

## Review

# Water Market Development in the Yellow River Basin: Challenges and Opportunities

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**Abstract:** Water market development in the Yellow River Basin (YRB) unfolds new opportunities for alleviating water scarcity and improving water productivity. However, the further development of an effective water market in the basin faces challenges such as unclear water rights, regulatory deficiencies, market deficiencies, and insufficient compensation to third-parties, among others. Studying water market development in Western countries provides useful insights for addressing similar challenges, thus providing useful case studies despite the different cultural, economic, institutional, and political settings. This paper investigates water markets in the Murray–Darling Basin in Australia, the western United States, and Chile to synthesize cases of water market development that could potentially contribute to overcoming the challenges encountered in the YRB. After analyzing these cases, recommendations are made for enhancing the YRB’s water market development from the perspectives of water rights systems, as well as the roles of the government and market, legal system, and third-party effects.

**Keywords:** water market; water rights; Yellow River Basin



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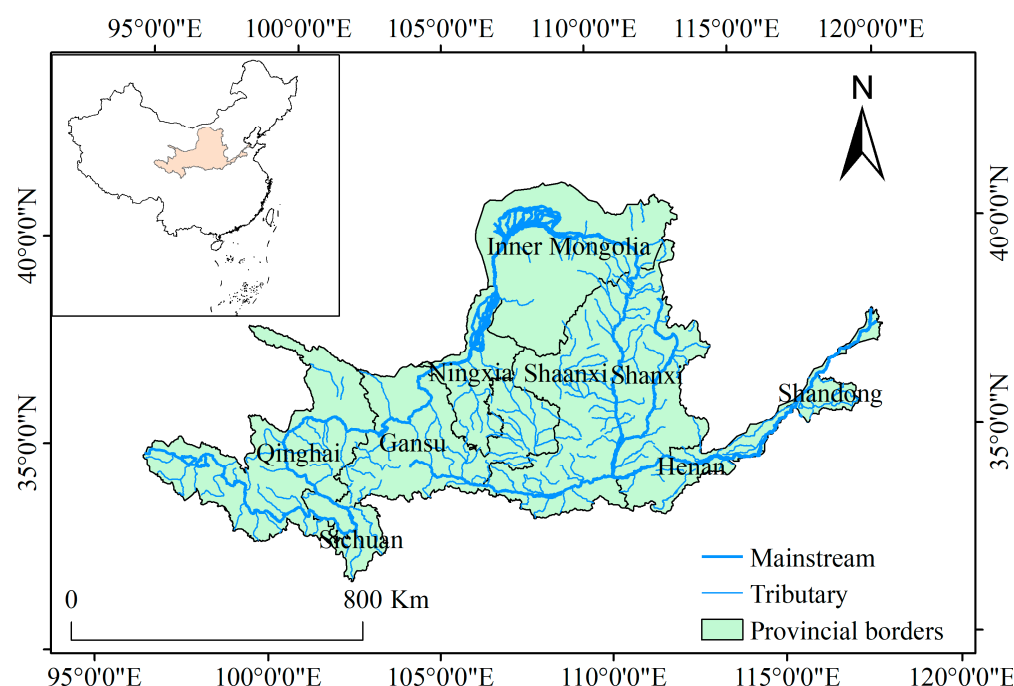
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## 1. Introduction

The Yellow River is the second longest river in China and fifth longest in the world, with an average annual runoff of 45.9 billion m<sup>3</sup>. There are 420 million people living in the nine riparian provinces Yellow River Basin (YRB), yet its annual average per capita water resources are 473 m<sup>3</sup>, just 23% of the national average (Figure 1) [1]. The water resources in the YRB hold paramount economic and strategic significance; however, they are subject to substantial annual fluctuations and exhibit an uneven spatial distribution, as the Ningxia Autonomous Region stands out as the only province within the YRB, possessing a mere 0.89 billion cubic meters of water resources [2]. Furthermore, the existing engineering regulation capacity within the basin falls short, encompassing incomplete hydraulic infrastructure, inadequate water diversion projects, and an imperfect water resource-sharing mechanism, thereby impeding the resolution of the water supply and demand contradictions prevailing in the region. The insufficient endowment of water resources has become an important factor restricting the economic development of the YRB [3].

