Water Rights Allocation, Management and Trading in an Irrigation District - A Case Study of Northwestern China

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1. Introduction

Demographic change, growing urbanization, intensification of agriculture and climate change all pose a continual challenge to the availability of water resources. The increasing competition for water demand among the sectors of human activities and for the environment requires the development of policies for water resources sustainability.

Policies to expand water resource supplies are currently not in vogue because they involve the regulation of water through physical impediments such as the construction of dams, weirs and channels. Over the last few decades demand management policies involving water pricing, assigning water rights and introducing water markets have received increased emphasis. Water rights, a prerequisite for water markets, are considered as a key water management instrument to improve water use efficiency.

In response to concerns of increasing water scarcity and seriously degraded river ecosystems, water policy in China over recent decades has shifted from investing in large storage and delivery infrastructure to policies and institutions designed to allocate the existing resource more efficiently. The definition and establishment of water rights allocation systems are important components of water management reform. Water rights allocation systems did not exist in China before 1988. The 1988 Water Law and its revision, the 2002 Water Law, have introduced initial water rights allocation across the country. In China, water rights are defined by the state according to the priorities assigned to competing users. Water resources in a trans-provincial (or prefectural) basin are shared amongst the jurisdictions administratively.

Northwestern China faces more severe water shortages for its arid climate. The agriculture water use is above 80% of total water use in this region. Therefore, agriculture water rights reform raises much concern currently. In some areas, the water rights defined for province or prefecture are allocated further to the irrigation districts and farmers. Then, the water trading happens in these places. For example, Hangjin Irrigation District on the south bank of the Yellow River, Inner Mongolia has traded some of its irrigation water to downstream factories. The trading is termed "irrigation water-saving supported by industrial investment, with saved water traded to industry". At the same time, Hangjin Irrigation District has conducted a comprehensive reform of irrigation water management focused on water rights.

This proposed chapter aims at introducing a framework for water rights allocation, management and trading in the farmers' lever, in order to address: (1) how the long-term water rights can be defined for the individual farmers in order to share the total water resource of the irrigation district; (2) how the farmers' water rights are administrated, monitored and accounted; (3) how the farmers to trade their water rights with the industry users or other farmers in the context of current Chinese Water Law.

The chapter will describe the current status of water management in the Hangjin district, outlines some of the problems water trading has produced, and presents a framework for further water rights reform focused on rights allocation, the granting of volumetrically-capped water certificates and tickets, water use planning and monitoring, and the responsibilities of water user associations in ensuring that individual farmers receive fair allocations. In additional, a water trading approach based on "water extraction period exchange" in Taolai irrigation distract, Gansu, China will be discussed in the chapter. The chapter then summarizes key recommendations of relevance to Hangjin and Taolai and other irrigation districts in China.

2. Water rights allocation among the farmers

2.1 Introduction

The Inner Mongolia Autonomous Region in China enjoys exceptional advantages. In particular, the region has an abundance of natural resources for the development of mining, electric power, metallurgy, chemical, and machinery processing industries. The Region plans to use these resources to build a large energy base in the "golden triangle" of Hohhot, Baotou and Ordos (Figure 2.1) to create an affluent society. However, the serious shortage of water resources hinders the development of the regional energy industry, and the region's allocation of water from the Yellow River Conservancy Commission (YRCC) is already fully committed. It is under such circumstances that that the autonomous region initiated a pilot program involving the transfer of water rights. Since 2003, a number of pilot projects for water right transfer have been launched by the YRCC and the Inner Mongolia Department of Water Resources (Shen et al. 2006), aimed at meeting the growing water needs of downstream industrial users.

One of the first such pilots has involved Hangjin Irrigation District. Beginning in 2004, the newly established Office of Water Rights and Transfer in Ordos city has overseen a program in which water saved through canal lining in the district is transferred to downstream industries, with the costs of lining met directly by the industrial beneficiaries. According to the Inner Mongolia Autonomous Region Water Rights Transfer Planning Report, in the three-year period from 2005 to 2007, 13 enterprises invested a total of RMB 600 million in canal lining. According to the plan, the implementation of the project will save as much as 138 million m3 of water. Industrial users funding the capital costs of canal lining are also obliged to meet the ongoing operations and maintenance costs of canal repair over a 25 year term.

