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Study on coupling coordination of the human settlement environment and tourism industry in the yellow river basin

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The human settlement environment is the basic space where people live, produce and live. The tourism industry is one of the industries closest to the development goal of the human settlement environment. The coordinated development of the human settlement environment and the tourism industry provides vital support for high-quality sustainable development in the region, but the related research is relatively insufficient. Based on the panel data from 2010 to 2019, this study takes the Yellow Basin as the research object, using comprehensive evaluation, coupling degree, and coupling coordination models. The study aims to comprehensively measure the development level of the human settlement environment and tourism industry in nine provinces of the Yellow River Basin and analyzes the spatio-temporal differentiation characteristics of the coupling coordination between the human settlement environment and tourism industry in the Yellow River Basin. The results demonstrate an interactive coupling relationship between the human settlement environment and the tourism industry. We observe an upward fluctuation in the development level of the two systems in the Yellow River Basin and converging development trends between the two; however, the tourism industry in the region is far behind in driving the construction of the human settlement environment. Regarding the spatial and temporal evolution of the coupling coordination of the two systems, in the time dimension, the coupling degree of the nine provinces in the Yellow River Basin was relatively stable from 2010 to 2019 and maintained a high level. The coupling coordination degree was on the rise, evolving from near-disorder to elementary coordination. The two systems in the Basin still showed a pattern of "high coupling-low coordination." Nevertheless, in the spatial dimension, the coupling and coupling coordination degrees of the two systems in the Yellow River Basin showed an unbalanced development pattern of "high in the southeast and low in the northwest." The regions with a low coordination level demonstrated that the development of the tourism industry lags behind in the construction of the human settlement environment. Findings in this study provide references for increasing the resonance between the human settlement environment and the tourism industry and promoting the overall

coordinated, balanced and sustainable development of the Yellow River Basin.

KEYWORDS

human settlement environment, tourism industry, coupling coordination, spatiotemporal differentiation, yellow river basin

1 Introduction

The human settlement environment is a place where human beings work, dwell, recreate, and interact socially and is an important indicator of regional, material, and cultural living standards and economic development (Ma et al., 2016). The formation of the human settlement environment results from continuous changes in human existence owing to the development of social productivity. With the rapidly expanding intensity and scope of human activities, both urban and rural areas are facing issues such as fragile ecosystems (Yang et al., 2018; Yang et al., 2019) and unequal distribution of public resources (Luehrs et al., 2018). With the promotion of peak carbon emissions and carbon neutrality, a social consensus on harmonious coexistence between humanity and nature is gradually formed, and the issue of the human settlement environment is receiving increasing attention. The tourism industry is characterized by comprehensiveness, long industry chains, strong radiant power, considerable driving force, and low pollution. It plays an active role in the economic, social, cultural, and ecological spheres, thus becoming an advantageous industry to promote the improvement of the human settlement environment. The human settlement environment and tourism industry develop coordinately. On the one hand, a good human settlement environment provides strong support and guarantees for tourism development. On the other hand, tourism, as a sunrise industry with a good promoting coefficient and low consumption of resources, serves as an essential carrier for improving production, living, and the ecological environment. This helps boost the improvement of the human settlement environment (Kang et al., 2022).

The Yellow River is the second-longest river in China, measuring 5,464 km in length. It spans three strategic regions in the west, middle, and east and runs through nine provincial regions: Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shanxi, Shaanxi, Henan, and Shandong. Its drainage basin is more than 750,000 km^2 and involves 418 million people in China. As an important ecological barrier and region for population activities and economic development, it is strategically significant for a country's overall development and modernization (Yuan et al., 2022). The improvement of the human settlement environment and industrial competitiveness provide vital support for sustainable development in the region. However, in the Yellow River Basin, less developed areas in the central and western regions of China constitute the majority, with lower industrial levels, a distinct feature of heavy industries, and weak development of technology-intensive manufacturing and modern service industries. These constrain economic and social development and challenge the human settlement environment (Kong et al., 2016). In 2019, at the symposium on ecological protection and high-quality development of the Yellow River Basin in Zhengzhou, Xi Jinping, the General Secretary of the Communist Party of China Central Committee, emphasized that we should strengthen the protection and management of the ecological environment of the Yellow River Basin. He also said that we should ensure the long-term stability of the Yellow River, pursue high-quality development in the region, improve people's living standards, and preserve, inherit, and carry forward the Yellow River culture to benefit the people. Thus, the fundamental issue of high-quality development of the Yellow River Basin is to achieve coordinated development of the human settlement environment and industrial competitiveness. With fewer conflicts with the human settlement environment, tourism is one of the industries that has the closest objectives. Moreover, tourism development is highly dependent on the human settlement environment (Kim et al., 2013). The nine provinces in the Yellow River Basin have 20 world heritage sites, 649 representative national intangible cultural heritage projects, 47 national "all-for-one" tourism demonstration zones, 84 national 5A tourist attractions, and 329 key villages for national village tourism. Additionally, the Yellow River gave birth to Chinese civilization, including Gansu-Qinghai civilization, Guanlong, Zhongyuan, and Qilu cultures. Having rich natural and cultural resources, the Yellow River Basin has the innate advantage of developing tourism. In the context of the Yellow River strategy, the coordinated development of the tourism industry and the human settlement environment has considerable research value.

Therefore, this study used theoretical and frequency analyses to construct a comprehensive evaluation index system of the human settlement environment and tourism industry. By adopting the comprehensive evaluation, coupling degree, and coupling coordination degree models, we empirically analyzed the coupling and coordination relationship between the human settlement environment and tourism industry in the Yellow River Basin from 2010 to 2019. Further, we investigated its spatio-temporal evolution characteristics to explore the path of coordinated and integrated development of the two and provide a reference for the high-quality development of the Yellow River Basin.

The major novelty of this study lies in the exploration of the interactive relationship between the human settlement

environment and the tourism industry *via* coupling coordination model so as to provide many specific suggestions for regional high-quality development. Other contributions are as follows: first, we constructed the index system of human settlement environment drawing on insights from the production-living-ecological space theory, expanding the theoretical perspective of human settlement environment research. Second, we chose the Yellow River Basin as the empirical research object to analyze the coordinated development of the human settlement environment and tourism industry, which enriches the relevant research in the field of human settlement environment in undeveloped regions. Third, we found the spatial and temporal evolution characteristics of the coupled and coordinated development of the two systems in the Yellow River Basin, which provides a reference for enhancing the driving force of the tourism industry on the human settlement environment construction and reducing the regional differences in the coordinated development of the two systems.

The remainder of this paper is organized as follows. Section 2 summarizes and analyzes the existing research on coordinated development of the human settlement environment and tourism industry. Further, Section 3 elaborates on the research design from three perspectives: index system construction, data source and processing, and methodology. Subsequently, Section 4 empirically analyzes the level of comprehensive development, coupling degree, and coupling coordination of the human settlement environment and tourism industry in the Yellow River Basin. Finally, Section 5 presents conclusions based on the empirical results and offers some targeted suggestions.