The YRB is a key area for economic development, as well as an important energy and food production base; thus, the government has backed its advancement its development through the implementation of various policies, regulations, and legislations. In September 2019, the YRB Ecological Protection and High-Quality Development Symposium was held in Zhengzhou, where General Secretary Xi [4] emphasized the national strategic status of ecological protection and high-quality development in the YRB. In October 2022, the Yellow River Protection Law, which provides legal protection for the high-quality development of the YRB, was approved by the 13th National People’s Congress of P. R. China. Therefore, addressing the water supply–demand imbalance in the YRB and improving the efficiency

of water resource utilization are crucial means to promote ecological protection and high-quality development in the region. Under such circumstances, the notions of water rights and water markets are gaining attention.



**Figure 1.** The Yellow River Basin in China.

Water rights refer to the legal entitlements granted to individuals, organizations, or communities that allow them to use and access water resources [5]. In accordance with various forms of water that border or exist on a property, water rights exist in different types. Water markets refer to systems that facilitate the voluntary exchange and transfer of water rights or allocations among stakeholders [6,7]. These markets enable the reallocation of water from areas with surplus water to areas facing water scarcity [8]. Using market-based approaches for water rights trading can effectively alleviate the water supply–demand imbalance [6]. In the 1980s, countries such as the United States and Australia started implementing water rights trading to address competition among agricultural, industrial, and urban water users [9,10]. At the 2000 Academic Conference of the China Society for Hydropower Engineering, the former Minister of Water Resources Wang [11] proposed the optimization of water resource allocation through paid water rights transfers and the establishment of water markets. China subsequently began pilot programs and explorations of water rights trading and [12], in the Outline of the YRB Ecological Protection and High-Quality Development Plan issued in October 2021, explicitly stated the use of active water rights trading to optimize water resource utilization in the basin. The report of the 20th National Congress of the Communist Party of China report emphasized the decisive role of the market in resource allocation and highlighted the significance of utilizing water markets to address the water scarcity issue in the YRB to promote ecological protection and high-quality development [13].

In this paper, Section 2 generalizes the development of the water market in the YRB. Section 3 analyzes the current deficiencies of the water market in the YRB. Section 4 compares the water market in the YRB with those in developed Western countries and draws lessons from their cases. Section 5 summarizes the lessons learned and provides recommendations for addressing the existing issues in the development of the water market in the YRB.

