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# Coordinated Strategy of Ecological Protection and High-Quality Development of the Yellow River Basin

***The Comprehensive Research Group for Research on Ecological Protection and High-Quality Development Strategy of the Yellow River Basin***

**Abstract:** Water is a key factor restricting the ecological protection and high-quality development of the Yellow River Basin. A coordinated strategy system that centers on water needs to be established for protecting and developing the Yellow River Basin, based on a systematic, holistic, and synergistic orientation. The system is critical for implementing major national strategies in the Yellow River. This paper evaluates the achievements and key challenges in the management of the Yellow River Basin. The system explored in this study comprises five aspects: (1) regional coordination, (2) coordination of water ecology, environment, resources, security, and culture, (3) environmental factor governance coordination, (4) pollution reduction and carbon reduction coordination, and (5) multiple policy coordination. Furthermore, we propose several policy suggestions from the strategic perspective of coordinated regional development, including constructing a coordinated policy system, establishing an overall coordination mechanism of basin protection and development, strengthening a market-oriented governance mechanism, improving a value realization mechanism of ecological products of the basin, implementing synergistic actions that coordinate pollution and carbon reduction, and implementing a systematic protection and management project.

**Keywords:** Yellow River Basin; ecological protection; high-quality development; coordinated strategy

## 1 Introduction

As the second largest river in China, the Yellow River, known as the cradle and Mother River in China, carries profound history. Since the 18th National Congress of Communist Party of China (CPC), the CPC Central Committee has taken the ecological protection and high-quality development in the Yellow River Basin as a grand plan related to the great rejuvenation of the Chinese nation. On September 18, 2019, General Secretary Xi Jinping, made an important speech at the Symposium on Ecological Protection and High-Quality Development of the Yellow River Basin, stating that the ecological protection and high-quality development of the Yellow River Basin shall be elevated to a major national strategy [1]. In January 2020, Xi Jinping presided over the sixth meeting of the Central Financial and Economic Commission and delivered an important speech where he emphasized the need to solve prominent problems for the ecological protection and high-quality development of the Yellow River Basin, implement certain projects for ecological protection, restoration, and pollution control, comprehensively carry out in-depth water conservation and control actions, and promote the economical and intensive utilization of water resources. In October 2021, Xi Jinping presided over a symposium on further promoting the ecological protection and high-quality development of the Yellow River Basin in Shandong Province, requiring that the ecological red line must be retained during development and construction along the Yellow River, the upper limit cannot be broken through when developing and utilizing resources, especially for water resources, and the quality and efficiency of

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development shall be improved under strong constraints.

Currently, many challenges still exist in the ecological protection and high-quality development of the Yellow River Basin. Of these challenges, water is the core factor which requires systematic thinking and overall design from a strategic perspective. Researchers at the national level have conducted numerous studies in the related fields and its application in the Yellow River Basin; these include coordinating the relationship between water and sediment [2,3], water ecological protection [4,5], water resource utilization [6,7], water eco-compensation [8], water pollution control [9,10], and cultural construction [11]. However, there is an absence of literature on the coordinated system of ecological protection and high-quality development in the Yellow River Basin, which can integrate water resources, water environment, water ecology, water–sediment relationship, and water culture as a whole [12–14].

In this paper, the existing barriers are scientifically analyzed for the current ecological protection, water resources development and utilization, water–sediment regulation, flood control, disaster reduction, and economic and social development in the Yellow River Basin. We focus on water resources and explore a coordinated strategic system for ecological protection and high-quality development in the Yellow River Basin. This is based on the paradigm of promoting coordination between multiple links, fields, and factors in combination with the major national strategy, and aims to provide a strong support for the coordination protection of the Yellow River.

## 2 Achievements in the protection and management of the Yellow River Basin

Till date, remarkable achievements in the protection and management of the Yellow River Basin have been made. The flood control and disaster reduction system has been established; the shrinking trend of river channels have been initially curbed; the excessive growth of water consumption has been effectively curbed; the water conservation in the upstream has been steadily improved; the water and soil conservation has been significantly enhanced in the Loess Plateau in the middle reaches; the area of estuarine wetlands in the downstream has rebounded year by year; and the biodiversity has increased significantly. The central cities (Zhengzhou, Xi'an, and Jinan) and urban agglomerations in the Central Plains are being rapidly developed. The status of the Yellow River Basin has been further consolidated as an important agricultural/animal husbandry and energy base in China.

### 2.1 Significant achievements made in major projects of ecological protection and restoration

In recent years, several major projects have been successively implemented, these include the ecological protection and construction of the Three-River-Source Nature Reserve, construction of the Three-North Forest Shelterbelt, natural forest protection, soil and water conservation, returning farmland to forest/grassland. Several pilot projects for ecological protection and restoration of maintains, rivers, forests, fields, lakes, grassland, and sands have been carried out in Qilian Mountain, Loess Plateau, South Taihang Mountain, and Mount Tai. The ecological protection and restoration have been gradually strengthened in the Yellow River Basin [15]. The ecological red line has been delimited for and enforced by nine provinces (or autonomous region) along the Yellow River and a nature reserve system based on national parks has initially taken shape. The Three-River-Source National Park has been officially established as the first group of national parks; the pilot of Qilian Mountain National Park is being actively promoted, and priority areas have been delimited for biodiversity protection, such as the Qiangtang–Three-River-Source and Qilian Mountain [16]. The ecosystem is kept stable in the Yellow River Basin as a whole. According to a remote sensing survey and evaluation results from 2000 to 2018, the areas with improved ecological quality accounted for 77% of the entire Yellow River Basin, among which the midstream was ranked first, and 74.97% of its area has been significantly improved [17].

### 2.2 The significant improvement of the environmental quality in the basin

From 2006 to 2019, the surface water quality of the Yellow River Basin has generally improved. Among the 137 river sections in the basin, the proportion of sections with Class I–III was increased by 23%, while the proportion of sections with inferior Class V was decreased by 16.2%. The overall water quality has been improving with the pollution levels changing from moderate to mild pollution [18]. The concentrations of major atmospheric pollutants decreased significantly in the Yellow River Basin; the average concentrations of $PM_{2.5}$, $PM_{10}$, and $SO_2$ decreased by 29.2%, 29.6%, and 58.7%, respectively, from 2015 to 2019. In 2019, the number of days with excellent ambient air quality accounted for 76.5% of the entire year in the Yellow River Basin [19]. The soil environmental protection in the Yellow River Basin has been carried out holistically. Since September 2020, 4103 enterprises in nine provinces (regions) in the Yellow River Basin have been listed in the directory of key units under the supervision of soil pollution. In addition, a risk management and control system has been established for the soil environment of the

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entire basin. The agricultural land is managed by classification, the lightly and moderately polluted arable land shall be utilized in safe mode, and the heavily polluted arable land shall be strictly controlled [20].

