Evaluation of the Development Level and Spatiotemporal Characteristics of Coupling Coordination of the Digital Culture and Tourism Industry in the Yellow River Basin: A Postprint

Authors: Sun Guojun, Li Jiayao, Wang Zixuan

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Abstract

As an important component of the high-quality economic development of the Yellow River Basin, the digital, cultural, and tourism industries and their coupled and coordinated development are of great significance for the sustainable development of the regional economy. On the basis of analyzing the coupling and coordination mechanism of the digital-culture-tourism industries, this paper constructs an evaluation index system for the coupling and coordination of these industries, and employs the weighted summation method and the coupling coordination degree model to analyze the spatiotemporal characteristics of the development status of the digital, cultural, and tourism industries and their coupling and coordination in the nine provinces (regions) of the Yellow River Basin from 2012 to 2022. The results indicate that: (1) The development of the digital industry in the Yellow River Basin shows a fluctuating growth trend of "rapid first, then slowing" ; the cultural industry rises steadily but declines slightly due to the impact of the pandemic; the tourism industry exhibits an "inverted U-shaped" evolutionary pattern; the comprehensive development level of the digital-culture-tourism industries is generally in a state of fluctuating ascent, and the spatial distribution pattern is characterized by "downstream > midstream > upstream." (2) The coupling coordination level of the digital-culture-tourism industries shows a fluctuating upward trend, demonstrating a spatial distribution pattern of "downstream > midstream > upstream," with significant regional disparities. (3) The regional evolution of the coupling coordination grade of the digital-culture-tourism industries is as follows: the upstream region has evolved from moderate maladjustment to mild maladjustment; the midstream region has evolved from mild maladjustment to on the verge of maladjustment; and the downstream region has evolved from basic coordination to primary coordination.

Full Text

Evaluation of the Development Level of the "Digital-Cultural-Tourism" Industries in the Yellow River Basin and Analysis of the Spatiotemporal Characteristics of its Coupling Coordination

SUN Guojun[1], **LI Jiayao**[2], **WANG Zixuan**[1]
[1] Economics School, Gansu University of Political Science and Law, Lanzhou 730070, Gansu, China
[2] Business College, Gansu University of Political Science and Law, Lanzhou 730070, Gansu, China

Abstract: The digital, cultural, and tourism industries constitute vital components of high-quality economic development in the Yellow River Basin, and their coupling and coordinated development holds significant implications for regional sustainable growth. This study constructs an evaluation index system for the coupling coordination of these three industries based on an analysis of their underlying mechanisms. Using the weighted summation method and coupling coordination degree model, we analyze the spatiotemporal evolution of development levels and coupling coordination across nine provinces and autonomous regions in the Yellow River Basin from 2012 to 2022. The findings reveal: (1) The digital industry exhibited a fluctuating growth trend characterized by "rapid expansion followed by slowdown" ; the cultural industry demonstrated steady growth with a slight decline due to COVID-19 impacts; and the tourism industry displayed an inverted U-shaped evolutionary pattern. Overall, the comprehensive development index of the three industries showed a fluctuating upward trend, with spatial distribution following a "downstream > midstream > upstream" pattern. (2) The coupling coordination level of the three industries displayed a fluctuating upward trajectory, also manifesting a "downstream > midstream > upstream" spatial distribution with significant regional disparities. (3) Regional evolution of coupling coordination grades proceeded as follows: upstream areas transitioned from moderate dysregulation to mild dysregulation; midstream areas evolved from mild dysregulation to near-dysregulation; and downstream areas advanced from basic coordination to primary coordination.

Keywords: digital industry; cultural industry; tourism industry; coupling coordination degree; Yellow River Basin

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The digital, cultural, and tourism industries serve as crucial pillars of high-quality economic development in the Yellow River Basin. In 2021, the National Development and Reform Commission, Ministry of Culture and Tourism, and other ministries jointly issued the *Yellow River National Cultural Park Construction and Protection Plan*, which proposed comprehensive implementation of key tasks including heritage conservation, cultural-tourism integration, and digital smart presentation of the Yellow River. This strategic initiative highlights the

basin' s pivotal national position and charts a clear course for integrated development of digital, cultural, and tourism industries. Assessing the development status and coupling coordination among these three sectors is essential for optimizing industrial structure and promoting high-quality economic growth in the region.