## 2. Water Market Development in the Yellow River Basin

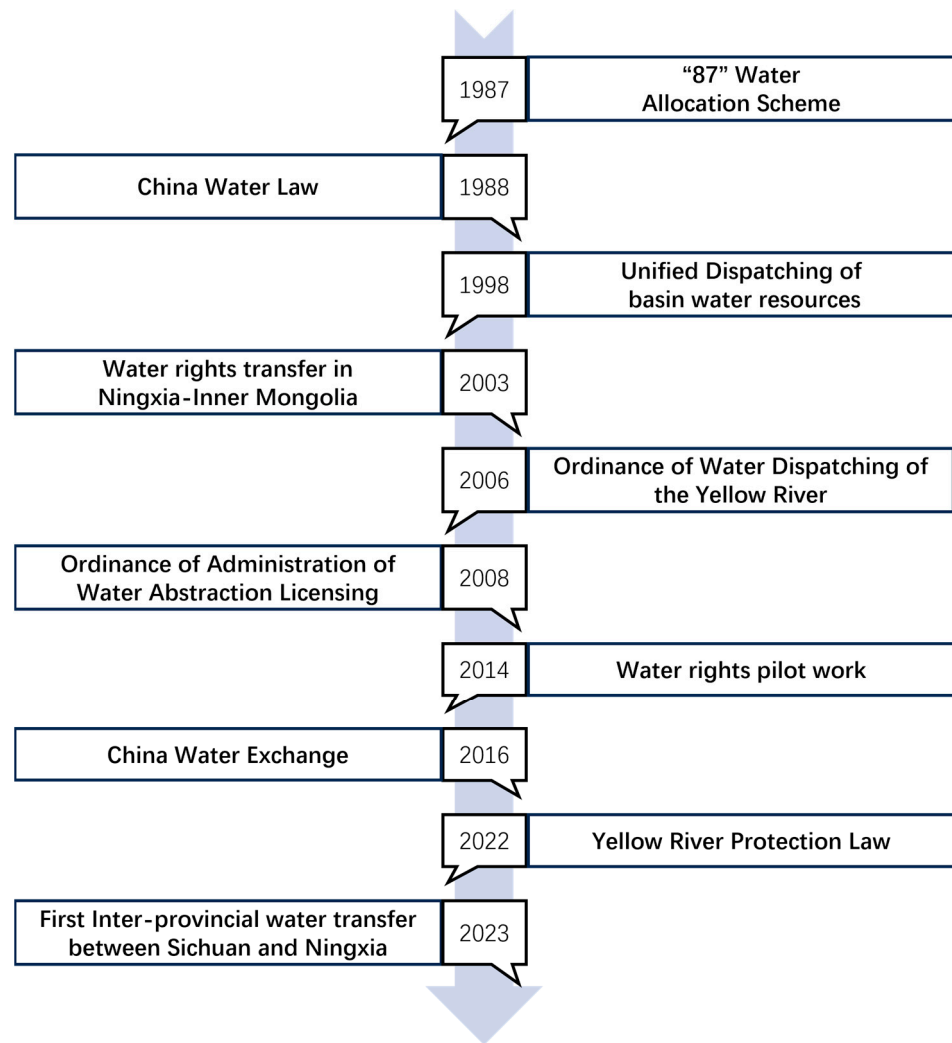
Following the establishment of the People's Republic of China, rapid economic development ensued, resulting in a significant increase in water diversion across various regions along the Yellow River. This surge in water extraction has led to multiple drying up issues in the downstream segments of the river in later years. To address the Yellow River drying up issue, the State Council enacted a water allocation plan for the YRB in 1987 and initiated water rights delineation across the nine riparian provinces [14]. In the next year, the China Water Law was enacted, providing a legal framework to regulate the water usage behaviors of various economic entities [15]. After the promulgation of the “87” water allocation scheme, due to inadequate regulatory measures, the plan was not effectively executed. In 1997, the Yellow River experienced its most severe drying up event in history, and subsequently, the Yellow River Conservancy Commission (YRCC) assumed unified water allocation throughout the entire basin in 1998 [16].

Moreover, in Ningxia and Inner Mongolia, a lack of water for newly planned industrial projects, agricultural water wastage, and aging irrigation infrastructure prompted explorations of transferring water rights from irrigation to industrial uses [17,18]. In 2006, the State Council issued China's first administrative regulation on basin water allocation management, known as the “Ordinance of Water Dispatching of the Yellow River”. The regulations aimed to further strengthen the unified regulation of water resources in the YRB [19]. In 2008, the State Council issued the “Ordinance of Administration of Water Abstraction Licensing”, which clarified the standards for the application, approval, and issuance of water withdrawal permits and promoted the improvement of water rights clarity [20].

Consequently, water rights pilot projects were implemented in 2014. In the YRB, the main form of work in the Ningxia Autonomous Region is to confirm the water rights of water users, the main form of work in the Inner Mongolia Autonomous Region is to promote water rights transactions between non-alliance cities, the main form of work in Gansu Province is to conduct water rights transactions in the Shule River Basin, and the main form of work in Henan Province is to facilitate water rights transactions between different river basins based on the South to North Water Diversion Project [21]. Recognizing the importance of effective water rights management, the China Water Exchange was established in 2016 with State Council approval [22]. Furthermore, the enactment of the Yellow River Protection Law in 2022 strengthened water rights regulation and management. The first inter-provincial water transfer between Sichuan and Ningxia reflects the development process of the water market in the Yellow River Basin [23].

Figure 2 shows the evolution of water resource management in the YRB, highlighting legislative and institutional milestones summarized based on the literature [14–23].

In the Yellow River Basin, water rights transactions primarily manifest in three forms: (i) regional water rights transactions, (ii) water withdrawal permit transactions, and (iii) irrigation water user rights transactions [24]. With the gradual development of the water market in the Yellow River Basin, particularly following the establishment of the Chinese Water Rights Exchange, water rights transactions are becoming increasingly frequent (Table 1). The water market in the YRB has also gradually emerged during this process, but it still lags significantly behind the water markets in developed Western countries [25].