2 Literature review

Research on the human settlement environment originated in the 1950s when Ekistics proposed the "human settlement" theory. Research in China began relatively late, and Wu Liangyong first proposed and established the science of the human settlement environment in the 1990s. With the gradual emphasis on green development at home and abroad, the issue of the human settlement environment has become a focus in both society and academia. Researchers at both home and abroad have mainly focused on economically developed regions. Foreign research concentrated on developed countries such as Europe, the United States, and Australia (Badland et al., 2014; Leach et al., 2017; Ghasemi et al., 2018; Martinez-Bravo et al., 2019; Mathee et al., 2021) and Asian emerging market countries (Saitluanga, 2014; Mahmoudi and Ahmad, 2015; Tan and Kaur, 2016; Paul and Sen, 2018; Tan et al., 2018). Domestic research focuses on the following: the national level (Liu et al., 2017); regions such as the Yangtze River Delta (Yang et al., 2021) and the Bohai Economic Rim (Wang et al., 2016); provinces such as Zhejiang (Wang S. H. et al., 2020), Jiangsu (Yi et al., 2021), and Liaoning (Guan et al., 2022); municipalities such as Beijing (Ma et al., 2018), Qingdao (Zhou et al., 2021), and Nanjing (Wang et al., 2021). In terms of research content, studies on the human settlement environment are mostly oriented toward social issues, mainly looking at the type (Bassolas et al., 2019), quality (Teo, 2014), livability (Reis et al., 2019), satisfaction evaluation (Okulicz-Kozaryn, 2013; Mouratidis, 2020), and external coordination of the human settlement environment with other systems (Hauser, 2015; Asare et al., 2016; Dimelli, 2017). There is a consensus among scholars that the human settlement environment includes the natural environment dimension and the economic, cultural, and social environment dimensions. Therefore, the human settlement environment is a systematic and complex project, and the development of the relevant evaluation index system usually involves multiple economic, social, cultural, and ecological dimensions. Additionally, some scholars have suggested that the development of the human settlement environment evaluation index system serves as the main basis for quantitatively evaluating the quality of and theoretically studying the human settlement environment (Xiong, 2011).

The analysis of the external coordination of the human settlement environment with other systems mainly involves the economy (Hauser, 2015), natural environment (Asare et al., 2016), and tourism industry (Dimelli, 2017). As the human settlement environment and tourism industry are closely related, the discussion on their relationship has received increased attention. The environmental requirements of the tourism industry for the host society are consistent with the living, production, and ecological spaces pursued by high-quality human settlement environments (Wang S. H. et al., 2022). The improvement in the human settlement environment provides strong economic support, improved infrastructure, diversified social services, and a good ecological environment for tourism development. Moderate tourism development has positive effects on living, production, and ecological spaces in the human settlement environment (Liu et al., 2022). Specifically, the improvement of living space is conducive to optimizing the social soft environment and civic literacy, which will be internalized as a soft power contributing to tourism development. The improvement of production space can provide financial support and material security for tourism development, which will promote the improvement of the tourism supply capacity. Further, ecological space is a basic condition for tourism development, and strengthening the protection and management of the ecological environment can enhance tourism quality. The tourism industry, with its long industrial chain and employment attributes, can help boost regional economic development and effectively promote the improvement of production space. The rational development and protection of tourism resources necessitate sustainable development, which can promote the construction of ecological space. The construction and improvement of tourism infrastructure can improve residents' living space while enhancing tourists' comfort (Andereck et al., 2005).

TABLE 1 Comprehensive evaluation index system for the human settlement environment and tourism industry.

Target layer	System layer	First-level index layer	Second-level index layer	Unit
Comprehensive evaluation of human settlement environment and tourism industry	Human settlement environment f(x)	Production space X_1	Gross regional product per capita X_{11}	Yuan per person
			Share of value-added of the Tertiary Industry in GDP X_{12}	%
			1–3 per capita disposable income of urban families X_{13}	Yuan per person
			Investment in fixed assets (excluding farm households) X_{14}	Billions
			Employees of the entities in the urban areas (per 10,000 people) X_{15}	10,000 people
		Living space X_2	Population density X_{21}	Persons/km^2
			Road area per capita X_{22}	m^2/person
			Prevalence rate of gas X_{23}	%
			Number of doctors per 10,000 people X_{24}	Person
			Average number of students in general schools per 100,000 population X_{25}	Person
			Library floor space per 10,000 people X_{26}	km^2
		Ecological	Urban sewage treatment rate X_{31}	%
			Forest cover X_{32}	%
		environment	Harmless disposal rate of domestic waste X_{33}	%
		X_3	Day of air quality equal to or above grade ll X_{35}	Day
	Tourism g (y)	Industrial foundation Y_1	Number of hotels Y_{11}	Unit
			Number of A-Grade tourist attractions Y_{12}	Unit
			Number of travel agents Y_{13}	Unit
			Number of public toilets per 10,000 people Y_{14}	Unit
		Input factors Y_2	Number of persons employed in tourism Y_{21}	10,000 persons
			Number of tourism schools and colleges Y_{22}	Unit
			Total social fixed asset investment in the accommodation and food catering Y_{23}	Billion yuan
		Output performance Y_3	Number of inbound tourists Y_{31}	Million people
			Domestic tourist arrivals (billion people) Y_{32}	Billion people
			Foreign exchange earnings from tourism Y_{33}	Million dollars
			Domestic tourism revenue (billion yuan) Y_{34}	Billion yuan

Reviewing the relevant literature based on studies conducted domestically and abroad, research on the human settlement environment has yielded fruitful results. The investigation of the relationship between the human settlement environment and other systems is progressing rapidly, and research on the relationship between the human settlement environment and the tourism industry has gained scholarly attention. In terms of content, exploration has shifted from a one-way relationship to a more in-depth analysis of coupled and coordinated relationships. In terms of perspective, mechanism elaboration has shifted from static relationships to long-time series dynamic characteristic analysis. Further, in terms of methods, it has shifted from qualitative analysis to the application of complex quantitative models. However, existing studies have certain weaknesses. Current analyses of the quality evaluation of the human settlement environment have mostly focused on the indicators of the living environment and less on the indicators of the production space (Witten et al., 2003; Li et al., 2019). Although the research scope has involved national, regional, provincial, and municipal scales, most studies have focused on economically developed regions, lacking attention to less developed regions. Few studies have delved into the Yellow River Basin, although its human settlement environment serves as a crucial component of a major national strategy: the high-quality development of the Yellow River Basin. Research on the relationship between the human settlement environment and tourism has gradually been emphasized, with existing studies focusing

on the influence of one side on the other. Although some researchers have discussed their interactions, relatively few empirical studies have examined the level of coupling and coordination between the two, and current research mainly focuses on the Yangtze River Delta region. Research on the development of the tourism industry in the Yellow River Basin has achieved fruitful results. Nevertheless, there has been little research on the level of coupling and coordination between the tourism industry and the human settlement environment.