Although the digital, cultural, and tourism industries originate from distinct developmental paths, they have formed cross-cutting symbiotic relationships in technological approaches, value expression, and service objects. On one hand, the digital industry, with its high permeability and reconstructive capacity, provides critical support for digital preservation, dissemination, and immersive experiences of cultural resources, enabling a leap from "physical display" to "virtual interaction." On the other hand, the cultural industry supplies content resources and symbolic systems that not only offer creative sources for digital technology applications but also inject spiritual connotations and cultural memory into tourism product development. The tourism industry serves as the practical carrier and experiential arena for both, with cultural experience at its core and technological drive as its means, forming a multi-dimensional linkage mechanism of "culture promoting tourism, digital strengthening culture, and tourism driving industry." This synergy manifests not only in the integration of "substance" and "application" but also in deep logical symbiosis evident in cultural identity construction, consumption value connection, and experiential scene reconstruction.

Existing domestic research has explored interactions among digital, cultural, and tourism industries. Studies on digital-culture relationships propose a "technology embedding-value symbiosis" interaction path with bidirectional influence mechanisms ranging from digital empowerment to cultural feedback. Research demonstrates that digital technology transforms relationships between actors and contexts, broadening cultural dissemination channels, and that technological innovation significantly impacts cultural industry development. Culture endows digital products with expressive content and emotional value, while cultural resource conversion capacity enhances the quality of industrial digital transformation. Digital-tourism research focuses on access channels, service processes, and intelligent experiences, emphasizing the role of digital infrastructure in improving tourism efficiency and visitor experiences, while noting tourism' s feedback mechanism in promoting digital infrastructure layout. Culture-tourism studies examine integration dynamics, influencing factors, and locational differences, concluding that culture provides identity-based spiritual cores for tourism while tourism serves as culture's living dissemination platform, jointly promoting the visualization and commodification of cultural values. However, most existing research concentrates on pairwise industry integration, with scarce holistic analysis of three-industry system fusion and coordination mechanisms, particularly regarding spatial differentiations and temporal evolution paths within specific regional contexts.

As a vital economic belt and ecological civilization pilot zone spanning eastern,

central, and western China, the Yellow River Basin possesses rich natural resources and profound cultural accumulation, providing a solid foundation for developing integrated digital-cultural-tourism industries. Currently, the region faces challenges including uneven industrial development levels, significant disparities in technological penetration capacity, and suboptimal cultural resource conversion efficiency. Therefore, a systematic perspective is necessary to evaluate the development status and integration degree of these three industries while clarifying their coupling coordination' s spatiotemporal evolution characteristics. This study examines nine provinces and autonomous regions in the Yellow River Basin from 2012 to 2022, constructing an evaluation index system covering digital, cultural, and tourism industries. Using weighted summation and coupling coordination degree models, we quantitatively measure and spatially analyze regional development levels and integration synergy to reveal the dynamic mechanisms and coordination pathways of digital-cultural-tourism integration, providing theoretical support and policy references for promoting high-quality development in the Yellow River Basin and implementing the national cultural digitization strategy.

1.1 Overview of the Study Area

The Yellow River Basin extends from the Bayan Har Mountains in Qinghai Province to the Bohai Sea estuary, spanning approximately 5,464 km with a total drainage area of about 795,000 km^2. According to the Yellow River Conservancy Commission standards, the upstream includes Qinghai, Sichuan, Gansu, Ningxia, and Inner Mongolia; the midstream comprises Shaanxi and Shanxi; and the downstream includes Henan and Shandong. Due to substantial geographical, economic, and social environmental differences among provinces, digital-cultural-tourism development levels vary considerably, and cross-regional coordination mechanisms remain underdeveloped.

Note: Based on the standard map with approval number GS(2023)2767 from the Ministry of Natural Resources Standard Map Service website, with no modifications to base map boundaries. The same applies below.

[Figure 1: see original paper]

1.2 Data Sources

The study period spans 2012–2022. Data were obtained from the *Peking University Digital Inclusive Finance Index*, *China Provincial Database (2021 Edition)*, *China Statistical Yearbook*, *China Culture, Cultural Heritage, and Tourism Statistical Yearbook*, and *China Science and Technology Statistical Yearbook*. Missing data for inbound tourism arrivals and revenue were interpolated using linear interpolation.