The channel lining and water transfer program in Hangjin highlights one response to a wider problem in China – the problem of increasing scarcity and growing competition for water between uses and users. In this context, agriculture is under growing pressure to release water to urban and industrial users. Clear rules are needed for doing this and, increasingly, clear rights will be needed within irrigation districts (IDs) so that farmers can be confident about how much water they will get, and when they will get it. Moreover, a system of clearly defined, secure water rights provides the foundation for many other reforms aimed at managing demand and increasing efficiency, including water pricing and water trading.

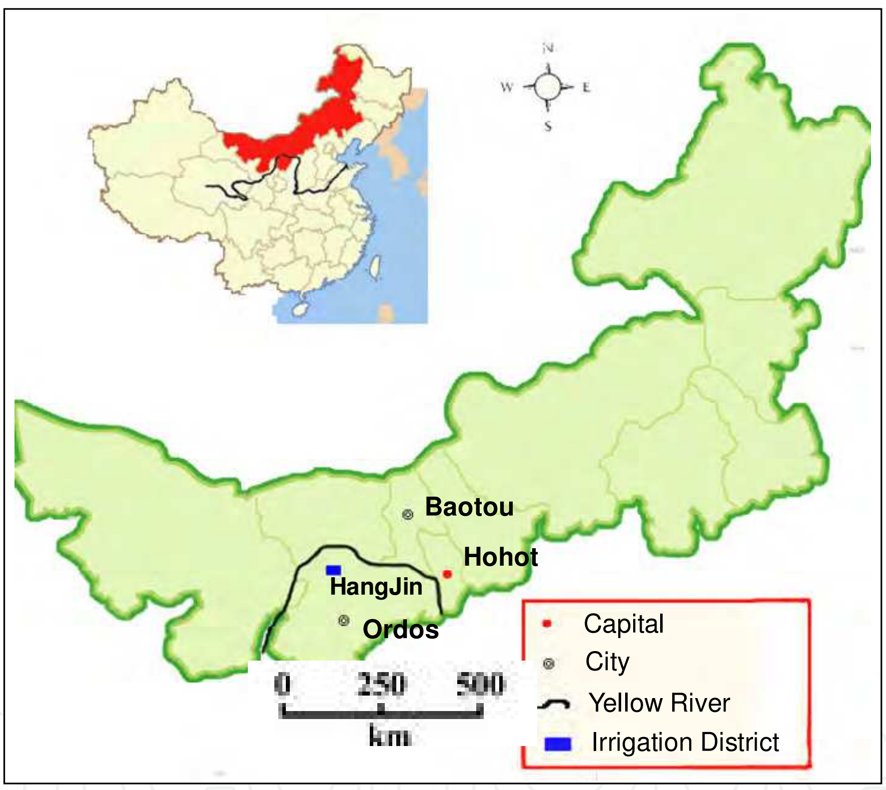


Fig. 2.1 Map of Inner Mongolia showing the Yellow River, major cities and Hangjin ID

2.2 Hangjin irrigation district

Hangjin County is located to the northwest of Ordos City in Inner Mongolia (Figure 2.1). Along its northern margin the Yellow River winds down with a length of roughly 253 km, making Hangjin County the longest flowing section of Yellow River of all counties nationwide. The county includes nearly 40,000 ha of designated farmland along the Yellow River, and is one of three major irrigation zones of Inner Mongolia. It is also one of China's main grain producing areas. Hangjin Gravity Irrigation District (HID) in Hangjin County – the focus of this study – is the only irrigation district in Ordos with the right to take water from the Yellow River. HID is located on the south bank of the Yellow River and covers an area of approximately 23,000 ha. Of this, roughly 21,000 ha is gravity fed and 1700 ha is pumped (at the head of the system).