### 2.3 Water–sediment regulation capacity enhanced greatly

In the past 20 years, large scale soil-water conservation and ecological engineering have been conducted on the Loess Plateau with an increased area of soil-water conservation up to $2.13 \times 10^5$ km$^2$ and an increased terrace area of $3.32 \times 10^4$ km$^2$. In predominantly sandy areas, the effective coverage rate of forest and grass terraces increased from 18% in 1978 to 61% in 2018 [21]. The number of check dams on the Loess Plateau, mainly distributed in gully areas of hills and highland, increased from approximately 2000 in 1950 to approximately 52 000 in 2015 (including about 16 000 key and medium dams). Seven key projects have been completed to regulate water and sediment that have overcome 12 major floods with flow over 10 000 m$^3$/s in the lower the Yellow River. These projects have reversed incidences of frequent river bank bursts and the diversion at the lower reach of the Yellow River; for more than 60 years, the embankment has not burst during the autumn flood [22].

### 2.4 Important progress made in the construction of Yellow River culture

As the core area of dry farming and the origin of modern humankind, the Yellow River Basin is also the birthplace of the early nation and urban civilization. Being a component of the Chinese civilization, Yellow River culture is the root and soul of the Chinese nation. The construction of the Yellow River National Cultural Park has been incorporated into the 14th-Five Year National Plan and the Long-Term Goal of 2035, which is aimed to further establish the value system and landmark system of Yellow River culture, explore the Yellow River harnessing history, and protect and inherit the intangible cultural heritage in the Yellow River Basin [23]. In recent years, the provincial (regional) governments in the Yellow River Basin have issued a series of administrative measures, regulations and plans, and successively built the Yellow River Culture Ecological Area at the Three-River Source region, the Yellow River scenic spot in Zhengzhou, the Yellow River estuary wetland ecotourism area in Dongying City of Shandong Province, and the Baili Yellow River ecological corridor in Sanmenxia City. The combination of ecological protection and cultural inheritance and tourism along the Yellow River is an important contribution in the protection of ecological resources in the Yellow River Basin and inheritance and perseverance of Yellow River culture [24].

### 2.5 Green development system of the Yellow River Basin improved continuously

Using real conditions in the Yellow River Basin, top-level design and strategic planning have been carried out by the Chinese government for the protection, governance and high-quality development of the Yellow River Basin from the strategic perspective of holistic regional coordinated development, poverty alleviation and building a well-off society. In addition, legislation to protect the Yellow River is being actively promoted. In October 2021, the *Yellow River Protection Law of the People's Republic of China (Draft)* was deliberated and adopted by the State Council; on October 8, 2021, the *Outline of Ecological Protection and High-Quality Development Plan for the Yellow River Basin* was issued jointly by the CPC Central Committee and the State Council; the *Implementation Plan for Urban Sewage and Waste Treatment in the Yellow River Basin during the 14th-Five Year Plan* was jointly issued by the National Development and Reform Commission and the Ministry of Housing and Urban Rural Development to guide the construction, operation, and maintenance of urban sewage/waste treatment facilities and other infrastructure in the Yellow River Basin; the *Opinions on the Implementation of In-Depth Water Conservation and Control Actions in the Yellow River Basin* was issued by the Ministry of Water Resources, comprehensively implementing the in-depth water conservation and control actions with water resources as the rigid constraint and promoting the intensive and economical utilization of water resources in the Yellow River Basin.

## 3 Key bottlenecks for high-quality development in the Yellow River Basin

The Yellow River Basin accounts for only 2.5% of the country’s total water resources [25]. In 2019, the volume of water extracted from the Yellow River Basin was $5.56 \times 10^{10}$ m$^3$ and neared the capped extraction volume for the basin, while the development and utilization rate of water resources was up to 80% [26]. The upstream discharge from Lanzhou accounts for approximately 60% of the natural runoff of the Yellow River [27], while water usage for residents, cultivated land, minerals and energy are concentrated in the lower reaches [28]. On the whole, various factors, including insufficient total amount and unbalanced spatiotemporal distribution of water resources, extensive mode of water consumption, low-level pollution control and high proportion of traditional resource-consuming

industries, have become key constraints on the ecological protection and high-quality development in the Yellow River Basin.

### 3.1 Uncoordinated relationship between water and sediment in the basin

In the Yellow River Basin, the uncoordinated relationship is featured as less water and more sediment. In recent years, the volume of freshwater in the Yellow River Basin has continuously decreased as a result of climate change impacts, water resources development and utilization, and other human activities, and the sediment discharge in the middle and upper reaches has accordingly decreased. Water shortages, therefore, are becoming more severe. Human activities play an increasingly negative role in the reduction of sediment discharge, especially in ecological construction projects; main river channel was silted and shrunk due to the siltation of middle and lower reaches and insufficient river-regulation project, resulting in the phenomenon of secondary suspended river, which exert pressure in flood control during flood season. In addition, drought and flood occur frequently, and the water ecological security is facing more challenges.

### 3.2 Sensitive and fragile ecosystem background

The ecosystem in the upper and middle reaches of the Yellow River is sensitive and fragile and faces significant issues such as desertification and soil erosion. In addition, the ecosystems of glaciers, permafrost, and grassland are being degraded in the upper reaches, resulting in the decline of water conservation in some areas. The contradiction between water-soil conservation and economic development is becoming increasingly prominent in the middle reaches; it is still difficult to control water and soil loss, which is crucial to adjust the existing pattern. Due to the reduction of water and sediment in the middle and upper reaches, the ecosystem has been seriously degraded in the lower reaches of the Yellow River Delta. Ecological and environmental issues, such as the continuous reduction of ecological flow, intensification of ecosystem fragmentation, reduction of biodiversity, and serious shrinkage of river/lake/wetland area have become increasingly prominent.

### 3.3 Ecological functions of rivers and lakes damaged by water pollution

In 2019, the proportion of inferior Class V water bodies was 8.8% in the Yellow River Basin; a total of nine river sections with inferior Class V water quality were mainly distributed in the Sanchuan River, Quchan River, Fenhe River and its tributaries. Among them, the Fenhe River Basin has continuously suffered from severe pollution from 2006 to 2019. For example, the water quality of the mainstream of the Fenhe River at Wennanshe section, maintained inferior Class V from 2012 to 2019. The water quality of the Sushui River at the Zhangliuzhuang section was also severely polluted [29]. Overall, water pollution has caused significant harm to the watershed ecosystem, especially by causing large loss of biodiversity in the river and lake; moreover it exacerbated the shortage of available water resources in the basin due to poor water quality, resulting in severe water shortages in some areas.

