinated development of ecological environment and town modernization in the Yellow River Basin

Development stage	Degree of coordination	Subclass	Comparison between U_1 and U_2	Basic type
Coordinated development	[0.6,1.0]	Coordinated development（IV）	$U_1-U_2>0.1$	Coordinated development - ecological environment lagging type（IV-1）
			$\|U_1-U_2\|\geq 0.1$	Coordinated Development – Synchronized （IV-2）
			$U_2-U_1>0.1$	Coordinated Development - Lagging Type of Urban Modernization（IV-3）
Transitional phase	[0.5,0.6)	Barely coordinated development（III）	$U_1-U_2>0.1$	Barely coordinated - ecological environment lagging type（III-1）
			$\|U_1-U_2\|\geq 0.1$	Barely coordinated-synchronized （III-2）
			$U_2-U_1>0.1$	Barely coordinated - lagging urban modernization （III-3）
	[0.4,0.5)	On the verge of deficient decline（II）	$U_1-U_2>0.1$	On the verge of disorder - ecological environment lagging type（II-1）
			$\|U_1-U_2\|\geq 0.1$	Near-disorder-synchronized（II-2）
			$U_2-U_1>0.1$	On the verge of dissonance - lagging type of urban modernization （II-3）
Dissonance stage	[0.0.4)	Dissonance Decline（I）	$U_1-U_2>0.1$	Dissonance Decline - Ecological Lag Type （I-1）
			$\|U_1-U_2\|\geq 0.1$	Detuned decay-synchronized（I-2）
			$U_2-U_1>0.1$	Unbalanced Decline-Lagging Type of Urban Modernization（I-3）

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3. ANALYSIS OF RESULTS

The Yellow River Basin covers nine provinces and regions of Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong, and is an important economic belt in central and western China. This puts forward higher requirements for the protection and management of the ecological environment, so it is necessary to do a good job of ecological protection in the Yellow River Basin. While promoting high-quality economic development, we must also take into account the balance between the economy and the environment. To this end, this section evaluates the ecological construction and economic construction of the Yellow River Basin and proposes the comprehensive evaluation indicators of the two and the coupling characteristics of comprehensive analysis.

3.1. COMPREHENSIVE EVALUATION INDEX ANALYSIS OF TOWN ECOLOGICAL ENVIRONMENT AND LOCAL ECONOMY

Urban ecological environment and local economic development are closely related, and it is necessary to study the combined index of both. On this basis, the coupling and coordination characteristics between the two can be better described. The following will be a specific analysis of the town's ecological environment and the degree of regional urbanization construction respectively.

3.1.1. COMPREHENSIVE INDEX ANALYSIS OF THE URBAN ECOLOGICAL ENVIRONMENT

From 2011 to 2020, with the promulgation of national policies and the vigorous propaganda of local governments, the concept of "green water and green mountains are the silver mountain of gold" has become more and more popular. The overall ecological environment level of the Yellow River Basin towns shows a fluctuating upward trend, as shown in Figure 1. It can be broken down into the following three trends.

2011-2014, the stable development phase. In these four years, the development rate was the fastest in 2011, while the development leveled off in the following two years. the development rate between 2013 and 2014 was the same as that in 2012. The main reason is that the provinces, cities and towns in the Yellow River Basin have caused greater damage to the ecological environment in the past due to their transitional dependence on the exploitation of local natural resources. Take Shanxi Province as an example, as a typical resource-based province and city. The long-standing reliance on coal and other non-renewable energy sources and a single industrial production method has led to serious ecological and environmental problems. Since the government's intervention during the 11th Five-Year Plan, many provinces and cities in the Yellow River Basin have been implementing pollution

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reduction and building "blue sky and blue water projects", and ecological environmental protection work has begun to change.