Hangjin Irrigation District draws all of its water from the Yellow River. Its water use is therefore controlled, ultimately, by the YRCC, which sets minimum flow requirements for the river at provincial/regional boundaries based on an Annual Allocation Plan (Table 2.1), and allocates relative shares to individual provinces and regions according to supply and demand conditions. In a normal year, Inner Mongolia therefore receives 5.86 billion m^3 out of a total flow of 37 billion m^3. The maximum (sometimes termed 'normal') gross diversion to the Hangjin district –the permitted volume – is 410 million m^3 per year, including a mandatory return flow of 35 million m^3 per year. So, the normal net diversion to HID is 375 million m^3. Return flows are fed back to the river through four main drainage channels. Savings of 130 million m^3 per year from canal lining, traded out of the irrigation district, will leave an ongoing diversion of 280 million m^3 per year, illustrated in Figure 2.2.

Province/ region	Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shaanxi	Shanxi	Henan	Shandong	Heibei & Tianjin	Total
Annual water use billion m^3	1.41	0.04	3.04	4	5.86	3.8	4.31	5.54	7	2	37
%	3.8	0.1	8.2	10.8	15.8	10.3	11.6	15.0	18.9	5.4	100

Table 2.1 Water allocation in the Yellow River (YRCC, 2005)

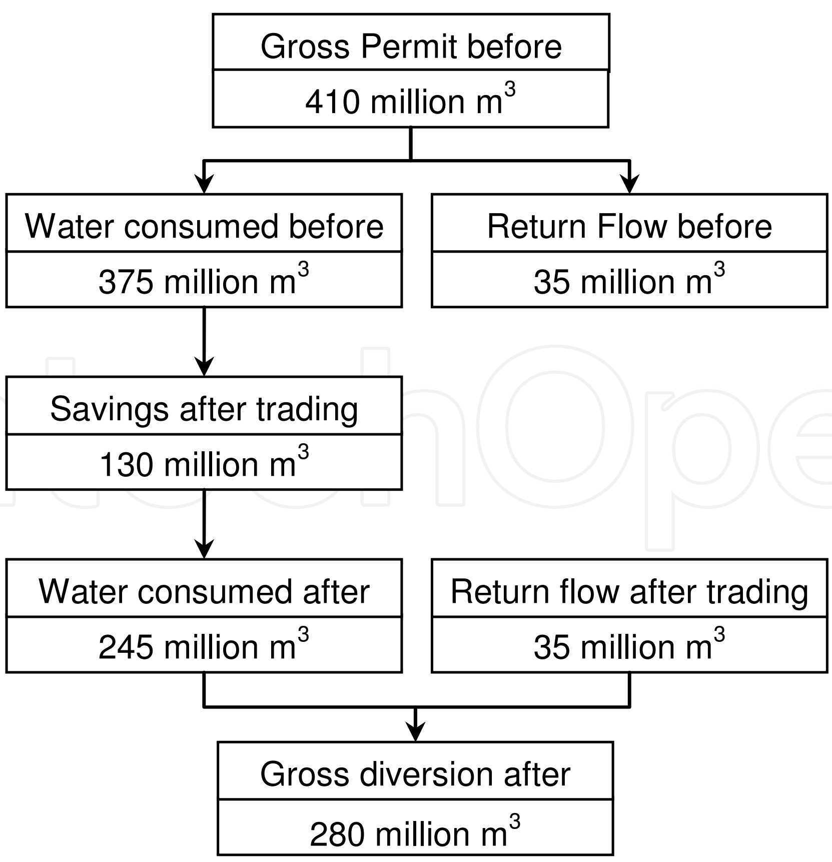


Fig. 2.2 Diversion, consumption and return flows for Hangjin Irrigation District

By 30 September 2006, a total of six canal lining subprojects had been completed, each funded by a separate industrial enterprise. The idea of "Industrial Investment in Water Saving for the Transfer of Agricultural Water Rights" has helped alleviate the water shortages experienced by industry, and has also helped reduce the burden of farmers by saving water and reducing farm costs. Currently, the annual water fee for each householder has been reduced by around 20-30 RMB/year. Farmers' costs have reduced because they no longer have to pay for water losses in the channels that deliver water to the point where water user associations (WUAs) make bulk purchases on behalf of the farmers they represent.

The channel lining and transfer project has had many benefits. However, trading has also created a number of problems, particularly for the irrigation agency that is responsible for managing and maintaining irrigation infrastructure above WUA purchase points – Hangjin Irrigation Management Bureau (HIMB). Moreover, the rights of farmers within the district remain ambiguous.