### 3.4 Unreasonable utilization structure of water resources

In the Yellow River Basin, water is mainly utilized for agricultural irrigation and accounts for 67.5% of the total water consumption, which is higher than the national average level (61.4%) [30]. In 2018, Ningxia used the highest proportion of 85.6% for agricultural water consumption out of the nine provinces (regions) in the Yellow River Basin (Fig. 1). With the increasing arable land area in the middle and upper reaches, water use for agricultural irrigation will be insufficient under the existing irrigation method [31]. The industrial sector in the upper and middle reaches is mainly composed of an energy-based industry, such as coal mining and beneficiation, coking and natural gas mining, which consumes a large amount of water and puts significant pressure on water supply in the middle and lower reaches [32]. In 2020, data from the national first-class water resources area (Fig. 2) indicated that the development and utilization rate of surface water is 80.2% in the Yellow River District (mainly including the Yellow River Basin) [33], which ranked first. Furthermore, the exploitation level of groundwater is high in the Yellow River Basin; in some areas the exploited amount of shallow groundwater reached up to 80% of total exploitable amount [34,35]. In recent years, with the strict management enforced on groundwater exploitation in provinces or autonomous region along the Yellow River Basin, the groundwater level in urban areas tend to be stable; however, the groundwater level in some agricultural irrigation areas continues to show a downward trend [36].

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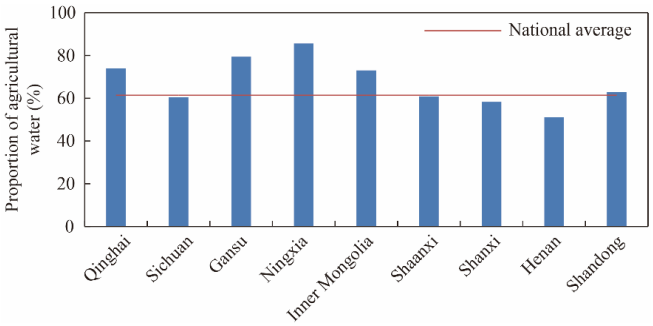


**Fig. 1**. Proportion of agricultural water consumption in the Yellow River Basin in 2018.

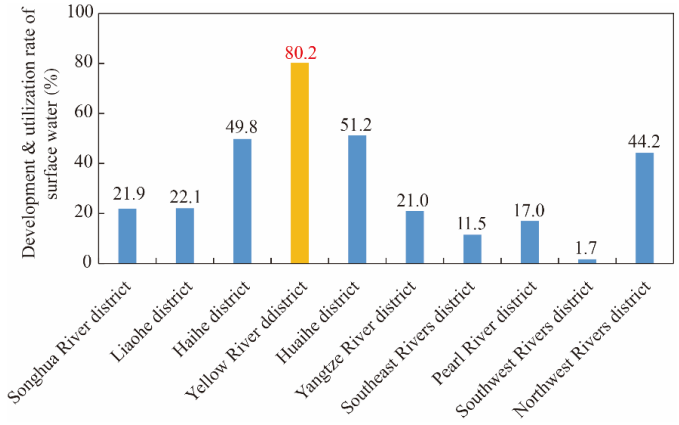


**Fig. 2**. The national development and utilization rate of surface water resources in first-class water resources areas in 2020.

### 3.5 Coordination system for high-quality development not formed yet

The Yellow River Basin has a high proportion of plantation, animal husbandry [37], low-end industries, resource-based industries, and labor-intensive industries [38], while there are fewer strategic emerging industries, high-end manufacturing, high value-added industries, and capital- and technology-intensive industries [39]. Therefore, there is path dependence in industrial transformation and upgrading, and the progress of transformation is slow. A reasonable industrial division and characteristic industrial clusters have not been formed within each city, among cities or urban agglomerations, thereby showing a situation of parallel competition. In addition, development in the Yellow River Basin is unbalanced and uncoordinated, with the developed, underdeveloped, and poor areas coexisting, and the gap is more prevalent between urban and rural areas [40]. There are many challenges in scientific and technological innovation, such as disorderly competition, lack of cooperation, and disproportionate influence. The decline of technological innovation and industrial competitiveness makes the overall competitiveness of various regions in the Yellow River Basin weak; therefore, it is difficult to jointly coordinate development.

## 4 Construction of a synergy strategic system in the Yellow River Basin

With a focus on ecological protection and high-quality development, a synergy strategic system must be established according to local conditions and by considering the overall and long-term interests of the entire Yellow River Basin. This system comprises five aspects: regional coordination, coordination of water governance (including water ecology, water environment, water resources, water security, and water culture), environmental factors (including water, air, and soil) governance coordination, pollution-carbon reduction coordination, and multiple policy coordination (Fig. 3). It is necessary to improve the systematic, integrated, and synergistic protection, governance, and green development in the Yellow River Basin and build it into a modern watershed economic belt with following characteristics: a stable and healthy ecological environment, intensive and economical utilization of water resources, developed and sound infrastructure and public services, an open and orderly market system, a reasonable and high-quality industrial layout, and a prosperous and revitalized Yellow River culture, which can realize the coordinated development among ecology, livelihoods, resources, economy, and culture.