From 2015 to 2017, the fluctuating development stage. This phase shows a specific trend of rising and then declining, with the ecological environment construction efficiency rising in 2015-2016. 2016 was the year with the highest level of regional ecological environment construction in this period. In this period, all regions of the Yellow River Basin took active and effective measures for ecological management, however, pure ecological prevention and control cannot solve the fundamental problems. The ecological environment is a protracted war, purely under prevention and control due to the lack of effective treatment measures, no publicity on the importance of anti-pollution and there is situation of pollution while treatment. There was even a time when the degree of pollution was higher than the degree of ecological environment treatment, exposing the contradictory relationship between ecological environment construction and economic and social development. Thus, there was a decline in the degree of ecological environment in 2016-2017.

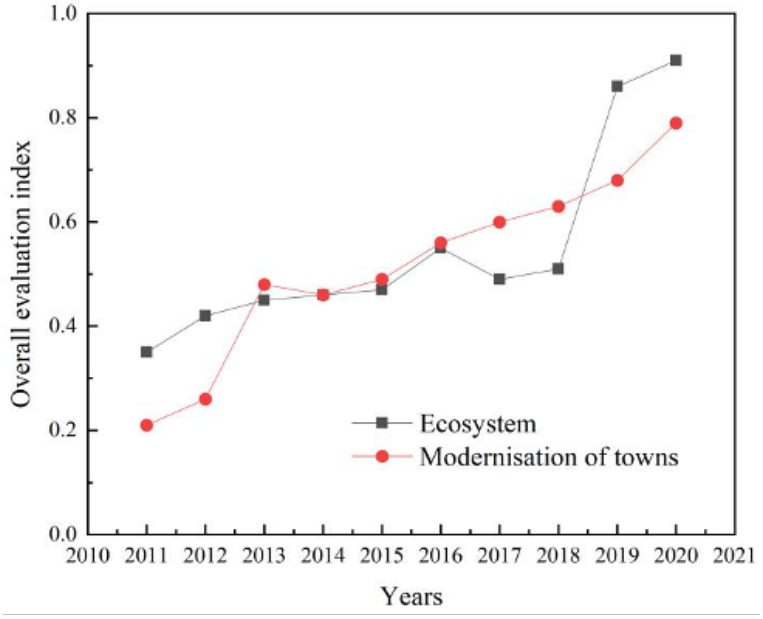

Figure 1. Evaluation of the comprehensive index of modernization and ecological environment of towns in the Yellow River Basin

2018-2020, the rapid development phase. During these three years, the comprehensive evaluation index of ecological and environmental management in each region of the Yellow River Basin shows a historical spike. This is mainly because the regions actively explore industrial transformation and development within this phase, and set clear standards for the pollution emissions of factory enterprises. In particular, in 2019, Secretary Xi Jinping said at the Symposium on Ecological Protection and High-Quality Development in the Yellow River Basin, "The Yellow River Basin is an important ecological reserve in China and plays a very important role in my country's economic and social development". This has placed higher demands on ecological management in the Yellow River Basin regions and has yielded immediate results. In 2019, the negative indicators of industrial wastewater, dioxide, and

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industrial waste gas smoke particles all showed significant reductions compared to 2017. Emissions of industrial wastewater decreased by 39.6%, emissions of SO_2 decreased by 62. 7% and emissions of industrial exhaust smoke particles decreased by 73.5%.

3.1.2. COMPREHENSIVE URBANIZATION INDEX ANALYSIS

During the nearly ten years from 2011 to 2020, the level of urbanization in the Yellow River Basin regions is generally on an upward trend, with slower development in the first two years. The main reason for this is that since the impact of the global financial crisis in 2008, the prices of abundant coal resources and other resources in the Yellow River Basin have dropped significantly. Therefore, there is a serious overcapacity, which has impacted the development of coal companies. Especially for the central and western regions, such as Gansu Province, where most of the youths with low education have become more difficult to be employed. In addition, in the Sichuan basin, due to the Wenchuan earthquake in 2008, the modernization of towns in the local region was slow in the post-earthquake home reconstruction and recovery phase. After rebuilding homes, reshaping industrial chains and local governments stepping up investment and paying attention to education development, there was a period of growth between 2012 and 2013.