1.3 Construction of the Indicator System

Drawing upon previous research methods and following fundamental indicator selection principles, this study constructs an evaluation index system for the coupling coordination level of digital economy, cultural industry, and tourism industry across nine provinces and autonomous regions in the Yellow River Basin . The first-level indicators comprise three subsystems: digital industry, cultural industry, and tourism industry. Given the collaborative development model of resources, markets, functions, and actors among these industries, each subsystem includes second-level indicators covering resource endowment, market demand, and industrial economy. This multidimensional combination ensures comprehensive measurement of each industry' s development level while providing data support for coupling coordination calculations, forming an integrated evaluation system of "element-function-benefit."

1.4.1 Weighted Summation Method

This study employs the weighted summation method to calculate industrial development indices for Yellow River Basin provinces. The procedure involves: first, extreme value standardization preprocessing of raw data; second, entropy method for indicator weighting; and finally, weighted summation to compute digital industry development indices for each province. The formula is:

$$x = \sum_{i}$$

where n represents the number of indicators in the subsystem, x_i denotes the standardized value of the ith indicator, and w_i represents the weight of the ith indicator. Cultural industry development index (U_c) and tourism industry development index (U_t) are calculated using the same formula. Finally, the comprehensive development index of digital-cultural-tourism industries (T) is computed as:

$$T = \alpha U_d + \beta U_c + \delta U_t$$

where α, β, and δ are weight coefficients for digital, cultural, and tourism industries respectively. This study assigns equal importance to all three industries, setting $\alpha = \beta = \delta = 1/3$.

1.4.2 Coupling Coordination Degree Model

First, the coupling degree (C) among the three industries is calculated using their comprehensive development indices to characterize inter-industry correlation levels:

$$C = \frac{3\sqrt[3]{U_d U_c U_t}}{U_d + U_c + U_t}$$

Second, the coupling coordination degree (D) of digital-cultural-tourism industries is computed using the coupling degree and comprehensive development index, with values ranging from 0 to 1, where values closer to 1 indicate better coordination. Drawing upon existing research, coupling coordination degrees are classified into ten levels . The formula is:

$$D = \sqrt{C \times T}$$

2.1 Spatiotemporal Analysis of Digital-Cultural-Tourism Industry Development Levels

2.1.1 Spatiotemporal Analysis of Digital Industry Development in the Yellow River Basin The spatiotemporal characteristics of the digital industry development index are illustrated in [Figure 2: see original paper]. Temporally, the digital industry development index exhibited an overall fluctuating upward trend from 2012 to 2022, increasing from 0.14 to 0.31 with an average annual growth rate of 8.17%. During the "Digital China" construction planning period (2016–2019), the basin' s digital industry index achieved rapid growth, rising from 0.19 to 0.27 at an average annual rate of 11.09%. From 2020 to 2022, COVID-19 impacts caused fluctuating declines, with the index dropping from 0.30 to 0.31 at an average annual decrease rate of 2.76%.

Spatially, average digital industry development indices for upstream, midstream, and downstream regions were 0.15, 0.22, and 0.39 respectively, showing a clear "downstream > midstream > upstream" pattern that reveals significant regional imbalances. Using 2022 data as an example, downstream mobile base station density reached 6.42 units/km^2, compared to 3.27 units/km^2 upstream and 4.35 units/km^2 midstream—downstream density being 1.96 times that of upstream areas. Information service employment in downstream provinces totaled 3.72$×10^{5}$ persons, 1.13 times the combined total of upstream and midstream provinces, indicating concentrated digital talent resources downstream while midstream regions show insufficient attraction for innovative digital talent. Due to substantial infrastructure and talent gaps upstream, technological innovation relies heavily on external input with weak autonomous development capacity, resulting in relatively lagging digital industry development.