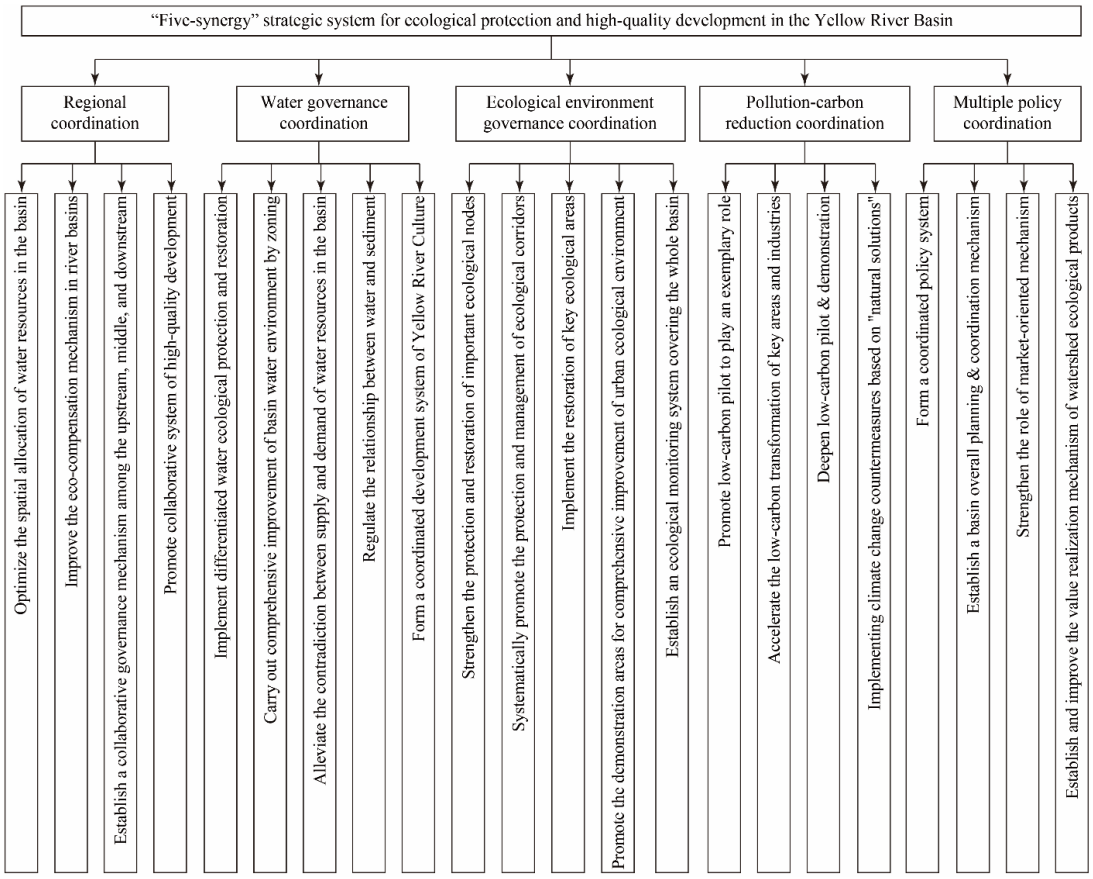


**Fig. 3.** A framework for a coordinated strategy system for the ecological protection and high-quality development in the Yellow River Basin.

### 4.1 Regional synergy strategy

It is necessary to focus on the utilization and regulation of water resources in the Yellow River from the strategic perspective of regional coordinated development. The area of cities and land, population, and production shall be determined with water resources as a rigid constraint. By optimizing the allocation of water resources, implementing the eco-compensation mechanism, and establishing the joint meeting system in the river basin, overall planning must be made to coordinate the amount of available water resources and quality of water environment, and drive the development of surrounding cities with central cities and urban agglomerations. This can enable the realization of coordination between the ecological protection and high-quality development of the Yellow River Basin, including the upper, middle, and lower reaches, as well as the left and right river banks.

(1) Optimizing the spatial allocation of water resources can accelerate the construction of a water rights trading market, improve the cross-regional allocation of water rights among the upstream, midstream, and downstream, and establish a regional water rights cooperation mechanism. It is necessary to implement the replacement of water rights and water use indicators in the middle and lower reaches of the Yellow River, and coordinate the contradiction between the supply and demand of water-use indicators among various areas to promote water equity in the Yellow River Basin. The water price of the Yellow River Diversion Project should be adjusted, and water efficiency should be enhanced in the middle and lower reaches to further optimize water resources allocation.

(2) The eco-compensation mechanism in the river basin should be improved. According to on the *Pilot Implementation Plan for Supporting and Guiding Establishment of Horizontal Eco-Compensation Mechanism in the Yellow River Basin*, the cross-regional eco-compensation shall be accelerated in the whole Yellow River Basin for the purpose of improving water resources and the environment; it is, therefore, necessary to establish a management platform for the eco-compensation mechanism in the Yellow River Basin to support and guide the nine provinces along the Yellow River. Moreover, it will establish diversified horizontal eco-compensation and better promote the market-oriented compensation mechanisms, such as carbon sink trading, water rights trading, and emission rights trading.

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(3) A coordinated governance mechanism should be established among the upper, middle, and lower reaches of the Yellow River. A linkage mechanism shall be explored and established for ecological and environmental protection in the upper, middle, and lower reaches of the Yellow River Basin with features of unified planning, standards, environmental assessment, monitoring, law enforcement, and emergency response. It is necessary to strengthen capacity building for ecological law enforcement in the basin, and improve the joint law enforcement mechanism across regions and departments. The improvement of the water-sediment regulation system in the basin can comprehensively promote water conservation in the upper reaches, water and soil conservation in the middle reaches, beach treatment and flood control in the lower reaches, and realize the coordinated treatment of water and sediment in the upper, middle, and lower reaches. Moreover, a large data platform will be established to uniformly monitor and manage water resources, environment, ecology, and disasters in the Yellow River Basin.

(4) A high-quality coordinated development system should be promoted. It is necessary to design a high-quality coordinated development path according to the overall situations of industrial development, watershed harnessing and social development of the whole basin, and accelerate the construction of transportation (e.g., high-speed railway, civil aviation, expressway, and information network) between and within urban agglomerations in the basin. A cross-regional cooperation mechanism shall be established from which inter-provincial governments can build a communication platform to promote the participation of enterprises and social organizations. It is also necessary to strengthen the planning, coordination, and connection of urban agglomerations, clarify the key areas of regional cooperation, coordinate urban agglomerations in the Central Plains and Shandong Peninsula, and give play to their leading role in the basin and promote the coordinated development of multiple regions. This system can introduce the guiding policies for industrial transformation and upgrade, promote the optimization and adjustment of industrial system, vigorously develop high-tech industries in central cities, and build a modern industrial system based on the knowledge intensive and environment-friendly industries.

### 4.2 Synergy strategy of water governance

Giving priority to ecology, a strategic system shall be built for the overall planning of water ecology, water environment, water resources, water security, and water culture This strategy can inform the establishment of water governance objectives, indicators, and evaluation methods, which reflect the characteristics of the Yellow River Basin. Considering the features of water ecology, water environment, water resources, water security, and water culture in the upper, middle, and lower reaches of the Yellow River, a roadmap shall be formulated to implement the synergy strategy of water governance.