During 2013-2014, the growth rate development was leveled off. During this period, the government began to increase its efforts to build local infrastructure, provide more convenient and efficient transportation, establish stronger healthcare measures, and continuously improve the level of social and public services. At the same time, the government began to gradually reduce the level of capacity intervention, focusing on cultivating the local people's self-development ability, training employment knowledge, increasing employment opportunities, and providing strong support for people to escape from poverty and become well-off. The year 2014 was also the year when the degree of ecological environment construction and the degree of urban modernization were the closest, indicating that the governments in the Yellow River Basin paid attention to the protection and construction of the ecological environment along with economic construction during the year.

Table 4. Comparison of government economic interventions in the Yellow River Basin, 2011-2014

Indicator name	Estimated year			
	2011	2012	2013	2014
The level of economic development	842	875	926	917
Percentage of infrastructure	367	384	413	457
Government intervention	865	914	907	896

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The year 2020 is the decisive year in the battle against poverty and the year when the whole country will achieve prosperity. It can be seen that this year, the modernization of towns in the Yellow River Basin reaches its peak. This is mainly due to the effective implementation of a series of anti-poverty policies introduced by the central government and the strong support provided by local governments in terms of resources, education and employment. The development of each region has entered a reasonable range since 2014, and the primary, secondary and tertiary industries have achieved good results in a smooth transition. The economic structure shows positive changes, with the output value ratio of primary, secondary and tertiary industries at 5.2:49.4:58.5. New production capacities such as tourism and the Internet economy have played a significant role in leading innovation, resulting in a significant increase in the overall evaluation index of the modernization of towns.

The higher the coincidence of the two curves shown in Figure 1, the closer the environmental and economic development rates are, but it is not that this is better, for example, the higher the overlap of the two, the development of both may be relatively slow, 2011-2012 The deviation is significantly due to the slower economic development than the construction of the ecological environment, 2017-2018 The deviation between the years is significantly due to the government's economic policies to stimulate the process of urban modernization so that economic development began to catch up with the construction of the ecological environment.

3.2. ANALYSIS OF THE COUPLING AND COORDINATION CHARACTERISTICS OF TOWN MODERNIZATION AND ECOLOGICAL ENVIRONMENT

The general situation of each region in the Yellow River Basin is analyzed. The coupling degree and coupling coordination degree of urbanization and ecological environment is calculated through the comprehensive evaluation index of the two. The result is shown in Figure 2. It can be seen from the figure that the coupling degree between urban modernization and the ecological environment of the whole Yellow River Basin region is above 0.95 in the decade of 2011-2020, except for 2012. The high level of coupling between urban modernization and the ecological environment indicates that the interaction between economic and ecological systems in the Yellow River Basin is high, and the low coupling degree in 2012 is mainly due to the economic downturn and slow development in that year. This led to the degree of modernization of towns and cities lagging behind the construction of the ecological environment, while the comprehensive ecological environment evaluation index increased steadily during the year.

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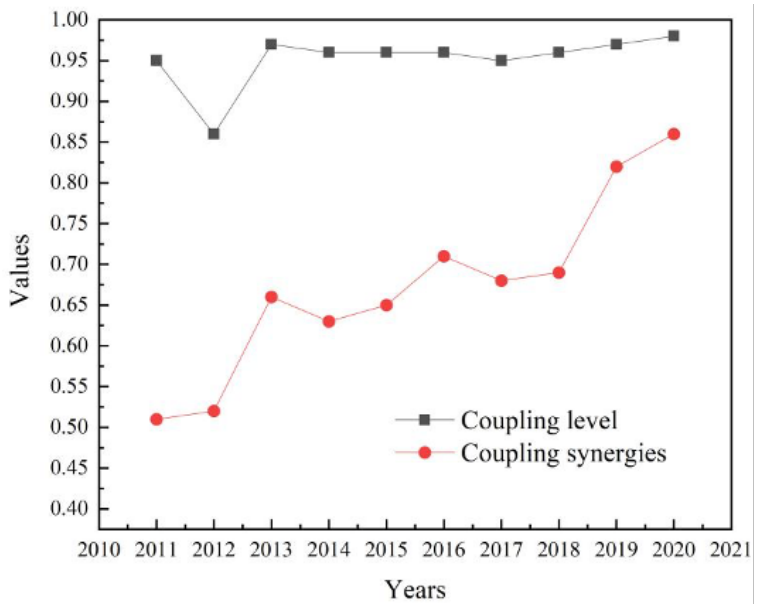