A framework for a modern system of volumetrically defined water rights in HID has been developed (WET, 2007). It is proposed that this serves as a template for guiding reform in other IDs in China as competition for water increases, and agricultural users face growing pressure to account for their water and release 'surpluses' to urban and industrial users.

The sections below discuss rights definition, allocation and management issues within HID. The principal focus is on improving the distribution of water within an ID so that farmers receive secure, transparent and equitable allocations within the overall permitted allowance of the ID.

2.3 Long-term Initial water rights allocation

Drawing on field work conducted in HID, WET (2007) describes how the water diverted to the district under its irrigation permit is currently allocated through main and branch canals, and down to individual farm households. In common with many IDs in water-scare northern China, the allocation process combines bulk volumetric charging to farmer groups (increasingly WUAs) established on branch canals, with area-based charging for farmers. Water User Associations purchase pre-paid water tickets on behalf of farmers, and are responsible for (amongst other things) distributing water within their command areas and collecting fees.

WET describe how water allocation to WUAs could be improved according to the principles of fairness, efficiency and environmental sustainability, amplified below. They also describe how the water rights of WUAs could be volumetrically defined and capped through the issue of Group Water Entitlements (GWEs) at the point at which WUAs pay for bulk deliveries. Below this point, farmers would continue to pay for water on an area basis, as delivery and monitoring infrastructure in Hangjin, and most IDs in China, is not in place to monitor individual entitlements at the household level.

A volumetric cap on the water rights of WUAs needs to fully consider existing patterns of water use within and between WUAs, and the experience of farmers, WUA representatives and HIMB staff in administering present systems. Hence it is proposed that rights allocation follows existing practice by linking land and water rights. In other words, rights assigned would be directly linked to the (existing) irrigated areas of each WUA, and could not be negotiated upwards by a WUA seeking to expand its irrigated area or plant more water-intensive crops, for example. Hence one objective of defining and enforcing WUA-based GWEs would be to end the requirements approach to water use planning that currently prevails so that, in future, water savings rather than additional supply would be used to maintain or increase farm production and farmer incomes.

Different regions and different groups of people should enjoy equal rights to water for survival and development. Hence the allocation of rights should guarantee fairness between different management sections of an ID, different WUAs and different water users and, in particular, afford protection to those farmers with small land holdings. In defining and allocating rights, consideration should also be given to 'third party' impacts on (linked) environmental services and other downstream users, such as groundwater users dependent on return flows from the irrigation district. How can the GWEs of individual WUAs be calculated to account for these factors, and to account for channel losses incurred to the points in the system at which WUAs purchase water? WET (2007) describe the calculations involved. A water allocation model is used in the water rights allocation process. The farmers' irrigation land area and crop mix are considered in the model (Figure 2.3).