3 Research design

3.1 Construction of the index system

Drawing on the existing literature, we screened and selected indicators through theoretical and frequency analyses, constructing a comprehensive evaluation index system of the human settlement environment and tourism industry following the principles of scientificity, typicality, and accessibility (see Table 1). Considering that the human settlement environment is the aggregation of ecology, production and living environment in space, this study introduces the production-living-ecological space theory into the human settlement environment system, setting three major level indicators: production, living, and ecological environment. Among them, the ecological environment is the guarantee and constraint of the human settlement environment, the production environment is the foundation of the human settlement environment, and the living environment is the final destination of human settlement construction. The tourism industry system is guided by input-output theory by setting three major level indicators: industrial foundation, input factors, and output performance. The entire index system comprises the following: target layer (coordinated development of the human settlement environment and tourism industry); system layer (human settlement environment and tourism industry), first-level index layer (production space, living space, ecological space, industrial foundation, input factors, and output performance); second-level index layer (26 second-level indicators).

3.2 Data sources and processing

In this study, we selected the data of 26 evaluation indicators from the nine provinces in the Yellow River Basin from 2010 to 2019 as the object of measurement. The data were mainly obtained from the annual China Statistical Yearbook, China Statistical Yearbook on Environment, and the Yearbook of China Tourism Statistics and partly from the National Economic and Social Development Statistical Bulletin of the nine provinces in the Yellow River Basin. In the case of inconsistent data statistics, data from higher authorities should prevail.

All indicators were positive. Raw data with different dimensions were standardized to ensure comparability of the indexes. Specifically,

$$X_i = x_i / \max(x_i), \text{ in which } i = 1, 2, \ldots 9;$$
$$Y_i = y_i / \max(y_i), \text{ in which } i = 1, 2, \ldots 9$$

where X_i and Y_i denote the standardized values of the *i*th indicator in the two systems, x_i and y_i denote the raw data of the *i*th indicator, and max (x_i) and max (y_i) denote the maximum values of the raw data of the *i*th indicator in the nine provinces in the same year.

3.3 Research methodology

3.3.1 Comprehensive evaluation model

To ensure the scientific rigor and objectivity of the comprehensive evaluation results and avoid the tendency of subjectivity in determining the weights, this study adopted the entropy method (Smieja, 2015) to measure the weights of each indicator. The linear weighting method was applied to measure the comprehensive development evaluation index of the human settlement environment system and the tourism industry system to evaluate the development level of the two systems comprehensively. The comprehensive evaluation functions of the human settlement environment and tourism industry systems are as follows:

$$\mathbf{f}(x) = \sum_{i=1}^{m} a_i X_i \quad (1)$$

$$\mathbf{g}(y) = \sum_{i=1}^{n} b_i Y_i \quad (2)$$

where f (x) and g (y) represent the comprehensive evaluation functions of the human settlement environment system and the tourism industry system, respectively—the comprehensive scores of the indicators in the two systems. Further, m and n denote the numbers of the corresponding indicators in each subsystem, and a_i and b_i are the weights of the corresponding indicators in each subsystem, respectively. Moreover, X_i and Y_i are the standardized values of the *i*th indicator, respectively. The comprehensive evaluation function is proportional to the development rate of the two major systems—the higher the score, the faster the development rate, and *vice versa*.

3.3.2 Coupling degree model

Coupling degree is used to measure the degree of interaction between two or more systems. A coupling model was constructed for the interaction between multiple systems because the human

TABLE 2 Criteria for classification of coupling level between human settlement environment and tourism industry.

Coupling degree C value interval	Coupling level
C = 0	The two systems are in an unconnected state and moving toward disorder
C ∈ (0.0, 0.3]	The two systems are at a low level of coupling
C ∈ (0.3, 0.5]	The two systems are at a moderate level of coupling
C ∈ (0.5, 0.8]	The two systems are at the breaking-in coupling and entering a benign coupling
C ∈ (0.8, 1.0)	The two systems are at a high level
C = 1	The two systems reach a benign resonant coupling and converge to a new ordered structure

TABLE 3 Criteria for classification of coupling coordination degree between human settlement environment and tourism industry.

Coordination level	Coupling coordination degree D-value interval	Degree of coupling coordination
1	D ∈ [0.0, 0.1]	Extreme disorder
2	D ∈ (0.1, 0.2]	Serious disorder
3	D ∈ (0.2, 0.3]	Moderate disorder
4	D ∈ (0.3, 0.4]	Mild disorder
5	D ∈ (0.4, 0.5]	Near-disorder
6	D ∈ (0.5, 0.6]	Reluctant coordination
7	D ∈ (0.6, 0.7]	Elementary coordination
8	D ∈ (0.7, 0.8]	Moderate coordination
9	D ∈ (0.8, 0.9]	Good coordination
10	D ∈ (0.9, 1.0]	Quality coordination

settlement environment system and tourism industry system are interdependent and mutually constrained.

$$C_n = n\{u_1 \times u_2 \times \ldots \times u_n / \prod \left[u_i + u_j\right]^n\}^{\frac{1}{n}} \quad (3)$$

When $n = 2$, this is the coupling model of the two systems "Human settlement environment–Tourism Industry":

$$C_2 = 2\{[f(x) \times g(y)] / [f(x) + g(y)]^2\}^{\frac{1}{2}} \quad (4)$$

where C denotes the coupling degree, and C ∈ [0, 1]. According to the value of C, referring to the classification criteria proposed by other scholars (Sun et al., 2022), the coupling degree C was classified into the following classes (Table 2).

3.3.3 Coupling coordination degree model

Although the coupling degree model can reflect the strength of the interaction between the human settlement environment and the tourism industry, it cannot judge the level of coordinated development between the systems. In other words, it cannot characterize whether the systems promote or constrain each other at a high or low level, respectively (Shen et al., 2022). To remedy the one-sidedness of coupling degree evaluation, the coupling coordination degree evaluation model of the human settlement environment and tourism industry was constructed to reflect the level of benign coupling in the interaction of the two systems objectively—the overall development degree under the constraint of coordination degree. Specifically, the formula is as follows:

$$\boldsymbol{D} = (C \times T)^{\frac{1}{2}} \quad (5)$$

$$T = af(x) + bg(y) \quad (6)$$

where D is the coupling coordination degree, C is the coupling degree, T is the comprehensive evaluation value of the human settlement environment and tourism industry, and a and b are the coefficients to be determined. To ensure that D ∈ [0,1], it is necessary to make T ∈ [0,1] during the application process. Based on the above discussion about the relationship between the two systems and combined with expert scoring, we believe that the human settlement environment and tourism industry are equally important. Therefore, the values a = 0.5 and b = 0.5 were assigned. Drawing on existing results (Zhang and Li, 2020), the coupling coordination degree is ranked (see Table 3) to show the coupling and coordination relationship between the two more intuitively.