**Figure 2.** Evolution of water resource management in the YRB.

**Table 1.** The number of water rights transactions and volumes of water traded in the YRB in the past 5 years.

	Regional Water Rights Transactions		Water Withdrawal Permit Transactions		Irrigation Water User Rights Transactions	
	Value/ Million Yuan	Volume/ Million m <sup>3</sup>	Value/ Million Yuan	Volume/ Million m <sup>3</sup>	Value/ Million Yuan	Volume/ Million m <sup>3</sup>
Qinghai	0	0	0	0	0	0
Gansu	0	0	0.23	1.6	11	110
Ningxia	18	15	31	33	0.63	3
Inner Mongolia	342	268	1588	2610	0	0
Shanxi	0	0	24	47	0.13	1.1
Shaanxi	0	0	0.24	2	0	1
Henan	287	368	0.23	5.7	0	0
Shandong	76	138	7.9	72	0.07	1.3

Note: Source: Data published online by the China Water Exchange Co., Ltd. [21].

### 3. Barriers to Water Market Development in the YRB

As can be inferred from Section 2, significant progress has been achieved in water rights trading within the Yellow River Basin, but the current water market still faces various limitations, hindering its effectiveness in addressing prevalent water scarcity. As a result,

the full potential of the water market in the Yellow River Basin remains largely unrealized, indicating that several barriers to its development exist.

### *3.1. Unclear Water Rights*

Although Chinese law stipulates that water resources belong to the state, basin management agencies and local governments are the actual water rights owners. This has led to difficulties in defining water rights in legal terms, a lack of clarity in the obligations between rights holders, and disputes over the distribution of benefits among stakeholders. In the YRB, the Ningxia Autonomous Region has made progress in piloting water rights confirmation, but in most areas of the YRB, especially in administrative regions below the county level, water rights confirmation and registration are still incomplete and non-standardized, which results in the buyer being unable to accurately ascertain the quantity and quality of water being traded during the process of water rights transactions. Furthermore, in these areas, water rights have not been allocated to water user associations or individual users, and the existence of collective water rights can affect the maintenance of individual water rights for water users [26,27].

### *3.2. Deficiencies in Regulations and Related Laws*

Despite occupying a large area, the YRB has an inadequate water infrastructure, and there is considerable room for improvement in its management strategies [28]. There are many issues, for instance, aging water intake monitoring facilities, insufficient comprehensive monitoring of water resources in the YRB, and incorrect measurements of agricultural and industrial water withdrawals. In the process of agricultural water rights being converted to industrial water rights in many areas of Ningxia and Inner Mongolia, the buyers often lack long-term repair and maintenance support for the irrigation facilities and canal systems constructed for purchasing water. Additionally, the promotion of cross-regional water rights transactions imposes greater requirements on water conveyance channels and water rights measurement facilities [29]. In the process of water rights transactions, the government plays a role not only in guiding and participating in such transactions but also in regulating them. Government oversight is necessary with respect to water rights transaction prices, the maintenance of water infrastructure, ensuring ecological water use, and so on. However, at the current stage, water rights transaction regulation still has deficiencies. The enactment of the Yellow River Law encourages the development of water markets and water rights transactions in the YRB, but there are legal gaps in protecting the interests of water rights transaction participants and third parties [27]. A comprehensive legal framework for the operation of the water market in the YRB has not yet been established.

### *3.3. Insufficient Utilization of Market Mechanisms in Resource Allocation*

Since the initiation of the water rights transfer from agriculture to industrial users in the YRB in 2003 [30], nearly 21 years have passed, and the number of water rights transactions in the basin has been increasing. However, market mechanisms have not been fully utilized in resource allocation. Although the China Water Rights Exchange has been established, bulk transactions are still predominantly government-led, resulting in a lack of market influence in realizing the economic value of water resources and leading to a weakened market bidding mechanism, meaning that the water rights market in the YRB is not very active. At the same time, there are significant differences in the development of the water markets in the different regions of the YRB. For example, Inner Mongolia and Ningxia, where pilot projects were implemented earlier, have more developed water markets, while Qinghai and Shaanxi have less developed water markets. In these regions, it is more challenging to leverage the market's role in resource allocation.