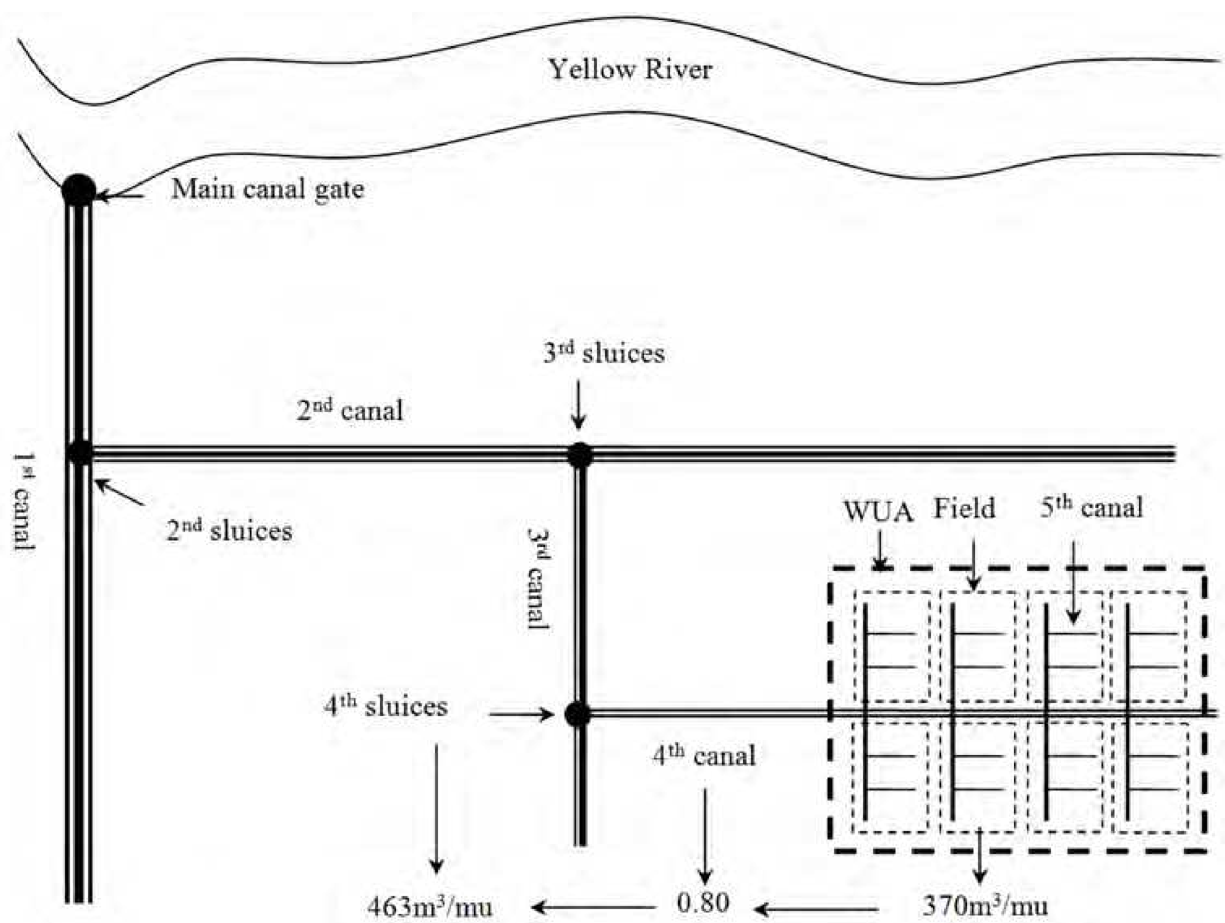


Fig. 2.3 Water allocation model for HID

The combined irrigated area of all 43 WUAs in the gravity flow section of HID is estimated at 21,322 ha. The total volume of water that needs to be delivered to fourth level sluices (and therefore WUAs), after subtracting losses in the canals above, is estimated at

143 million m^3/year. The total volume of water that needs to be diverted from the Yellow River to meet WUA requirements and cover conveyance losses is 225 million m^3/year. Total losses in the canals above fourth level sluices are estimated at 82 million m^3/year. Using this data, and similar calculations covering allocations to individual WUAs, the long term, initial water rights of each WUA in HID can be determined as GWEs. These, in turn, form the basis for the issue of water certificates.

In contrast to the current farmer-driven approach to estimating water needs in ID, such an allocation provides a more scientifically-sound basis for defining and capping rights within the overall allowance of the irrigation district, and for accounting for all transmission losses through main and branch canals to WUAs. Since losses in each canal have now been estimated, future conservation efforts – including trading in transmission savings – can be better targeted and quantified. In this way, the approach to defining and allocating GWEs described above can form the basis for rights reform in other IDs.

3. Water rights management in an irrigation district

An integrated framework of irrigation water use in compliance with the farmers' water rights will be proposed in this section for Hangjin irrigation district, including the water use monitoring and accounting, accounting the farmers' water use to ensure that their water uses are under the allocation quota and water tickets as well as the role of water users association, et al.

3.1 Water rights certificates and water tickets

A system of water rights certificates can be used to formalise the rights of WUAs, providing information on long-term rights (defined by GWEs), annual water entitlements (defined by available supply in any given year) and the water purchased in each irrigation period. In addition, the system can provide information on any water transactions that have occurred between WUAs, and between WUAs and the irrigation management agency. Table 3.1 provides a summary of certificate functions and uses.