(1) Differentiated water ecological protection and restoration should be implemented to promote the construction of beautiful rivers and lakes. The strategy of water governance is to implement management and restoration through zoning and classification, gradually restore the water ecosystems of trunk, tributaries, and important lakes, improve the upstream water conservation, and effectively rehabilitate damaged river/lake ecosystems in the middle and lower reaches. In addition, the strategy is to strengthen the protection of natural forests and grasslands in the catchment areas of the Yellow River and its main tributaries, prioritize enclosure protection, implement closure-ban management, relieve anthropogenic pressures, and maintain the originality and integrity of ecosystem as far as possible. Moreover, it is necessary to actively undertake the ecological protection and restoration of riparian ecological buffer zones and aquatic vegetation of rivers with severely damaged aquatic ecosystems, such as the Fenhe River and Sushui River. It is also necessary to conduct the comprehensive treatment specific to ridge, plateau, slope, ditch, and river according to local conditions for the tributaries with severe soil erosion, such as the Taohe River, Weihe River, Jinghe River, Beiluo River, Wuding River, and Kuye River. It is also integral to carry out water ecological restoration for major rivers and lakes, such as Dawen River and Dongping Lake in the lower reaches; implement projects, such as the construction of water conservation forests around rivers and lakes, and the restoration of vegetation on banks and embankments; and restore the function of river/lake water system and corridors. We should focus on the protection and restoration of wetlands in the Yellow River Delta, accelerate the returning ponds to rivers, returning farmland to wetlands or beaches, implement ecological water replenishment projects, and connect estuarine water systems to expand the area of natural wetlands.

(2) The water environment in the basin can be comprehensively improved with policies by zoning and strengthening the systematic treatment of environmental pollution. It is necessary to focus on the upgradation and reconstruction of urban sewage treatment facilities and construction of pipe networks along the Huangshui River, Kuye River, Shichuan River, Beiluo River, and Jinghe River. Water pollution control shall be under the unified control of industrial agglomeration areas, such as Erdos city and Yulin city and the responsibilities of enterprises for

pollution control shall be clarified, so as to ensure the consistent quality standard of discharge into the rivers. Agricultural non-point source pollution shall be intensively controlled in the main production areas of Fenwei Plain and Hetao irrigation area; the ecological irrigation area shall be constructed with some effective measures taken, such as ecological interception ditch and soil testing and formula fertilization, so as to comprehensively control non-point source pollution. The industrial wastewater treatment projects shall be implemented in key industries, such as coal chemical, coking, pesticide, agricultural and food processing, and active pharmaceutical ingredients manufacturing. This is to continuously promote the advanced treatment and recycling of wastewater from industrial enterprises, gradually improve the comprehensive utilization rate of wastewater, and reduce the discharge of industrial wastewater.

(3) Focusing on the intensive conservation and optimal allocation to alleviate the supply-demand contradiction of water resources. Water conservation shall be rooted in all aspects from agriculture, industry to daily life, and in the whole process from water intake, water supply to water consumption, implement water quota in place, overcome the shortcomings of water-saving projects, and strengthen the supervision on water conservation. It is necessary to curb the unreasonable demand for water through the rigid constraint of water resources, improve the utilization efficiency of water resources, and promote the spatial balance of water resources in the basin. For Lanzhou–Xining Economic Belt, the solution to the supply-demand contradiction of water resources shall focus on improving the rational utilization and enhancing the carrying capacity of water resources. For Ningxia–Inner Mogolia Irrigation Area, we should focus on strengthening water conservation and efficiency improvement, as well as water-soil balance. For the energy base in the middle reaches, it focuses on ensuring water supply and improving the water use efficiency. For the downstream and the Yellow River Diversion Irrigation Areas, we should focus on scale control and water source replacement. According to the principle of "local adjustment under overall stability," it is available to optimize and adjust 1987 Water Diversion Scheme, and the water use indicators can be appropriately increased for some upstream provinces.

(4) Regulating the relationship between water and sediment to ensure the water safety in the basin. The purpose of regulating the relationship between water and sediment is to adjust the spatial pattern of soil erosion control, and further control the soil erosion in areas with high vegetation restoration potential, such as loess hilly and gully areas, earth-rock mountainous areas, and arid grassland areas. For the Loess Plateau gully area, highland grassland area and windy sand area, the construction of forest and grass vegetation shall be appropriately slowed down according to the amount of water resource. Combined with the regulation of water and sediment in Xiaolangdi Reservoir, as well as river regulation, the ditch and dike river can be silted and blocked through dredging by flood diversion and mechanical dredging in beach area, and then leveled into the available land, and the secondary suspended river shall be solved the soonest possible. The beach areas shall be treated by classification, so as to make most of them into permanent safety areas.

(5) Forming a coordinated development system of Yellow River culture on the basis of water culture pattern of one river, two parks, and three mountains. In the context of forming a coordinated development system, the overall pattern shall be formed to protect the Yellow River culture with the Yellow River as an axis and Songshan Mountain, Huashan Mountain, and Taishan Mountain (by which the Central Plains Culture, Guanlong Culture, and Qilu Culture are respectively bred) as cultural protection areas, as well as the construction of the Three-River-Source National Park and the Yellow River Estuary National Park. It is necessary to tap into the value of Yellow River culture and promote the deep integration of culture and tourism; the water culture industry can be coordinated and developed throughout the entire basin by integrating the development of the Yellow River culture and its radiating and driving effect. Using Zhengzhou, Xi'an, and Taiyuan as examples, the Yellow River culture can be expanded in three provinces (e.g., Shanxi, Shaanxi, and Henan) as the demonstration area and Lanzhou–Xi'an urban agglomeration, Hohhot–Baotou–Ordos–Yulin urban agglomeration and Shandong Peninsula urban agglomeration as the carriers.

### 4.3 Synergy strategy of ecological environment governance

Based on the integral ecosystem in the Yellow River Basin, the pollution control shall be carried out according to the pattern of point (multipoint) − line (one trunk line and ten corridors) − area (seven areas), which can form an interconnected network for ecological environment control, so as to jointly protect and control the environment and water, atmosphere and soil ecosystem of the entire basin.

(1) Strengthening the protection and restoration of important ecological nodes. It is necessary to protect key lake and reservoir ecosystems, such as Ulansuhai Lake, Hongjiannao Lake, Dongping Lake, and Shahu Lake. Soil pollution risk shall be prevented and controlled with emphasis on some areas, including Baiyin in Gansu, Xining in

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Qinghai, Baoji and Shangluo in Shaanxi, Sanmenxia and Luoyang in Henan, as well as enterprises utilizing heavy metals. The habitats shall be protected and restored for important wildlife, such as the Tibetan antelope, snow leopard, wild yak, indigenous fish, and rare plants.

(2) Systematically protecting and managing ecological corridors. This is to stabilize water quality of the main stream of the Yellow River, so as to ensure the ecological flow and health; moreover, it is necessary to promote the water environmental governance and water ecological protection and restoration of key tributaries, such as Huangshui River, Taohe River, Kuye River, Wuding River, Yanhe River, Fenhe River, Weihe River, Qinhe River, Yiluo River, and Dawen River and maintain the function of the ecological corridor.