### 3.4. Insufficient Compensation for Related Interests

In the process of water rights transactions, the interests of third parties and farmers are often compromised. Existing studies [31,32] have analyzed the impact of third-party benefits and compensation regarding farmer's interests and agricultural risks in water rights transactions. The attention afforded to and measures for mitigating third-party effects in water rights transactions are generally inadequate, often leading to environmental damage and exacerbating conflicts over water uses between upstream and downstream regions. In the long run, this will affect the allocation of water resources in the basin. Additionally, since industrial water use is generally more profitable than agricultural water use, farmers require more safeguards in the water rights transfer process to enhance their motivation in water rights transactions. Currently, there is a lack of specific calculation methods for compensating for agricultural, farmers, and ecological benefits, which is crucial for constraining water supply.

## 4. Lessons from Western Countries' Water Market Development

The water market in the YRB is under-developed and lacks practical experience in comparison to the well-established water markets in the Murray–Darling Basin (MDB) in Australia [33,34], the western United States [35,36], and Chile [37,38] (Table 2). The water markets in the MDB, the western United States, and Chile have earlier origins, more mature systems, and are more representative compared to those of other Western countries. Although there are significant differences between the YRB and Western countries, the challenges faced by the water market in the YRB are also present in the development of the water markets in these countries, where many cases have been summarized and lessons been learned. In light of this, it is of paramount importance to draw lessons from countries or regions with more mature water markets in order to tackle the challenges confronting the water market in the YRB, as outlined in Section 3 of this paper.

**Table 2.** Comparison of domestic and international water market development.

	Water Resource Ownership	Water Abstraction Permit Duration	Law for Water Market	Forms of Water Rights Transactions	Channels for Water Rights Transactions	Water Rights Transactions Duration
YRB	Nation	5–10 years	The Yellow River Law in 2022	Regional water rights transactions, water withdrawal permit transactions, irrigation water user rights transactions	Government-guided transactions dominate	Short-term, long-term
MDB	Nation	Permanent	Victoria's Water Act in 1989, the Federal Water Act in 2007	Water rights transfer, water stock system	Water market	Short-term, long-term, permanent
western US	States	10–50 years	Each state has a Water Act	Water rights transfer, water bank, dry year options, etc.	Water market	Short-term, long-term, permanent
Chile	Nation	Permanent	The Water Act in 1981	Water rights transfer, water leasing system	Water market	Short-term, long-term, permanent

Notes: Short-term refers to water rights transactions with a duration of less than 1 year. Long-term refers to water rights transactions with a duration of more than 1 year.



#### 4.1. Water Rights Systems

Australia, Chile, and the legal system in China all stipulate that water resources are owned by the state, while the United States, as a federal country, grants water resource ownership to individual states. The MDB in Australia, the western United States, and Chile have all developed relatively well-established water permit systems. In the late 20th century, Australia formally established a water permit system to address water shortages in the 1960s. The states in the MDB imposed limitations on water extraction under given permits and gradually stopped issuing new permits. In places like New South Wales, “high security” water permits were approved to ensure irrigation water for certain crops [33,39]. Most western US states adopted a system based on prior appropriation rights, and in the early 20th century, each state established different permit systems that required written applications to state water management agencies to obtain water rights. Clear water rights registration has overcome the uncertainties in the prior appropriation rights system [35,40]. In Chile, water rights are separated from land rights, allowing water rights to be registered with the Real Estate Registry. It is required to obtain water extraction permits through registration, and in times of water scarcity, water rights can be proportionally reduced [37]. Compared to the YRB, the MDB, the western US, and Chile have undergone long-term development in water rights delineation, resulting in relatively clear water rights. The water abstraction permits in these regions have extended durations exceeding 10 years or even have no set duration, running permanently, providing a solid foundation for the development of water markets.