Function	Use
Voucher for long term rights	The irrigation management agency records each WUAs long-term water rights (GWEs) in a water certificate.
Calculation of purchase limits	At the beginning of the year, the irrigation management agency calculates the water purchase limit (annual entitlement) of each WUA and records this information on the certificate. After purchasing tickets in each irrigation period, the purchase amount will be recorded on the certificate to calculate the remaining purchase limit for the following periods. WUAs can purchase tickets up to the limit.
Record of water trading	The irrigation management agency records all information on water transactions.
Reference for water rights reallocation	The irrigation management agency will accumulate data on actual water use across seasons and between years, helping to guide any future adjustment.

Table 3.1 Functions and uses of water certificates

To establish and operate such a system, the following steps are proposed (WET, 2007):

- After an initial water rights allocation process, the irrigation agency grants rights to each WUA in the form of a water certificate. This will show each WUAs long term water right.
- At the beginning of each year, the agency calculates the proportional water share that each WUA is entitled to (an annual entitlement) based on expected water availability in that year.
- Before each irrigation, the agency adjusts, as necessary, each WUAs annual entitlement in light of predicted supply to give a corresponding water purchase limit for all remaining irrigation periods. The purchase limit is recorded on each WUAs water certificate.
- After purchasing water tickets in any given irrigation period, the purchase amount is recorded on the certificate to calculate the remaining purchase allowance, or entitlement, of the WUA for the next period. In other words, a process of continuous water accounting is adopted between irrigation periods.
- Any water trading is recorded by the relevant agency section office on the water certificates of both buyer and seller. Trading with other sections is also checked and registered with the agency. Certificates would also show actual water deliveries after trading.

After a reasonable period of operation (5-10 years), the irrigation management agency can review certificates in light of actual water use and trading experience, and revise as necessary. Following any long term trade of water rights, the irrigation management agency can take back old certificates and issue new ones after thorough auditing and recording.

For each WUAs purchase of water, it is proposed that the current system of pre-payment through water tickets is continued. Water tickets provide the basis for water purchase, water delivery and water trading within prescribed limits. The ticketing system can ensure that both WUAs and the irrigation management agency have clear information on prices, deliveries and volumetric rights, allowing WUAs to trade savings freely (Wu & Wu, 1993). Water User Associations would buy water tickets according to their water certificates before each irrigation, and would also be allowed to purchase extra water from those WUAs deciding not to use their full allowance (Feng & Li, 1993). Table 3.2 provides a summary of ticket functions and uses.

Function	Use
Support for permit control and quota management	WUAs buy tickets up to their caps; HIMB sells tickets according to water availability and water rights limits.
Pre-payment for water	Water is only supplied by HIMB once WUAs have purchased tickets.
Water trading and monitoring	WUAs can buy and sell 'saved' tickets; HIMB monitors ticket turnover and adjusts caps as necessary.
Payment voucher – rights and duties	Tickets provide information on GWEs, actual delivery and payment – a summary of entitlement and payment obligation.

Table 3.2 Functions and uses of water tickets

In summary, water rights certificates would formalise the long-term water rights of WUAs within an ID. Water tickets would then 'translate' these rights into real-time rights for WUAs, allowing them to purchase water within the cap for a specific period, and according to how much water has been purchased previously. Long-term and real-time water rights are then connected through water use planning, which converts long-term GWE into the real-time water cap and water use scheduling according to the planned water demand and the runoff forecast of the river. The relationship between water rights, water rights certificates and water tickets is shown in Figure 3.1.