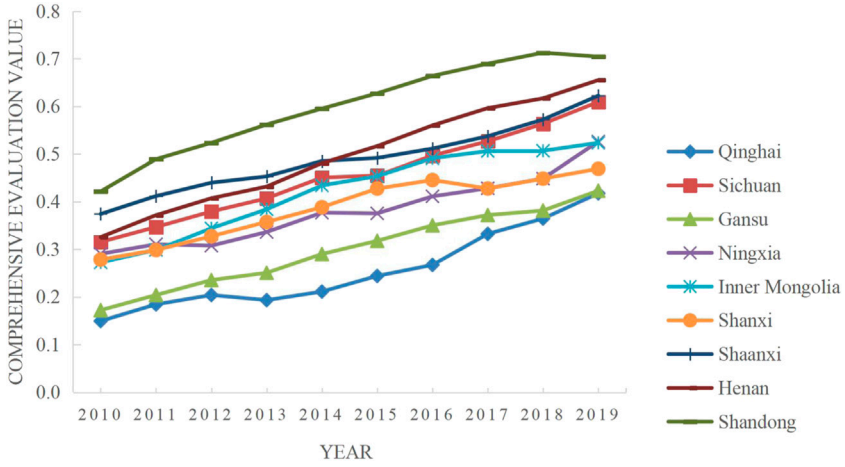

FIGURE 1
Comprehensive evaluation value of human settlement environment for 9 provinces in the Yellow River Basin.

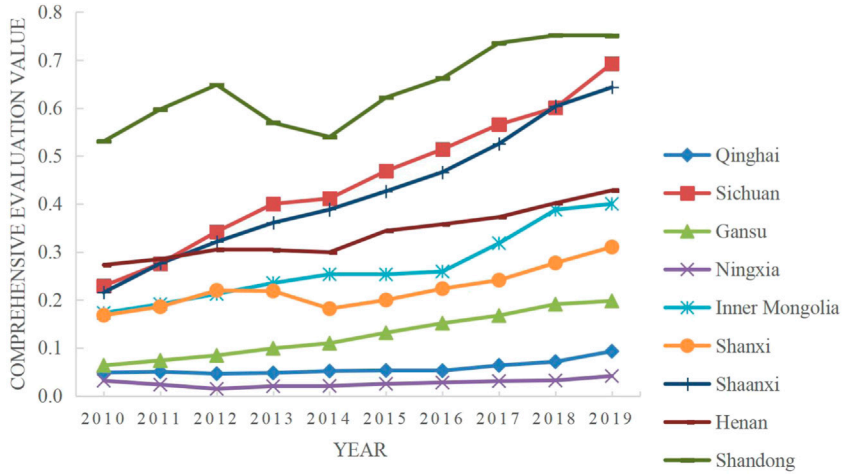

FIGURE 2
Comprehensive evaluation value of the tourism industry in 9 provinces in the Yellow River Basin.

4 Research findings

4.1 Analysis of the comprehensive development level of the human settlement environment and tourism industry in the yellow river basin

We obtained the weights of each indicator of the two major systems in the nine provinces of the Yellow River Basin using the entropy method and applied the linear weighting method to calculate the comprehensive evaluation indexes of the human settlement environment and tourism industry (see Figures 1, 2).

1) Overall analysis. Figures 1, 2 show that the two major systems—the human settlement environment and tourism industry—in the nine provinces of the Yellow River Basin reveal a similar development pattern. The overall trend is on the rise, although there are fluctuations in the comprehensive evaluation indices of individual regions in individual years. Shandong, Henan, and Shanxi experienced significant decrease in the comprehensive evaluation value of the

tourism industry in 2014. This was caused by the thick smog in December 2013, which affected almost all regions in the central and eastern regions. The continuous severe air pollution in Shandong, Henan, and Shanxi in the Yellow River basin resulted in significant concern in the international community and produced an "environmental crowding-out effect," directly affecting inbound tourism in the relevant provinces in 2014. With the introduction of the concept of high-quality development in 2015, several environmental policies were unveiled. Subsequently, the tourism industry in the Yellow River Basin showed an overall fluctuating upward trend, bringing new opportunities for its development.

2) Analysis of provincial differences. There are obvious spatial differences between the human settlement environment and tourism industry in the Yellow River Basin, with the overall trend of "high in the southeast and low in the northwest." This directly reflects that the level of development in the southeastern provinces is significantly higher than that in the northwestern provinces and indicates the relevance of the development of the human settlement environment and tourism industry. Specifically, the development of both systems in the Yellow River Basin showed obvious stratification. Based on the comprehensive evaluation index, the two systems can be divided into three echelons: Shandong (in the lower reaches of the river), stands in the first echelon, coming out on top for both systems; Henan (in the middle and lower reaches), Shaanxi (in the middle reaches), Inner Mongolia (in the upper and middle reaches), and Sichuan (in the upper reaches) are in the second echelon; Ningxia, Gansu, and Qinghai (in the upper reaches) and Shanxi (in the middle reaches) is in the third echelon, with a gap with other provinces in the Yellow River Basin—the comprehensive evaluation value from 2010 to 2019 of both systems is less than 0.53. The reason for this spatial pattern is that Shandong has a leading position in the Yellow River Basin, with advantages in transportation, industry, talent, science and education, and culture, which can produce a strong siphon effect, prompting Shandong to lead in the quality of the human living environment and tourism industry development. However, most provinces in the upper reaches are located in remote areas in the western region, and the overall development is relatively lagging behind due to natural and historical conditions, leading to gaps in the development of the human environment and tourism industry in Qinghai, Gansu, and Ningxia as compared with other provinces. Simultaneously, Shanxi is rich in resources, and there was once a serious path dependence in the development process. Although it has been actively transformed in recent years, the adverse effects of environmental pollution and a single industrial structure on the human settlement environment and tourism industry affected by resource dependence persist.