Analyzing provincial distribution characteristics using ArcGIS 10.0 natural breaks classification, average digital industry development indices were categorized into high (0.253–1.000), medium (0.111–0.253), and low (0.000–0.111) levels [Figure 2: see original paper]. Shandong, Sichuan, and Henan ranked at high levels with average annual growth rates of 9.90%, 7.92%, and 6.09% respectively, benefiting from solid resource foundations and steady index growth. Shaanxi, Shanxi, and Gansu exhibited medium levels, with Shanxi

achieving the highest growth rate at 13.95% and Shaanxi at 11.12%, though both showed significant improvements from 2012 to 2022. Their industries remain concentrated in energy and chemical sectors with relatively weak digital foundations. Gansu' s digital industry index regressed from 2012 to 2022 with a -0.64% annual decline rate, indicating substantial pandemic impacts. Inner Mongolia, Qinghai, and Ningxia ranked at low levels, with digital-related industries accounting for only 10.90%, 10.09%, and 15.38% of GDP respectively in 2022, reflecting low proportions and insufficient economic support for industrial development.

2.1.2 Spatiotemporal Analysis of Cultural Industry Development in the Yellow River Basin The cultural industry development index spatiotemporal characteristics are shown in [Figure 3: see original paper]. Temporally, the index demonstrated overall fluctuating growth from 2012 to 2022. During the "Twelfth Five-Year Plan" period, the Ministry of Culture issued the *Cultural Industry Doubling Plan* and *Cultural Reform and Development Plan*, providing policy, economic, technological, and land-use support that enabled steady growth from 0.19 to 0.33 at 8.75% average annual growth. From 2020 to 2022, COVID-19 disrupted cultural-tourism activities along the Yellow River, halting offline operations without adequate online revenue alternatives, causing the index to fluctuate downward from 0.42 to 0.40 at a -2.11% average annual decline rate.

Spatially, downstream regions showed higher average cultural industry development indices (0.38) compared to midstream (0.27) and upstream (0.19) areas, exhibiting a "downstream > midstream > upstream" pattern likely because downstream areas, as the Yellow River' s cultural core region, possess more complete cultural industry facilities. Using 2022 data, downstream cultural institutions (art performance groups, museums, public libraries) totaled 4,812—approximately the combined total of upstream (2,433) and midstream (2,379) institutions. Additionally, higher downstream population densities (2.62$\times$10^{3}$ persons/km^2 versus 1.37$\times$10^{3}$ persons/km^2 upstream) generate greater market demand and development potential for cultural industries.

Provincial analysis using ArcGIS 10.0 natural breaks classification categorized average cultural industry development indices into high (0.331–1.000), medium (0.158–0.331), and low (0.000–0.158) levels [Figure 3: see original paper]. Shandong, Henan, and Sichuan ranked at high levels with substantial improvements and average annual growth rates of 7.93%, 5.90%, and 3.52% respectively. These provinces possess large cultural market demands, with 2022 revenues from art, cultural heritage, library, and cultural market operations reaching 2.22$\times$10^{10}$ yuan, 1.92$\times$10^{10}$ yuan, and 1.15$\times$10^{10}$ yuan respectively—providing strong economic support. Shaanxi, Shanxi, and Gansu exhibited medium levels, with 2022 revenues of 1.04$\times$10^{10}$ yuan, 0.78$\times$10^{10}$ yuan, and 0.43$\times$10^{10}$ yuan respectively, indicating relatively limited market scale and insufficient development momentum. Inner

Mongolia, Qinghai, and Ningxia, with fewer cultural resources and lagging development and utilization, ranked at low levels.

2.1.3 Spatiotemporal Analysis of Tourism Industry Development in the Yellow River Basin Tourism industry development index spatiotemporal characteristics are presented in [Figure 4: see original paper]. Temporally, the index showed an inverted U-shaped pattern from 2012 to 2022. From 2012 to 2019, steady national economic growth and increasing demand for quality living drove tourism development upward from 0.16 to 0.22 at 4.92% average annual growth. From 2020 to 2022, pandemic impacts caused fluctuating declines from 0.20 to 0.15 at -14.50% average annual decrease.

Spatially, tourism industry development indices averaged 0.16 upstream, 0.18 midstream, and 0.27 downstream, maintaining consistency with digital and cultural industries in a "downstream > midstream > upstream" pattern. Downstream provinces, as national transportation hubs with stronger scenic area accessibility, averaged 2.22$×10^{9}$ passenger trips and 5.27$×10^{10}$ passenger-kilometers in 2022—far exceeding upstream and midstream averages. Downstream regions also host larger-scale tourism infrastructure, with 14,014 A-level scenic spots, travel agencies, and accommodation/food service enterprises in 2022, compared to 13,140 midstream and 7,310 upstream, facilitating tourism resource concentration and industry development.