#### 4.2. Water Rights Legal Frameworks

The water laws of each state in the MDB provide a legal basis for water rights trading. Established in the 1980s, Victoria’s Water Act required water users to register their water rights, and water rights transactions could only be conducted with registered records. It also established regulations for water rights transactions. Similar laws exist in other states, and the legislative bodies of each state will revise the Water Act as needed based on practical circumstances. In addition, the Australian federal government enacted the Federal Water Act in 2007, which stipulated the total water allocation and ecological water requirements in the MDB. It also promoted interstate water rights trading through the principles of water rights transactions [41]. The water laws in most US states are relatively comprehensive, providing clear guidelines on water rights allocation and transactions. California’s first Water Act in 1914 made initial regulations for water permits, and by the 1990s, it had added provisions for water rights transactions and water markets [42,43]. Oregon’s first Water Act in 1909 adopted the prior appropriation rights system, and by the 1990s, it had added provisions for surface water and groundwater usage rights, new water rights applications, related fees, and water rights transfers. Similar laws exist in other western US states and are continuously being updated and improved over time [44]. In Chile, the Water Act of 1981 regulated the use and ownership of water resources, allowing for the free trading of water rights [45]. The 2005 revision of the Water Act introduced strict water rights registration, ensured the ecological water requirements of rivers, and encouraged water users to participate in water market management [38]. The regulations on water rights trading in the YRB, as outlined in the Yellow River Law, are not currently as clear. Parts of the MDB, the western United States, and Chile’s water laws concerning water markets are relatively developed, and these well-established water resource laws provide safeguards for the normal operation of water markets.

#### 4.3. Market Mechanisms

The MDB water market facilitates the trading of two types of water rights: (a) water entitlements (permanent water), categorized as high-security, general-security, or low-security entitlements, and (b) water allocations (temporary water), the seasonal allocation received by specific water entitlements [46]. The volume of water allocated to water entitlement holders during a given water year depends on the available water in storage, system losses,

demand projections, delivery capacity, and other pertinent considerations [47,48]. As a result of the MDB's characteristics, various forms of water rights trading have emerged. In Victoria, water entitlements are converted into water stock, endowing water resources or water rights with clear property rights and tradable attributes [49]. The water markets in different western US states have developed differently, and there are diverse forms of water rights trading tailored to each state's market characteristics. These include water rights transfers, water banking, dry year options, etc. [40]. California's "water banking" system, which serves as an intermediary for water rights transactions, provides an excellent example for optimizing water resource allocation [50]. In Chile, water rights trading includes short-term water rights trading among farmers, long-term water rights trading among farmers, and water rights trading between farmers and urban water users. Due to the government's loose control over the water market, a water leasing system has spontaneously formed [51]. In the MDB, the western US, and Chile, forms of water rights trading with local characteristics have been established based on their respective water market developments, fully leveraging the financial attributes of water rights. Clearly, more diverse forms of water rights transactions can significantly enhance people's willingness to participate in water rights transactions and increase the activity of the water market, and the free circulation of water rights in the market is conducive to improving water resource utilization efficiency. There is still huge space for the development of forms of water rights trading in the YRB, and the financial attributes of water rights are yet to be fully leveraged. Transaction prices are important, influencing water rights trading [52], and reducing transaction costs can promote water market-based transfers. The MDB has reduced transaction costs by lifting water trade restrictions [53], while the state of Colorado has lowered the cost of water rights transactions through making modifications to its water laws [40]. Chile's implementation of the "water leasing" system has also helped reduce transaction costs [54].

#### 4.4. Compensation for Related Interests

In the 21st century, water resource planning in the MDB has focused on ensuring water for ecological environments. In 2008, the Australian federal government introduced the "Future Water Plan", which aimed to spend \$3.1 billion over ten years to purchase water rights from water users to increase river flow and improve environmental water supply [55,56]. In the process of water rights trading in western US states, any third party has the right to question water rights transfers that cause losses or do not serve the public interest [57]. Meanwhile, short-term water rights leasing may impact a third-party's interests. In the state of Colorado, laws have been enacted to allow for short-term leasing, reducing the impact on the third party [58]. Western US states have placed emphasis on water environmental protection for a long time. After the 1970s, environmental water use became more of a priority within the prior appropriation rights system. The federal government and individual states have enacted relevant laws to protect environmental water [59]. Chile's water law reforms emphasize protecting the interests of third parties. A water board was established to approve river water usage rights, and approved water users bear the costs and responsibilities associated with third-party interests [60]. From the above cases, it is evident that local governments attach great importance to third-party effects, especially negative ones. Failure to address conflicts between different stakeholders can result in the dysfunction of the market's efficient allocation of water resources. For the still under-developed water market in the YRB, it is even more crucial for the government to make institutional arrangements to protect its interests.