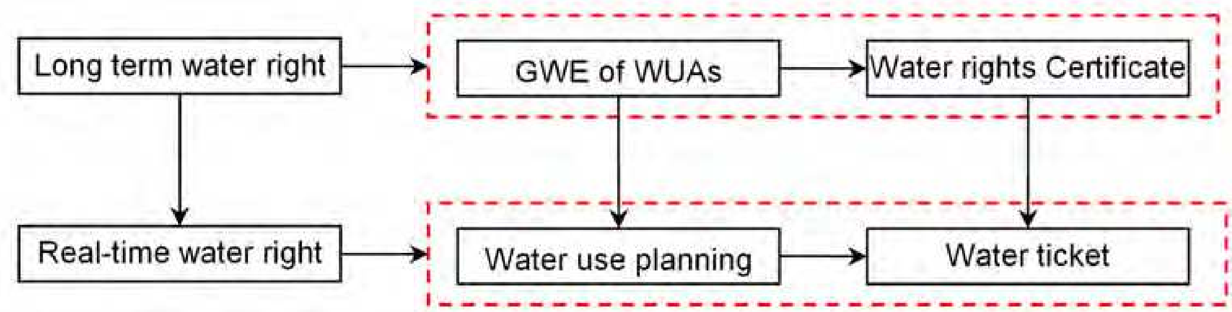


Fig. 3.1 Relationship between water rights certificates and water tickets

3.2 Water use planning

The objective of water use planning is to schedule water diversion, storage, delivery and use in an ID according to the requirements of farmers, available supply from the river and flow through the irrigation channel system. A water use plan is a guideline for the rational delivery and use of water within an ID, and can help improve irrigation efficiency and save water. In this section, it is proposed that the water use plan takes the GWEs discussed previously as a starting point, and then translates them into a real-time irrigation schedule for WUAs. WET (2007) propose that this occurs through a computer-based model that can balance demand and supply, guide allocation between WUAs and help manage rights in a quick and transparent manner.

At the beginning of the year, the annual water use plan for the ID would be prepared by the irrigation management agency, based on the annual water use plans submitted by each WUA (within capped limits), and submitted upwards through the irrigation agency to the higher level department for approval, such as the river basin management department. The river basin management department would then revise and approve the annual available water cap and the water scheduling of the ID, according to the water abstraction permit of the ID and the annual runoff forecast of the river. Afterwards, the irrigation district management agency would adjust the annual plan accordingly, and announce it to WUAs.

Prior to each irrigation, a WUA would then prepare and submit a plan for that period to the irrigation management agency for approval. The agency would check the available water allowance for each WUA, accounting for previous purchases, use under cap and overall irrigation scheduling, and make any necessary revisions or suggestions. Following ticket purchase, a final water use plan would be confirmed in accordance with sold ticket volumes and the scheduling needs of all WUAs.

The computer model would help managers prepare, modify, summarize and publish schedules, and could be interrogated quickly by all relevant stakeholders. The model would also help managers deal with the effects of runoff variation and hydrological uncertainty, including emergency planning in the event of floods or droughts.

3.3 Water users associations

A key element of irrigation reform is the promotion of WUAs as farmer run, participatory institutions that take the place of village leader-run water control organisations or government agencies, and take over management of water allocation and infrastructure management at a local level (Wang et al., 2006). Water User Associations are registered as legal entities under Chinese Company Law.

In HID, a total of 43 WUAs have been established since 2000 under 3rd level canals in the gravity flow sections, with a further 40 planned for completion by the end of 2008.. The boundaries of WUAs are defined by areas irrigated by tertiary and fourth canals. As a result, WUA and village boundaries do not always match. HIMB works with WUAs on the development of Annual Water Allocation Plans and scheduling arrangements, and WUAs are obliged to purchase water tickets prior to each irrigation period. It is proposed that WUAs hold and democratically manage GWEs on behalf of farmers and, within capped limits, continue to develop scheduling plans for household members, collect water fees, purchase water tickets from the ID management agency and undertake maintenance work on the infrastructure within their command areas.

The ability of WUAs in Hangjin (and elsewhere in China) to manage water rights effectively under capped GWEs depends on a number of different factors. WET (2007) identify four key pre-conditions, based on a survey of WUAs and farm households conducted in 2007.

Firstly, GWEs-based accounting through water certificates would need to be carefully monitored and enforced. The allocation system in HID combines bulk volumetric charging to WUAs established on branch canals, with area-based charging for farmers. Under such a system, the irrigation district management agency supplies water to WUAs on a contractual basis; contracts have no (current) legal authorization, but do specify the rights and obligations of both the agency and WUAs. Such contracts, or agreements, provide a type of group water right, albeit one of limited security. In Hangjin, moreover, the delivery of water to WUAs is governed by service contracts between WUAs and HIMB. Field work in HID (WET, 2007) suggests that these arrangements provide a sound basis for clarifying rights and responsibilities around water delivery and payment, and for the monitoring and recording of delivery and payment. They are recommended for other irrigation districts embarking on quota-based rights reform.