3) Systematic difference analysis. The comprehensive evaluation level of the human settlement environment and tourism industry in the nine provinces in the Yellow River Basin can be divided into two types based on the size ratio of f (x) to g (y). For the first type, tourism development lags behind (f (x) > g (y)). In other words, the level of the human settlement environment construction has been higher than that of tourism industry development, having a greater role in promoting the development of the tourism industry. However, the driving force of the tourism industry on the human settlement environment construction is relatively weak. Henan, Shanxi, Inner Mongolia, Ningxia, Gansu, and Qinghai can be categorized as such. For the other type, the tourism industry is catching up (f (x) < g (y)). The level of development of the tourism industry gradually exceeds that of the development of the human settlement environment, and the driving role of the tourism industry in the construction of the human settlement environment has begun to be highlighted. This type includes provinces such as Shandong, Shaanxi, and Sichuan. Moreover, there were differences in the dynamic trends and characteristics of the two systems. From the dynamic change curve of the comprehensive evaluation value of the two systems, the development quality of the human settlement environment in the nine provinces continued to improve, and the regional differences gradually reduced. The quality of development of the tourism industry is growing, but there are large fluctuations, and the gap within the region is expanding as the tourism industry is vulnerable and sensitive to external influences. Additionally, Qinghai, Ningxia, and other provinces in the upper reaches of the river have a low starting point for tourism industry development. Although the compound growth rates over the past 10 years have reached 7.4% and 3.0%, respectively, they are not as high as the 10-year compound growth rate of 8.4% in the nine provinces in the Yellow River Basin, and the gap with other provinces has increased. Although the upper reaches of the Yellow River are rich in ecological resources, provinces such as Ningxia and Qinghai lack competitiveness in the tourism industry owing to the extensive economic development, low efficiency of the tourism industry, and gaps in talent and tourism facilities.

4.2 Spatio-temporal differentiation characteristics of the coupling degree and coupling coordination degree between human settlement environment and tourism industry in the yellow river basin

4.2.1 Spatio-temporal differentiation characteristics of coupling degree

We used the coupling degree model to calculate the coupling degree values of the human settlement environment and tourism industry in the nine provinces of the Yellow River Basin from

TABLE 4 Coupling degree of human settlement environment and tourism industry in 9 provinces of the Yellow River Basin.

Year	Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shanxi	Shaanxi	Henan	Shandong	Mean
2010	0.8609	0.9874	0.8876	0.5963	0.9748	0.9690	0.9632	0.9961	0.9934	0.9143
2011	0.8218	0.9935	0.8835	0.5121	0.9757	0.9726	0.9803	0.9913	0.9950	0.9029
2012	0.7772	0.9987	0.8813	0.4168	0.9717	0.9805	0.9878	0.9897	0.9943	0.8887
2013	0.7983	1.0000	0.9012	0.4641	0.9707	0.9706	0.9936	0.9848	1.0000	0.8981
2014	0.7959	0.9990	0.8924	0.4467	0.9649	0.9320	0.9938	0.9726	0.9988	0.8885
2015	0.7665	0.9999	0.9101	0.4859	0.9591	0.9319	0.9975	0.9798	1.0000	0.8923
2016	0.7418	0.9999	0.9182	0.4885	0.9511	0.9434	0.9989	0.9755	1.0000	0.8908
2017	0.7344	0.9994	0.9254	0.5014	0.9737	0.9604	0.9999	0.9731	0.9995	0.8964
2018	0.7400	0.9995	0.9432	0.5008	0.9912	0.9718	0.9996	0.9774	0.9996	0.9026
2019	0.7717	0.9979	0.9320	0.5205	0.9911	0.9791	0.9999	0.9778	0.9995	0.9077

2010 to 2019 and the average value of the coupling degree of the whole region (see Table 4). The coupling stages in the nine provinces of the Yellow River Basin were obtained according to the criteria for the coupling coordination degree level classification.

As shown in Table 4, in the time dimension, the average value of the coupling coordination degree of the human settlement environment and tourism industry in the nine provinces of the Yellow River Basin hovers between 0.8885 and 0.9143 from 2010 to 2019, with small fluctuations. However, overall, it is relatively stable and always at a high-level stage, indicating a high degree of interaction between the two systems in the whole region. In the spatial dimension, Sichuan, Gansu, Inner Mongolia, Shaanxi, Henan, and Shandong had a high degree of coupling between the human settlement environment and tourism industry, which remained above 0.88. This suggests that the two systems tended to develop in an orderly manner between the above provinces. The coupling degree values of Ningxia and Qinghai provinces in the upper reaches of the Yellow River are relatively low and have certain fluctuations. The coupling degree of the two systems in Ningxia slips from the breaking-in stage to the moderate level, and that of the two systems in Qinghai slips from the high-level stage to the breaking-in stage. Combined with the comprehensive evaluation value of the human settlement environment and tourism industry in the Yellow River Basin, we found that the quality of the tourism industry in Ningxia and Qinghai provinces is not high. Further, the development of their tourism industry lags significantly behind that of the human settlement environment. These two systems fail to form concerted efforts and are disconnected.

In summary, the coupling degree of the two systems of the Yellow River Basin—the human settlement environment and the tourism industry—is at a high level overall. However, there are significant differences between regions, with the coupling degree showing a distribution pattern of high in the southeast and low in the northwest. In the upper reaches, especially for Ningxia and Qinghai, there is still potential for improvement in the coordinated development of the human settlement environment and tourism industry.

4.2.2 Spatio-temporal differentiation characteristics of coupling coordination degree

The coordination degree enables us to view the coupling relationship between the human settlement environment and tourism industry as a whole, which is more comprehensive and intuitive than a single coupling degree. Based on this, we calculated the coupling coordination degree values and the average value of the coupling coordination degree of the whole region in the nine provinces of the Yellow River Basin from 2010 to 2019 using the coupling coordination degree model (see Figure 3). The coupling coordination stage, in which the nine provinces are located, was obtained according to the criteria for the coupling coordination degree-level classification.

In the time dimension, as shown in Figure 3, the value of the coupling coordination degree between the human settlement environment and the tourism industry in the Yellow River Basin is increasing, with the mean value gradually increasing from 0.4602 in 2010 to 0.6491 in 2019. The coupling coordination relationship gradually evolved from near-disorder to elementary coordination. The connection and permeability relationship between the two systems were enhanced, and the overall development level improved significantly. This suggests that the human settlement environment and tourism industry in the Yellow River Basin have a relationship of mutual promotion and common development. The development of the coupling coordination degree between the human settlement environment and tourism industry can be roughly divided into three stages: near-disorder in 2010–2011, reluctant coordination in 2012–2016, and elementary coordination in 2017–2019. This indicates that the coupled coordination relationship between the human settlement environment and the tourism industry in the

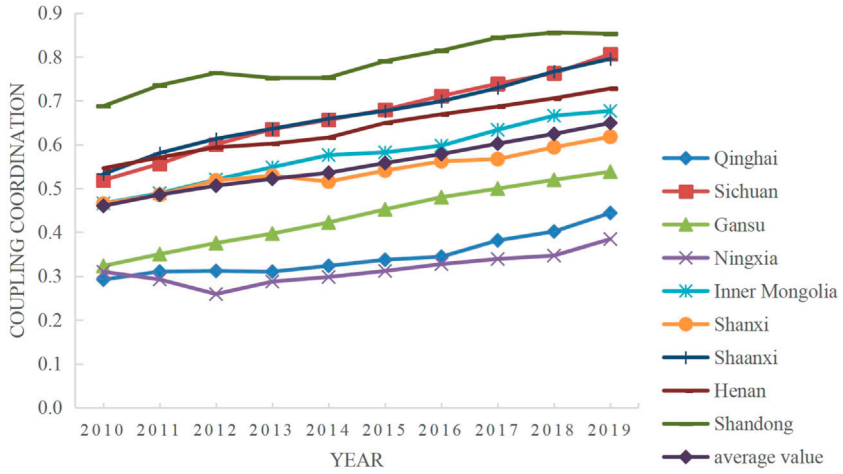

FIGURE 3
Coordination of the coupling of habitat and tourism industry in 9 provinces of the Yellow River Basin.