Provincial analysis using ArcGIS 10.0 natural breaks classification categorized average tourism industry development indices into high (0.350–1.000), medium (0.148–0.350), and low (0.000–0.148) levels [Figure 4: see original paper]. Shandong, Sichuan, and Henan ranked at high levels with large-scale tourism infrastructure. In 2022, these provinces hosted 0.87$×10^{4}$ A-level scenic spots and travel agencies, with accommodation and food service enterprises totaling 0.53$×10^{4}$, demonstrating strong transportation network convenience and laying a demand foundation for tourism development. Shaa
yuan, 3.04$×10^{10}$ yuan, and 6.65$×10^{10}$ yuan respectively, indicating relatively lagging tourism economic efficiency requiring improved resource utilization to avoid misallocation and waste. Gansu, Qinghai, and Ningxia ranked at low levels.

2.1.4 Spatiotemporal Analysis of Comprehensive Digital-Cultural-Tourism Industry Development The comprehensive development index spatiotemporal characteristics are shown in [Figure 5: see original paper]. Temporally, the index exhibited fluctuating upward growth from 2012 to 2022. From 2012 to 2019, steady growth occurred from 0.17 to 0.26 at 8.01% average annual growth. From 2020 to 2022, pandemic impacts caused fluctuating declines from 0.24 to 0.23 at -5.63% average annual decrease.

Spatially, the comprehensive development index averaged 0.18 upstream, 0.21 midstream, and 0.31 downstream, again showing "downstream > midstream > upstream" distribution and demonstrating unbalanced comprehensive development. This relates to more rational downstream resource allocation, greater in-

dustrial vitality, and stronger regional coordination capacity, while midstream and upstream areas face constraints from industrial structure balance, policy support intensity, and innovation levels, resulting in relatively lower comprehensive development.

Provincial analysis using ArcGIS 10.0 natural breaks classification categorized average comprehensive development indices into high (0.311–1.000), medium (0.137–0.311), and low (0.000–0.137) levels [Figure 5: see original paper]. Shandong, Sichuan, and Henan ranked at high levels, with all three sub-indices at high levels, indicating more rational resource allocation and benign inter-industry circulation. Shaanxi, Shanxi, and Inner Mongolia exhibited medium levels, possessing certain industrial foundations but lacking balanced resource allocation due to structural shortcomings that hindered comprehensive development. Gansu, Qinghai, and Ningxia, with relatively low economic levels, insufficient fiscal support, and weak talent foundations, experienced intensified resource misallocation and lower comprehensive development levels. The provincial ranking similarity between the comprehensive index and individual industry indices further demonstrates the "Matthew effect" characteristic of development levels.

2.2 Spatiotemporal Analysis of Digital-Cultural-Tourism Industry Coupling Coordination

Based on the coupling coordination degree model, we calculated coupling coordination degrees for nine provinces and autonomous regions, with results shown in [Figure 6: see original paper]. Temporally, the basin' s overall coupling coordination degree displayed fluctuating upward growth from 0.38 to 0.46, with a 2.02% average annual growth rate. Since the 18th Party Congress (2012), inter-industry correlations and resource allocation rationality have steadily improved, with coupling coordination rising from 0.38 to 0.45 at 4.35% average annual growth. From 2020 to 2022, pandemic impacts caused declining resource allocation balance, with coupling coordination fluctuating downward from 0.47 to 0.46 at -3.23% average annual decrease.

Spatially, average coupling coordination degrees were 0.39 upstream, 0.42 midstream, and 0.54 downstream, again showing "downstream > midstream > upstream" distribution with significant regional differences, indicating varying resource allocation levels across the basin. Analyzing provincial evolution characteristics through three time cross-sections: In 2012, Shandong, Sichuan, and Henan were in basic coordination; Shaanxi in near-dysregulation; Inner Mongolia, Gansu, and Shanxi in mild dysregulation; and Qinghai and Ningxia in severe dysregulation [Figure 6: see original paper]. By 2022, Shandong reached intermediate coordination; Henan and Sichuan achieved primary coordination; Shaanxi attained basic coordination; Shanxi reached near-dysregulation; Inner Mongolia and Gansu remained in mild dysregulation; and Qinghai and Ningxia stayed in severe dysregulation. Notably, Shandong' s coupling coordination improved over 2012, demonstrating strong industrial recovery capacity and lead-

ership in coordinated development. Henan and Shanxi maintained 2022 levels equal to 2012, also indicating robust recovery capacity to efficiently repair pandemic-induced economic damage.