(3) Key ecological areas should be restored. The regional ecological environment shall be harnessed systematically and comprehensively with a focus on the following: (1) water conservation areas at the source of the Yellow River (including the Three-River Source, Qilian Mountains, Gannan, and Ruoergai ecological functional areas); (2) the desertification control area (including the southern edge of Inner Mongolia Plateau and central Ningxia); (3) the soil-water conservation area (including the Loess Plateau in Eastern Gansu, Northern Shaanxi, and Northwestern Shanxi); (4) key river/lake water pollution control areas (including the Fenhe River, Wushui River, and Ulansuhai Lake); (5) estuarine ecological protection areas (i.e.: wetlands in the Yellow River Delta); (6) air pollution prevention and control areas (e.g., Fenwei Plain); and; (7) soil pollution risk control areas (i.e., areas with intensive mineral resources development). In order to improve the water conservation function of source area of the Yellow River, it is necessary to restore and control the northwestern desertification control area and soil-water conservation area of the Loess Plateau, gradually restore the ecological function of wetlands in the Yellow River Delta, improve the water environment of key rivers and lakes and the atmospheric environment of the Fenwei Plain, and strengthen soil pollution risk control in mineral development areas and areas with high land development intensity.

(4) Demonstration areas should be constructed for a comprehensive improvement of urban ecological quality by focusing on central cities, such as Zhengzhou and Jinan. The key points of demonstration area shall cover ecosystem protection and restoration, optimization and adjustment of water function zoning, protection of healthy waterbodies, and the ecological transformation of industrial parks. It is necessary to carry out ultra-low emission transformation, comprehensive treatment of industrial kilns, prevention and control of motor vehicle pollution, and comprehensive treatment of volatile organic compounds. Furthermore, it will require the implementation of coordinated waste, gas, residue, sewage, and sludge treatment; control and remedy soil pollution risk. With comprehensive application of modern environmental technology and equipment, the governance system can be formed for various environmental elements to improve the overall quality of the regional urban environment and establish a model for modern urban environmental governance.

(5) An ecological monitoring system for the entire basin should be established. The purpose of an ecological monitoring system is to establish a comprehensive environmental monitoring network across districts and counties in the Yellow River Basin and to regularly carry out environmental law enforcement in the basin. Furthermore, it can establish an emergency linkage mechanism for environmental pollution events in the basin, and collectively coordinate responses to address these pollution events through information exchange, counterpart exchange, case investigation, and joint response.

### 4.4 Synergistic strategy for reducing pollution and carbon

In terms of achieving carbon peak and neutralization, the overall requirements shall be comprehensively followed to reduce pollution and carbon. By focusing on key areas and industries, the original end-to-end treatment shall be shifted to source treatment and systematic treatment. It is compulsory to meet total emission reduction, source emission reduction, and structural emission reduction with the goal of carbon peak and carbon neutralization as constraints to implement coordinated pollution and carbon reduction.

(1) Promoting the provinces and cities with low-carbon pilot to play an exemplary role and achieve the goal of carbon peak by stage and by region. This is to encourage some cities with a carbon peak trend (e.g., Pingliang in Gansu, Jiaozuo in Henan, and Zhongwei in Ningxia) to reduce their emissions from the peak from 2022. Several cities with carbon emissions already in the platform stage (e.g., Anyang in Henan, Tianshui in Gansu, and Xi'an, Baoji, and Weinan in Shaanxi) will reduce emission from the peak around 2025. The process management shall be strengthened to achieve the carbon peak target, and the intensity target shall be scientifically determined for carbon emission per unit of GDP. An implementation plan will be formulated for each province (region) in the Yellow River Basin.

(2) The low-carbon transformation of key fields and industries should be accelerated. The total carbon emission shall be strictly controlled specific to energy-intensive industries, such as coal power, steel, building materials, nonferrous metallurgy and petrochemical. It is necessary to strictly control the carbon emission intensity and total emission of newly-increased coal power and coal chemical projects in Inner Mongolia, Ningxia, Shaanxi and Shanxi; promote the process of "coal to gas" and "coal to electricity" projects, implement the reduction and substitution of industrial coal, and improve industrial electrification. In the development of energy and chemical industry bases in the upper and middle reaches of the Yellow River, it is necessary to construct modern high-standard energy demonstration parks for green and low-carbon recycling. Relying on major projects such as clean heating in the north, the clean transformation of building energy shall be further promoted in northern cities in the Yellow River Basin. The infrastructure shall be improved to build an intelligent transportation system for low-carbon travel.

(3) Increasing low-carbon pilot projects and demonstration. This is to construct demonstration areas with near-zero carbon emissions and neutrality, and build a several zero-carbon cities, zero-carbon communities, and zero-carbon parks in combination with regional and industrial characteristics. In the regions with preliminary works and inherent conditions, such as Shaanxi, Shanxi, and Inner Mongolia, key projects and clusters shall be deployed and constructed for $CO_2$ capture, utilization, and storage. The regions and cities with rich low-carbon development and strong willingness can be selected to implement the pilot and demonstration of environmental quality up to standards and carbon emission reaching peaks.

(4) Nature-based solutions climate change countermeasures should be adopted. In the water conservation areas of Three-River Source, Qilian Mountains, and Gannan in the upper reaches of the Yellow River, it is necessary to strengthen the protection of alpine grasslands and agro-pastoral ecotone ecosystems and make an overall plan for the integrated protection and restoration of "mountains, rivers, forests, fields, lakes, grassland and sands," it shall be delimited as forest, arable land or grassland according to its actual conditions. It is also necessary to strengthen the ecological protection and restoration of grassland wetlands in Qinghai Lake and wetlands at the estuary of the Yellow River and increase the carbon sink reserves of wetlands. Moreover, it is necessary to rationally arrange urban green space systems, such as green cores and green corridors, connect the urban river network and water system, transform the urban and rural infrastructure to be climate resilient, and formulate/revise relevant standards, norms, and policies. In addition, it can improve the construction standards of urban lifeline systems (e.g., power supply, heating, drainage, gas, and communication) according to extreme weather.

### 4.5 Synergistic strategy of multi-policy implementation

In terms of the core idea of "work together to protect and harness the Yellow River," a linkage effect shall be formed for the policies on ecological protection and economic development by improving the policy system and building a management platform. This will be followed by the establishment of a coordinated, systematic, and efficient administrative system to jointly promote the high-quality development of the Yellow River Basin.