## 5. Conclusions

Based on the case studies and lessons summarized above, the following recommendations are proposed in the hope of helping to improve and support the further development of the water market in the YRB.



### *5.1. Clarify and Solidify Water Rights down to User Level*

Water rights registration was carried out during the water rights pilot project in the Ningxia Autonomous Region in the YRB. However, the water permit system is not yet fully implemented throughout the entire basin except at the county level and above. Ensuring the water rights of users at lower administrative levels and irrigation districts is a must. The YRB could also consider granting higher water rights priority to users with a long-term stable water demand and extend the validity period of water abstraction permits to more than ten years to ensure the long-term stability of water rights to facilitate water rights transactions. The government needs to strengthen the management of water rights registration with the experiences from the water resources registration led by water administrative authorities in Ningxia, which could serve as a valuable example in this regard. Notably, the current Yellow River Protection Law does not include any provisions on water rights delineation, and thus, additional support is needed to clarify water rights within the existing legal framework.

### *5.2. Transform Government Functions and Improve the Legal Framework of the Water Market*

In the YRB, an enabling environment for market-based water transfers can be created and enhanced through transforming government functions and improving relevant laws and regulations. First, it is necessary for the government to monitor or guide the water rights trading prices in the basin. Factors affecting prices include hydroclimatic and geographical conditions, water storage capacities, water quality, market supply and demand, etc. [61]. However, the government needs to play its role in stabilizing water rights trading prices through implementing sound regulatory measures and a well-functioning legal system in order to prevent excessively high or low prices. Second, it is important to ensure the construction and maintenance of the water infrastructure needed for water transfer transactions. Adequately accurate flow measurements are indispensable for water transfer implementation, and well-functioning conveyance facilities are required for inter-regional water rights trading. In the current process of converting agricultural water rights to industrial water rights in many areas of Ningxia and Inner Mongolia in the YRB, it is necessary to supervise industrial users in the long-term maintenance and upgrading of agricultural water-saving facilities, which they have to undertake in lieu of paying for water conserved through using such facilities. Finally, the YRCC and water administrative authorities at different levels in the basin must assume regulatory roles in water transfers but with the intention of avoiding unnecessary administrative interventions. Adverse environmental impacts should always be avoided in water transfers through regulatory or legal means.

### *5.3. Give Full Recognition to the Market's Decisive Role in Resource Allocation*

Offering incentives such as subsidies and tax reductions to water-buying firms could promote spontaneous water rights trading. The financial attributes of water rights could be explored through developing water rights financial products and involving financial institutions in water rights trading. The use of water rights as collateral for loans in the Shizuishan City of Ningxia exemplifies the financial aspect of water rights in the YRB. The YRB could innovate water trading forms through using water banking where appropriate, with the China Water Exchange being a potential platform. It is also possible to explore new forms of water transfers by integrating economic, water-saving, and ecological protection objectives, aiming towards a well-functioning water market with diverse forms of water transfers.

### *5.4. Safeguard the Interests of All Parties*

The YRB needs to conduct thorough transaction assessments for the interests of all parties involved in water rights trading. This includes assessing the qualifications of both the selling and buying parties, monitoring water quantity and quality in the transactions, and taking preventive measures against potential environmental damages, conflicts between upstream and downstream users, and economic losses for farmers [31].

Involving third-party representatives in water rights trading processes is essential for safeguarding the rights of third parties affected by water rights transactions. If instream environmental water rights are involved, relevant government agencies in the riparian area should be involved as third parties. Compensation should be given to the third parties who bear the consequences of water transfers. Finally, as ecological protection in the YRB has become a national development strategy, environmental water rights should be prioritized in the water market and legally protected from being jeopardized.

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