Yellow River Basin is developing in a benign direction, and the degree of correlation and interactive integration of the two systems is increasing, gradually showing a coordinated and integrated posture. Specifically, in 2010, the coupling coordination degree ranged from 0.2921 to 0.6877, with the lowest and highest values appearing in Qinghai and Shandong, respectively. The types of coupling coordination degrees included moderate disorder, mild disorder, near-disorder, reluctant coordination, and elementary coordination, accounting for 11%, 22%, 22%, 33%, and 11%, respectively. The overall level was not high, with more than half of the provinces in the disorder. Even for provinces with coordination status, most of them have lower levels of coordination. In 2015, the coupling coordination degree ranged from 0.3120 to 0.7904, with the lowest and highest values appearing in Ningxia and Shandong, respectively. The coupling coordination types included mild disorder, near-disorder, reluctant coordination, elementary coordination, and moderate coordination, accounting for 22%, 11%, 22%, 33%, and 11%, respectively. The level of coordinated development of the human settlement environment and tourism industry is significantly higher than in 2010:67% of provinces have entered the coordination stage, and the proportion of both elementary and moderate coordination has increased. In 2019, the degree of coupling coordination ranged from 0.3843 to 0.8528. The lowest value was observed in Ningxia, and the highest value was observed in Shandong. The degree of coupling coordination includes mild disorder, near-disorder, reluctant coordination, elementary coordination, moderate coordination, and good coordination, accounting for 11%, 11%, 11%, 22%, 22%, and 22%, respectively. During this period, the degree of coupling coordination between the human settlement environment and tourism industry of 78% of the provinces in the Yellow River Basin reached the coordination stage. Further, more than 44% of the provinces were in the stage of moderate coordination and good coordination, which shows a significant increase compared to 2010. Guided by the 12th and 13th Five-Year Plans, China has implemented an overall regional development strategy, which has promoted the reasonable movement of production and living factors and established a regional development pattern of complementary regional economic advantages and harmonious coexistence between humanity and nature. The human settlement environment has been reasonably optimized, laying a solid foundation for the development of the tourism industry. In the process of promoting a new round of western development, vigorously promoting the rise of Central China, and actively supporting the strategy giving priority to the development of the east, the tourism industry has been considered a breakthrough to realize the coordination between industrial development and ecological protection and has been strongly supported and promoted in an orderly manner. Moreover, in the process of continuous adjustment between the human settlement environment and tourism industry, the type of coupling coordination has achieved a leap from near-disorder to elementary coordination.

In the spatial dimension, this study selected three time cut-off points (i.e., 2010, 2015, and 2019) and spatially visualized the coupling coordination degree of the human settlement environment and tourism industry in nine provinces of the Yellow River Basin through ARCGIS 10.3 software (see Figure 4). As shown in Figure 4, the spatial distribution of the coupled coordinated development of the human settlement environment and tourism industry in the Yellow River Basin from 2010 to 2019 has a certain stability, showing an overall

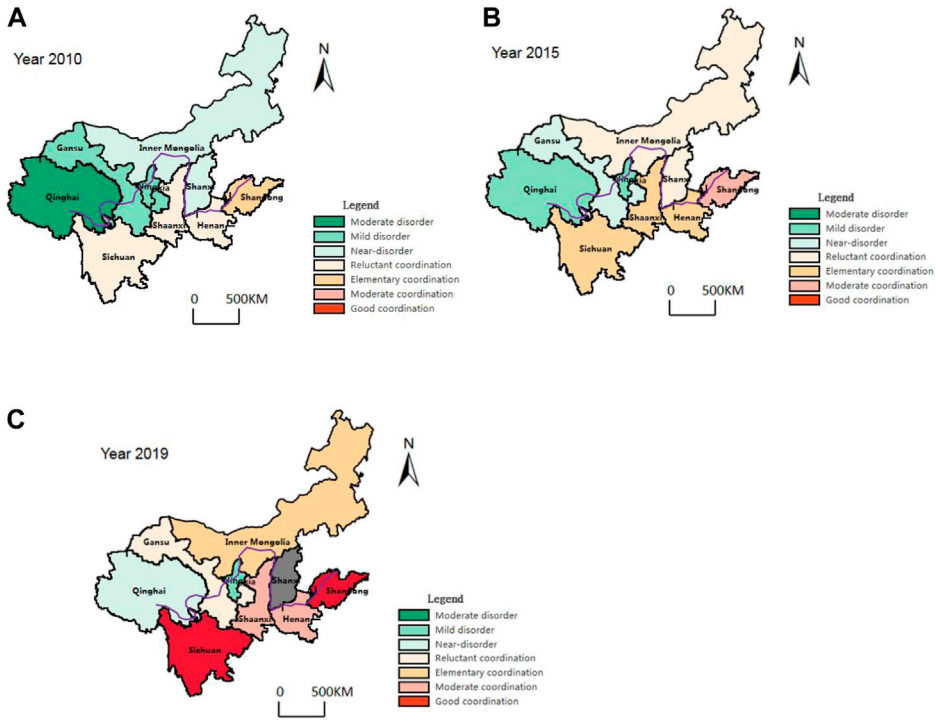

FIGURE 4
Spatial distribution of coupling coordination degree between the human settlement environment and tourism industry in the Yellow River Basin in 2010, 2015, and 2019. **(A)** represents spatial distribution of coupling coordination degree in 2010; **(B)** represents spatial distribution of coupling coordination degree in 2015; **(C)** represents spatial distribution of coupling coordination degree in 2019.

distribution pattern of high in the southeast and low in the northwest. Overall, the coupling coordination level decreased from the lower reaches to the upper reaches of the Yellow River, except for Sichuan. Specifically, Shandong, Henan, Sichuan, and Shaanxi have a high degree of coupling coordination, among which Shandong and Sichuan have moved from elementary and reluctant coordination to good coordination, respectively, while Henan and Shaanxi have moved from reluctant to moderate coordination.