Figure 2. Coupling degree and coupling coordination degree of urban modernization and ecological environment in the Yellow River Basin

Although the coupling degree can reflect a certain extent the degree of interaction between the modernization of towns and the construction of an ecological environment, it does not reflect whether they promote each other at a high level or constrain each other at a low level. For this reason, this paper calculates the coupling coordination degree according to the relative situation of different development levels between the two systems. The categories of mutual influence between urban modernization and the ecological environment are identified, and the results are shown in Table 5.

Table 5. Basic types of coupling and coordination between urban modernization and ecological environment

Year	2011-2012	2013-2016	2017-2018	2019-2020
Type	Barely coordinated - backward type of urban modernization（II-3)	Coordinated development - synchronous type（IV-2)	Coordinated development - ecological environment lagging type（IV-1)	Coordinated Development - Lagging Type of Urban Modernization

It can be seen that the situation of coordination between urban modernization and the ecological environment in the Yellow River Basin has been improving in the last decade. From 2011 to 2012, it is a barely coordinated and lagging type of urban modernization, and from 2013 to 2020, it is a coordinated development type. In 2013, as the economy recovered, the ecological protection of the environment also progressed steadily. Thus a period of synchronous development between the two systems was ushered in, but synchronous development only means that the gap between the two became smaller. This does not mean that the pace of development will be the same, for example, in the period 2013-2014 the modernization of towns will

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be slightly faster than the ecological construction. It also does not mean that a higher level of growth is ushered in, but rather that it is in constant development. After 2017, there was a small slowdown in ecological construction in the Yellow River Basin, mainly due to a decrease in precipitation across several provinces and cities in the Yellow River Basin during this period. the total average precipitation decreased by 9.4% and 11.5%, respectively, between 2017 and 2018, and also the recycling rate of industrial solid discharges, etc., decreased by about 6.8%. In 2019, ecological protection also reached a new climax as General Secretary Xi introduced the concept of the Yellow River Basin as an important ecological barrier and an important economic zone for China. The year 2020 is a decisive year for poverty alleviation and economic development, and the construction of the ecological barrier will be further improved to ensure that poverty is not returned. The construction of urban modernization will be slightly behind the construction of an ecological environment.

4. DISCUSSION

This paper takes each region of the Yellow River Basin as the research object and considers a variety of situations. A comprehensive index evaluation is made from the total degree of urbanization and the degree of ecological environment construction. The development level is also measured by comparing the coupling degree and coordination between the two subsystems of urban modernization and the ecological environment by integrating time and space differences. The main conclusions are shown below.

1. From 2011 to 2020, the development level of urban modernization in the Yellow River Basin regions generally shows an upward trend. It develops rapidly after 2018. the comprehensive evaluation index of urban modernization in 2011 is only 0.21 and grows to 0.63 in 2018. and keeps increasing to 0.79 in 2020, with an average annual growth rate of 12.6% in the latter two years, and a total increase of 276.2% in ten years.

2. During the decade, the ecological construction situation rose in fluctuation. It has gone through three stages of steady development - fluctuating stage - rapid development. In the latter two years of the rapid development phase, the comprehensive evaluation index of the ecological environment increased by an average of 35% per year.

3. In terms of coupling degree, the coupling degree of urban modernization and ecological environment is basically above 0.95 in the ten years studied in this paper. Thus, it can be seen that the correlation between the two is very large. In terms of the degree of coupling and coordination, excluding the two years of development in 2011-2012 when the economic development was relatively flat, the rest of the period of ecological environment and town modernization are all coordinated. From 2018 onwards, coordinated development enters the lagging

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period of town modernization, and the next stage is focused on improving the quality of town modernization development and promoting economic growth.

Nan Qiao and Xiaochuan Xu came up with the idea. Nan Qiao and Xiaochuan Xu designed the experiment. Nan Qiao performed an analysis of the results. Nan Qiao and Xiaochuan Xu finished the paper. All authors read and approved the final manuscript.

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