Regional evolution of coupling coordination grades shows: upstream areas transitioned from moderate dysregulation to mild dysregulation; midstream areas evolved from mild dysregulation to near-dysregulation; and downstream areas progressed from basic coordination to primary coordination. This reflects that downstream regions, with higher inter-industry correlations and stronger resource allocation rationality, can achieve high-quality synergistic development. From a coupling coordination perspective, cultural-tourism integration requires not only industrial correlation but also coordinated development among digital, cultural, and tourism industries.

3 Discussion

The Yellow River Basin, as a critical economic region and cradle of Chinese civilization, plays a vital role in advancing Chinese-style modernization. Since the 18th Party Congress, ecological protection and high-quality development of the Yellow River Basin have become major national strategic decisions, providing new opportunities for digital, cultural, and tourism industry development.

From an industrial development perspective, evolution patterns of digital, cultural, and tourism indices across Yellow River provinces show convergence due to strong interactions among digital innovation environments, cultural-tourism marketization levels, and tourism economic development. The cultural-tourism industry, characterized by high added value, integration, and permeability, naturally couples with strategic and future-oriented digital industries. This strong correlation indicates that the digital industry can provide technical support and infrastructure to accelerate cultural-tourism development and promote high-quality synergistic growth. The basin' s average coupling coordination degree is 0.46, indicating near-dysregulation. Shanxi, Inner Mongolia, Gansu, Qinghai, and Ningxia fall below average, primarily due to regional differences in geographical environment and tourism market attention.

This study employs weighted summation to evaluate development levels of the three industries. Its main contribution lies in analyzing spatiotemporal characteristics of development and coupling coordination across Yellow River provinces, revealing patterns in subsystem and index evolution that expand research perspectives and case applications on cultural-tourism integration. However, limitations exist: First, the indicator system emphasizes economic dimensions for cultural and tourism industries while limiting coverage of innovation, coordination, and sharing aspects. Future research should expand indicator selection to include more factors affecting industrial economy for more comprehensive evaluation systems. Second, data availability constraints limited the study period to 2012–2022. Since pandemic impacts on digital-cultural-tourism industries remain incompletely resolved, ideal development patterns cannot be fully captured.

Future studies should examine development under stable economic conditions and explore internal and external influencing factors using updated data.

4 Conclusions

From 2012 to 2022, the digital, cultural, and tourism industries in the Yellow River Basin exhibited fluctuating upward development trends, with both the comprehensive development index and coupling coordination degree gradually improving, demonstrating certain synergistic tendencies.

1) The three subsystems' comprehensive development indices and coupling coordination degrees showed consistent patterns: continuous growth from 2012–2019, brief decline due to pandemic impacts in 2020–2021, and gradual recovery after 2021.

2) Spatially, digital, cultural, and tourism industry development indices, comprehensive development indices, and coupling coordination degrees all displayed "downstream > midstream > upstream" distribution patterns, indicating stronger industrial foundations and integration capacity in downstream provinces.

3) Provincially, Shandong, Sichuan, and Henan ranked at high levels in both comprehensive development and coordination; Shaanxi and Shanxi showed advantages in certain subsystems but medium overall levels; Gansu and Inner Mongolia performed moderately; and upstream provinces like Qinghai and Ningxia lagged due to scattered industrial resources and weak technological foundations, with integration potential yet to be effectively activated.

4) The coupling coordination level of digital-cultural-tourism industries in the Yellow River Basin showed an overall positive trend, advancing from near-dysregulation to primary coordination. Upstream areas transitioned from moderate to mild dysregulation; midstream areas evolved from mild dysregulation to near-dysregulation; and downstream areas progressed from basic coordination to primary coordination. Future efforts should strengthen inter-regional policy guidance, optimize factor allocation efficiency, promote digital empowerment of cultural-tourism high-quality development, and achieve overall upgrading of integrated service industries in the Yellow River Basin.

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Note: Figure translations are in progress. See original paper for figures.