The main reason for the above four provinces entering the stage of high-level coupling is that Shandong and Henan, in the lower reaches of the Yellow River Basin, have better economic, social, and cultural development than regions in the upper and middle reaches, which provides important support and guarantees for the production, living, and ecological levels of the corresponding provinces. The higher quality of the human settlement environment is conducive to the development of the tourism industry, and healthy tourism development also contributes to economic growth, social development, and ecological protection in the two provinces. Sichuan and Shaanxi are located in the less developed regions in the upper and middle reaches of the Yellow River Basin, respectively. However, they took the initiative to integrate into major national strategies such as the Belt and Road and the development of western regions in the new era, optimizing the industrial structure and resource allocation, and becoming important growth poles for high-quality development in the upper and middle reaches of the Yellow River. The construction of a livable place for a high-quality life is effective, laying a solid foundation for the development of the tourism industry. Sichuan and Shaanxi are rich in tourism resources, and the local government attaches great importance to the tourism industry, which has become one of the pillar industries of the two provinces. The maturation of the tourism industry has driven the development of the local society and economy. The degree of coupling coordination between the human settlement environment and tourism industry in Ningxia and Qinghai has increased in the past 10 years, but it has been hovering at 0.29–0.44, which is still a big gap from the benign coordination. This is because, in recent years, the two provinces have taken the new development stage as the foothold and integrated it into the new development pattern. Practicing the strategy of "adhering to the priority of ecological protection, promoting high-quality development, and creating high-quality life," they promote economic, social, and ecological development in an integrated manner, and the quality of the human settlement environment has been

steadily improved. Nevertheless, due to their geographical location and historical conditions, Ningxia and Qinghai are relatively self-isolated, and the residents have outdated thinking and ideas. Although the two provinces have unique natural scenery and excellent historical and cultural resources, tourism momentum has not been fully developed and released, resulting in a poor coupling coordination degree between the human settlement environment and the tourism industry, which is a short board for the development of the Yellow River Basin.

In summary, the spatial and temporal distribution characteristics of the coupling coordination between the human settlement environment and tourism industry in the Yellow River Basin are relatively stable. The level of coordinated development of the two systems in the Yellow River Basin steadily increased from 2010 to 2019, with the overall spatial pattern of high in the southeast and low in the northwest. Shandong, Henan, Sichuan, and Shaanxi have a high level of coupling coordination between the human settlement environment and tourism industry, while Ningxia and Qinghai significantly lag behind.

5 Conclusion and discussion

5.1 Main findings

This study aims to explore the coupling and coordination relationship between the human settlement environment and the tourism industry to promote the high-quality development of the Yellow River Basin. To achieve this objective, we constructed a comprehensive evaluation index system for the human settlement environment and tourism industry based on the production-living-ecological space theory and the input-output theory. Using the comprehensive evaluation, coupling degree, and coupling coordination models, we conducted empirical analyses on the interactive relationship between the human settlement environment and tourism industry in nine provinces of the Yellow River Basin from 2010 to 2019. The results showed that from the relationship between the two systems, there is an interactive coupling relationship between the human settlement environment and the tourism industry, that is, the two systems interact and influence each other. This conclusion further verifies the existing research results (Andereck et al.,2005; Chaveesuk et al., 2020). Their interactions have different coupling coordination conditions. The current mainstream research views hold that the mutual promotion between the human settlement environment and the tourism industry is significant for high-quality development (Liu et al., 2017; Kang et al., 2022). Furthermore, from the perspective of the level of comprehensive development of the two systems, the development trend of the human settlement environment system and the tourism industry system in the nine provinces of the Yellow River Basin tends to be the same, with a fluctuating upward trend, which is consistent with the conclusions of existing research (Hao et al., 2021; Khalid and Kot, 2021; Huang et al., 2022). However, this study finds that the fluctuation in the development level of the tourism industry system in the river basin is more obvious than that of the human settlement environment system, and the gap between the development levels of the tourism industry in the Basin is widening. This indicates that the driving effect of the tourism industry on the construction of the human settlement environment lags behind the promoting effect of the construction of the human settlement environment on the tourism industry in most provinces of the Yellow River Basin. Concerning the time dimension of coupling coordination of the two systems, the overall coupling degree of the nine provinces in the Yellow River Basin from 2010 to 2019 is relatively stable and always at a high-level stage; the coupling coordination degree is steadily increasing, with the coupling coordination relationship moving from near-disorder to elementary coordination. This indicates that the interaction between the two systems is significant, and the level of interaction is steadily improving. Nevertheless, it is still at the stage of "high coupling-low coordination" and has not yet evolved to the benign resonance of "high coupling-high coordination." There is still considerable room for improvement. Regarding the spatial dimension of the coupling coordination of the two systems, there are significant spatial differences in the coupling degree and coupling coordination degree of the human settlement environment and tourism industry in the nine provinces of the Yellow River Basin, basically showing a spatial pattern of "high in the southeast and low in the northwest." The findings of this study show that the areas with lower levels of development and coordination demonstrate that the development of the tourism industry lags behind the construction of the human settlement environment (Huque et al., 2018), and the tourism industry has become an effective path to bridge development differences within the region.

5.2 Marginal contributions and limitations

We believe that our study can make the following marginal contributions to existing literature. First, it highlights the influence of production space on the quality of human settlement environments. Borrowing the production-living-ecological space theory, we built a system layer of the human settlement environment from three dimensions (i.e., production, living, and ecological spaces), which helps evaluate the development level of the human settlement environment more comprehensively, and provides a reference for further investigation. Second, we chose the Yellow River Basin as the empirical research object and used the coupled coordination degree model to analyze the coordinated development of the

human settlement environment and tourism industry. It shows the degree of interaction between the two systems in the Yellow River Basin and reflects the level of benign coupling in the interaction of the two systems more objectively, enriching the relevant research and filling the research gap on the interactive relationship between the human settlement environment and the tourism industry in the Yellow River Basin. Third, based on the empirical analysis, we found that in the Yellow River Basin, the spatial and temporal evolution of the coupled and coordinated development of the human settlement environment and tourism industry has two significant characteristics: "high coupling-low coordination" and "high in the southeast and low in the northwest." This provides important guidance for increasing the resonance between the human settlement environment and the tourism industry and promoting the overall coordinated, balanced and sustainable development of the Yellow River Basin.