(1) A coordinated policy system should be formed. The policies shall improve water resource allocation, to scientifically and reasonably determine the ecological flow (water volume) of rivers and lakes in the trunk and tributaries of the Yellow River in combination with the construction of major water-transfer projects, such as national water network project and follow-up project of South-to-North Water Diversion and optimize and refine the "1987 Water Diversion Scheme." The water-saving system that will be implemented, includes the formulation and implementation of an action plan for the economical and intensive utilization of water resources in the Yellow River Basin, formulating the supporting incentive policies for water-saving and guiding social capital investment to conserve water usage. The water rights trading platform shall be established to realize the cross-regional and cross-industrial circulation of water conservation. Moreover, the water-pricing mechanism shall be improved to implement differentiated water prices, stepped water prices and progressive pricing by region, industry or time period. It is necessary to prevent and control disasters at key river sections and weak links; establish a water ecological monitoring and assessment system, and build a supervision system based on the pollutant discharge permit specific to the fixed pollution source. The development plan shall be organized and developed for energy transformation in the Yellow River Basin, and the supporting policies shall be formulated and implemented for the green and high-quality development of industry in the Yellow River Basin.

(2) An overall planning & coordination mechanism should be established for watershed protection and development. The system and mechanisms need be innovated to incorporate regional synergy and sector cooperation into comprehensive decision-making on the protection and governance of the Yellow River, this is to minimize discontinuity among administrative regions and solve disorderly management. A coordination mechanism shall be

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established for the joint prevention and control of environmental pollution and ecological damage in key regions and river basins across administrative regions. The promotion mechanism shall be formed for multi-agent and multi-strength participation in the protection and governance of the entire basin, and the collaborative implementation mechanism formed among regions, urban and rural areas, departments, and society. An information-sharing platform shall be built for the ecological protection and high-quality development in the Yellow River Basin to implement the information-sharing system across regions, sectors, and industries in the Yellow River Basin.

(3) The role of market-oriented governance mechanism should be strengthened. The decisive role of the market shall be given complete consideration in resource allocation and a diversified and market-oriented investment mechanism shall be established in terms of the capital needs of water resources protection and economical utilization, ecological environment harnessing and restoration, and green infrastructure construction in the Yellow River Basin. It is also necessary to explore the cross-regional water rights trading mechanism and encourage water conservation and improve utilization efficiency of water resources, rationally connect the eco-compensation mechanism with the innovative mechanism based on the market allocation, such as emission trading, consideration of the role of the market, and establish a horizontal eco-compensation mechanism for the whole basin.

(4) It is essential to establish and improve the value realization mechanism of watershed ecological products. The basic information shall be investigated on watershed ecological products to estimate their quantity and quality. After this determination, it will be used to establish a database of ecological products, followed by calculating the value of watershed ecological products and evaluating the effectiveness of watershed ecological protection and the value of ecological products. Relying on ecological resources, such as forests, grasslands, and wetlands in the basin, the transformation path and mode shall be broadened according to the vision of “Lucid waters and lush mountains are invaluable assets,” so as to develop industries such as ecotourism, recycling agriculture, and low-carbon industry according to local conditions. Furthermore, it will promote the transformation of ecological advantages into industrial advantages in the basin, and select the representative ecological products of all provinces (regions) to build the regional brand of ecological products. The allocation mechanism shall be improved for financial transfer payment fund in terms of key factors, such as value accounting results of ecological products, ecological red line, and area.

## 5 Conclusions

Research on the ecological protection and high-quality development of the Yellow River Basin involves many aspects, such as ecological environment, resource development and utilization, disaster prevention and reduction, economic development, livelihood and well-being, and cultural inheritance. From a multi-dimensional perspective, this study constructs a strategic system that centers on water, which is composed of synergies among the regions , water governance, ecological governance, pollution-carbon reduction, and multi-policies. In the new development period, it is a new and important proposition to further promote the major national strategy of the Yellow River. Therefore, as an important energy base in China, the Yellow River Basin shall develop its resource advantages of non-fossil energy, optimize the energy structure, and realize energy transformation in combination with the objectives of carbon peak and carbon neutralization. In addition, under the context of the profound influence and deep integration of global climate change, ecological protection, and economic and social development, it is still necessary to further research many related themes, such as transformation path between the old and new drivers of economic development in the Yellow River Basin, the value realization mode of ecological products with regional characteristics, and the inheritance and promotion of excellent cultural resources in the Yellow River Basin.

## References

[1] Xi J P. Speech at symposium on ecological protection and high-quality development in the Yellow River Basin [J]. Qiushi, 2019(20): 4−11.Chinese.

[2] Zhang H W. Study on water and sediment regulation and flood control of the Yellow River based on high-quality development goal of the basin [EB/OL]. (2021-11-20)[2021-12-08]. https://kns-cnki-net.webvpn.las.ac.cn/kcms/detail/10.1746.TV.20211118.2139.002.html. Chinese.

[3] Su J Y, Wang B C, Wang F, et al. On the position and function of soil and water conservation in the strategy of ecological protection and high quality development in the Yellow River Basin [J]. Soil and Water Conservation in China, 2021 (11): 1−3. Chinese.

[4] Zhou X F, Cao G Z, Yu F, et al. Risk zoning of water pollution in the Yellow River Basin[EB/OL]. (2021-10-27)[2021-12-08]. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CAPJ&dbname=CAPJLAST&filename=HJKZ20211026004&uniplatfor