The essential connotation of the human settlement environment and tourism industry is relatively deep, achieving the coordinated development of both is thus a relatively complex system project. This study analyzes the coupling coordination of the human settlement environment and tourism industry in the Yellow River Basin. However, there is no specific analysis of the obstacles and internal mechanisms that affect the coordinated development of the two systems. Meanwhile, the study was conducted in the context of the two systems in the Yellow River Basin, where most of the provinces are still relatively underdeveloped. Therefore, implementing current study findings in other regions should be taken with caution (Jayashree et al., 2021). In the future, methods such as obstacle degree and structural equation models should be adopted to examine the obstacle factors that hinder the coordinated development of the two systems and the causal relationship and law between the coupling factors. Moreover, a comparative analysis between the Yellow River Basin and another comparable developed region needs to be carried out, which will help better understand the interactive relationship between the human settlement environment and the tourism industry.

5.3 Recommendations

Attention should be paid to the issue of the weak driving force of tourism development for human settlement environment construction in the Yellow River Basin. The nine provinces in the Yellow River Basin should strengthen their understanding of the tourism industry as a strategic pillar industry of the national economy, promote the optimization and upgradation of the industrial structure, and promote the high-quality development of the Yellow River Basin. Shandong, Sichuan, and Shaanxi, whose driving role in the tourism industry has been gradually highlighted, should take full advantage of national strategies such as all-for-one tourism, cultural and tourism integration, and supply side reform to actively explore the connection points in each link of the chain of the tourism industry and the human habitat environment in the high-quality development of the Yellow River Basin, accelerate the cultivation of new industries, foster new consumption growth areas, and promote tourism development from quantity to quality. On the one hand, they should advance the integration of tourism and other industries at a faster pace to broaden the industries and form new cross-advantageous industries. For instance, they should promote "tourism + agriculture," strongly support the development of village tourism, and make full use of the characteristic rural ecological resources, agricultural heritage, and folk art in Shandong, Sichuan and Shaanxi to promote the organic integration of agriculture with tourism, culture and ecology, realize the upgradation of village tourism, and improve the human settlement environment in rural areas. On the other hand, the cultural connotations of tourism products should be mined in depth, and the quality of tourism products should be improved. In particular, the tourism and local characteristic regional culture, history and culture, and food culture should be combined to create tourism products featuring qualities such as relevance to life, high-end, humane, and intelligent to advance the tourism development of in-depth cultural experience and the construction of community, neighborhood, and city, along with the promotion of the positive resonance between the tourism industry and the human settlement environment. Furthermore, the driving effect of tourism is not yet obvious in Henan, Shanxi, Inner Mongolia, Gansu, Ningxia and Qinghai. On the one hand, they should deepen the promotion of the construction of the human settlement environment to guarantee the development of tourism industry by providing the necessary facilities and services. On the other hand, they should maximize the advantages of the diverse natural landscape, ethnic culture, and distinctive regional characteristics in the upper and middle reaches of the Yellow River to develop low-carbon tourism, ecological tourism, cultural tourism, and green tourism, accelerate the release of its potential value, underscore the driving effect of tourism development on the efficient flow of industrial factors, and promote the tourism industry to become an important driving force for the optimization of production, living and ecological space, thereby forming a development pattern of coordinated promotion of tourism industry development and human settlement environment construction.

The spatial differences cannot be ignored in the coupling coordination development of the human settlement and tourism industries in the Yellow River Basin. Strengthening the ripple effects of regional growth poles and promoting regional integration have become effective measures for solving the problem of unbalanced development in the Yellow River Basin. Specifically, they should enhance the spatial spillover effect of Shandong, the growth pole of the human settlement environment and tourism industry in the

Yellow River Basin, leading to the development of the human settlement environment and tourism industry in the Yellow River Basin through industrial transfer, production factor flow, and intergovernmental cooperation. Meanwhile, as the secondary growth pole of the human settlement environment and tourism industry in the Yellow River Basin, the leading roles of Sichuan (in the upper reaches of the Yellow River), Shaanxi (in the middle reaches), and Henan (in the lower reaches) should be underscored. In particular, through the construction of national central cities including Chengdu, Xi'an, and Zhengzhou, the development of the city clusters around Chengdu and Chongqing, Guanzhong, Hohhot, Baotou, Erdos, and Yulin, and in central Henan province will be boosted to narrow the development differences of the human settlement and tourism industries among the provinces in the region. Provinces in the Yellow River basin should deepen cooperation comprehensively, and build a cooperative development platform with the creation of the Yellow River Basin specialty tourism industry zone as an engine, so as to lead the construction of regional integration and create a cooperative development community in the upper, middle, and lower reaches of the Yellow River with distinctive features, complementary advantages, and efficient coordination. The first is the construction of an integrated system and mechanism. A multi-level regional cooperation mechanism in the Yellow River Basin that combines regional, provincial, municipal, and county-level cooperation should be established; the level of integrated policy should be improved; and the flow of resources, talent, and other factors within the region should be reasonably guided, realizing factor sharing, integration, and optimization in a wider scope. The second aspect is the integration of infrastructure construction. The integration of infrastructure in the Yellow River Basin should be accelerated, especially the integration of transportation facilities, to guide the efficient gathering and diffusion of resources, thus promoting the construction of regional human settlement environments while helping to overcome the limitations of the division of the Yellow River Basin tourism market. The third is the integrated development of industrial collaboration. The integration of industrial cooperation in the Yellow River Basin should be promoted to avoid homogenization and low-level competition among provinces and to lead the differentiated development of the tourism industry with local characteristics in each province in the Yellow River Basin. Relying on primitive ecological scenery and red tourism resources, such as the revolutionary sites of Shaanxi, Gansu, and Ningxia and the route of Long March, provinces in the upper reaches of the Yellow River should support the adjacent areas of Qinghai, Sichuan, Gansu, and Ningxia to jointly build national demonstration zones of ecological tourism and red tourism corridors. Provinces in the middle reaches can depend on rich historical resources, including ancient capitals and historical sites, to create world-class historical and cultural tourism destinations. Provinces in the lower reaches can take advantage of the role of renowned cultural heritage, such as Mount Taishan and the three Confucius sites, to carry forward traditional Chinese culture. The fourth is the integrated protection of the ecological environment. In accordance with the principle of "who pollutes, who treats" and "who benefits, who compensates," horizontal cross-regional ecological compensation methods should be developed to increase ecological compensation for Qinghai, Ningxia, and other key ecological function areas. They should also encourage the beneficiary areas and ecological protection areas, and the upper and lower reaches to establish a mechanism for coordinating interests through financial compensation, counterpart collaboration, industrial transfer, park construction, technical guidance, and talent cultivation to bridge the spatial development differences in the Yellow River Basin and optimize the coordinated development of the human settlement development and tourism industry in the entire region.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The annual China Statistical Yearbook, China Statistical Yearbook on Environment, and the Yearbook of China Tourism Statistics and partly from the National Economic and Social Development Statistical Bulletin of nine provinces in the Yellow River Basin.

Author contributions

XY: conceptualization, methodology, data processing, and writing (original draft, review and editing); HC: data collection, visualization, investigation, and writing (original draft).

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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