m=NZKPT&v=xQUCJGvGRRHMP-O4syzzyh7EhpCyC2EKy8sDAFW1GbhH-OuFXjKB4sr81vtth46R. Chinese.
[5] Zhang M, Lyu Y H, Liu L. Main problems and countermeasures of water ecological protection in Yellow River Basin [J]. Sichuan Environment, 2021, 40(5):157−161. Chinese.
[6] Wu C F, Xian Y N. Evaluation of water resources utilization efficiency in the Yellow River Basin based on DEA model [J]. Journal of Hebei GEO University, 2021, 44(5): 119−124. Chinese.
[7] Li Y Y, Li Y L, Wang H J, et al. Thoughts and proactive measures for strengthening water resources regulation in the Yellow River Basin [J]. China Water Resources, 2021 (18): 8−10. Chinese.
[8] Li N N, Shi Z L. Consideration on water ecological compensation mechanism in Yellow River Basin [C]. Xi'an: Proceedings of the 9th China Water Ecology Conference, 2021. Chinese.
[9] Xia J, Liu B J, Cheng D D. Discussion on water security and high quality development of Yellow River Basin [J]. Yellow River,2021, 43(10): 11−16. Chinese.
[10] Li Z, Zhu X Y. Study on legislation of water pollution prevention and control in Yellow River Basin [J]. Country Agriculture Farmers (B), 2021 (8): 41−43. Chinese.
[11] Xu J F. The status and function of Yellow River culture in ecological protection a high quality development of Yellow River basin were analyzed [C]. Beijing: China Society of Water Economics, 2021. Chinese.
[12] Qin H, Ren B P. The Goal and realization path of high-quality development of urban agglomeration in the Yellow River Basin [J]. Review of Economy and Management, 2021, 37(6): 26−37. Chinese.
[13] Zhao Z Q. Ecological protection and high-quality development in the Yellow River Basin: Coordination mechanism and countermeasures [J]. Theoretical Research, 2021 (5): 73−80. Chinese.
[14] Zhang X Y, Liu L. On the Combination of economic growth and ecological environment in the Yellow River Basin from the perspective of high-quality development [J]. Journal of Shangqiu Normal University, 2021, 37(10): 73−77. Chinese.
[15] Dong Z F, Hao C X, Qu A Y, et al. Orientation and focus on construction of the ecological compensation mechanism in the Yellow River Basin [J]. Ecological Economy, 2020, 36(2):196−201. Chinese.
[16] Tang F L, Tian Y C, Yan Y. Reconstructing the nature reserve system in the context of national park system construction [J]. Journal of Beijing Forestry University(Social Sciences), 2021,20(2): 1−5. Chinese.
[17] Li G W, Gao X Q, Xiao N W. The spatial and temporal changes of ecosystem quality based on key indicators in the Yellow River Basin from 2000 to 2018 [EB/OL]. (2021-09-01)[2021-11-02]. https://doi.org/10.13198/j.issn.1001-6929.2021.08.28. Chinese.
[18] Cui P P, Zhao Y, Xia S Y, et al. Level measures and temporal and spatial coupling analysis of ecological environment and high quality development in the Yellow River Basin [J]. Economic Geography, 2020, 40(5): 49−57, 80. Chinese.
[19] Li H, Han Y. Analysis of the spatial and temporal evolution characteristics of $PM_{2.5}$ in the Yellow River Basin and its influencing factors [EB/OL]. (2020-07-20)[2021-10-29]. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CAPJ&dbname=CAPJLAST&filename=SJDJ202007160000&uniplatform=NZKPT&v=mRueCzqsRnRbrRMRUMlTSM_K_TFVNFhrfqZ0WK0djL2plJP1mDPOwTQvCCc1j_o2. Chinese.
[20] Liu R P, Wei N, Song Z X, et al. Strategic thinking on soil pollution control in Yellow River Basin [J]. Environmental Science and Management, 2021, 46(9): 45−49. Chinese.
[21] Chen C X, An C H, Luo Q S, et al. Study on the effect of the water and sediment regulation in the Yellow River [J]. Journal of Sediment Research, 2019, 44(2): 69−74. Chinese.
[22] Yao W Y, Jiao P. Water and sand changes in the Yellow River and prospects for research [J]. Soil and Water Conservation in China,2016 (9): 55−63, 93. Chinese.
[23] Niu J R. On the protection, heritage and rational use of the culture of the Yellow River Basin [J]. China Market, 2021 (6): 1−4. Chinese.
[24] Yue R B, Han Z G.A study on the quality development of ecotourism in the middle and lower reaches of the Yellow River during the flood season in coastal sites [J]. Social Scientist, 2020(11): 38−43. Chinese.
[25] Yellow River Conservancy Commission of the Ministry of Water Resources. Yellow River water resources bulletin 2019 [R]. Zhengzhou: Yellow River Conservancy Commission of the Ministry of Water Resources, 2019. Chinese.
[26] Wang Y，Peng S M，Wu J，et al. Review of the implementation of the Yellow River Water allocation scheme for thirty years [J]. Yellow River, 2019, 41(9): 6−13, 19. Chinese.
[27] Zhao Y Y, Yu F W. Sustainable utilization of water resources in the Yellow River Basin: Core, path and countermeasures [J]. Studies on Socialism with Chinese Characteristics, 2020 (1): 52−62. Chinese.
[28] Pan Q M, Zhang R S, Li Z Y. Analysis of water resources quantity and its distribution in Yellow River Basin [J]. Yellow River, 2008(8): 54−55. Chinese.
[29] Ministry of Ecology and Environment of the People's Republic of China. China ecological and environmental status bulletin 2019 [R]. Beijing: Ministry of Ecology and Environment of the People's Republic of China, 2020. Chinese.
[30] Zhang H, Liu Q J, Shi S J. Study of comprehensive evaluation of agricultural water resources utilization efficiency in the Yellow River Basin [J]. Meteorological and Environmental Sciences,2015, 38(2): 72−76. Chinese.
[31] Cheng W M, Gao X Y, Ma T, et al. Spatio-temporal distribution and transformation of cropland in geomorphologic regions of China during 1990–2015 [J]. Acta Geographica Sinica, 2018,73(9): 1613−1629. Chinese.

DOI 10.15302/J-SSCAE-2022.01.010

[32] Xiang X Z, Jia S F. Estimation and trend analysis of water demand of energy industry in China [J]. Journal of Natural Resources,2016, 31(1): 114−123. Chinese.

[33] Wang H, Zhao Y. Preliminary study on harnessing strategies for Yellow River in the new period [J]. Journal of Hydraulic Engineering, 2019, 50(11): 1291−1298. Chinese.

[34] Han S B, Li F C, Wang S, et al. Groundwater resource and eco-environmental problem of the Yellow River Basin [J]. Geology in China, 2021, 48(4): 1001−1019. Chinese.

[35] Li D, Pan Q M, Zhou N W, et al. Analysis of water resources utilization in Yellow River Basin [J]. Ground Water, 2021, 43(3):183−187. Chinese.

[36] Jia Y F, Zhao M, Shang C J, et al. Current situation and suggestions on groundwater environmental problems in the Yellow River Basin [J]. Environmental Protection, 2021, 49(13): 20−23. Chinese.

[37] Fang L N, Yin C B, Fang Z, et al. The promotion path of high quality agricultural development in the Yellow River Basin [EB/OL]. (2021-10-21)[2021-10-29]. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CAPJ&dbname=CAPJLAST&filename=ZGNZ2021101900C&uniplatform=NZKPT&v=lXP1LDpk_N2zoKQbcg4R4beBYWwyt4bCRFaUBgu-SG0Ph-eIAR7SqsbyQiKYOpj9. Chinese.

[38] Su Y W, Liu Z X. Research on the factors influencing the optimization of industrial structure in the Yellow River Basin under resource-environment constraints: Analysis based on the data from 2008 to 2018 [J]. Journal of Northwest University (Natural Science Edition), 2021, 51(3): 425−437. Chinese.

[39] Zhang R, Wang G Y, Sun X L. Fiscal decentralization, industrial structure and high quality development of the Yellow River Basin[J]. On Economic Problems, 2020 (9): 1−11. Chinese.

[40] Bai L F, Xu L M. Regional pattern and path selection of synchronous development of “Four Modernizations” in the Yellow River Basin [J]. Qinghai Social Sciences, 2021 (4): 94−106. Chinese.