Secondly, infrastructure needs to be compatible with defined rights and local management capacity. Any discussion on water rights reform cannot be isolated from an understanding of the infrastructure that is available to deliver, monitor and record water flows. In Hangjin, and in most other IDs in China, irrigation systems have not been designed to deliver and record flows to individual farmers. In these circumstances, volumetric rights can only be defined, monitored and enforced down to the level of the WUA and, conceivably, to production teams managing tertiary canals. Hence in such systems it is proposed that capped rights are allocated to WUAs through GWE-based certificates, recognising that farmer-level entitlements cannot (yet) be implemented.

Thirdly, WUAs need well-specified management functions, authority and accountability. A key issue here is whether WUAs genuinely represent the interests of all farmers, and whether they have the capacity to resolve competing claims and disputes. In Hangjin and other IDs where WUAs have been established, the management functions and authority of WUAs are spelt out in a charter, or set of written rules. The ability of farmers to assert individual claims within the bulk GWE will therefore depend on whether WUAs act as genuine organs of democratic self-management, and whether elections required under their charter are held in an open, inclusive and fair way. It is therefore suggested that the democratic management of WUAs is scrutinised closely by the ID management agency for a period of time after initial establishment. Periodic audits of WUA performance covering this and other tasks (e.g. financial book-keeping) are recommended.

Finally, WUAs require adequate resources. A common assumption in irrigation turnover programmes is that WUAs are better (than government agencies) at undertaking water allocation, distribution and fee collection in a cost-effective way. However, new obligations may be a serious burden on WUAs if they have been formed without adequate attention to their ongoing support needs. A key question in Hangjin and other IDs, therefore, is whether pressure to reduce government outlays – a key factor driving management transfer - has extended to an unwillingness to provide sufficient resources for WUAs to retain elected staff and carry out management tasks effectively, particularly in relation to long term water allocation, technical backstopping and maintenance. It is therefore recommended that WUAs are allowed to retain enough ticket revenue to cover the salary costs of their full-time staff, and to cover operation and maintenance tasks within the WUA command area. Resourcing issues could be similarly monitored through periodic audit.

3.4 Water metering and monitoring systems

Many existing monitoring systems in China are crude, and need to be upgraded to support the operation and management of a modern water rights system. In HID, for example, water levels are measured using simple gauges, and flows are measured with traditional flow meters. All measurements are done by hand, with staff having to monitor and regulate flows through over 20 gates to WUAs. In a large ID this creates a very heavy workload for staff and at times of peak water demand, there may be a shortage of manpower.

Future pressure on IDs to release water for urban and industrial users may increase pressure for more accurate monitoring of allocations to WUAs. In this context, automated water monitoring systems may help solve current and future problems, saving labour and money and providing more accurate monitoring and regulation of increasingly scare water.

Design and use criteria a monitoring system needs to meet are outlined below (WET 2007).

- Automated monitoring and data transmission. Automated systems are more accurate and less-labour intensive than manual ones, eliminating the need for station staff to travel between and monitor individual sites.
- Rapid calculation and easy access to data. Data calculation and analysis should be quick and accurate, and data interrogation should be simple and direct. At present, data

enquiries in HID can only be answered by sifting through large numbers of paper records.

- Remote control and monitoring of main sluices. The irrigation management bureau should be able to operate sluices on the main and branch canals at least remotely, avoiding long distance travel for station staff and the need to spend many hours at individual sites.
- Transparency. It is important that an automated system retains the transparency of the existing system. In particular, WUA managers and farmers should have easy access to information on water deliveries to WUAs to build confidence in the quota-based certificate and ticketing arrangements.
- Affordability. Any upgraded system needs to be affordable in terms of both capital costs, and the ongoing costs of repair and maintenance. Benefits can help off-set costs, however, and are likely to include time (labour) savings for irrigation management agency, and water security-income gains for farmers (through more timely and reliable water delivery).
- Durability and security. An upgraded system must be able to cope with the sediment-laden inflows of the river, and not require constant adjustment and maintenance. It should also be equipped with alarms to increase security, and data security and virus protection should be included.
- Ease of use. Advanced systems must be capable of being operated and maintained by station staff.

3.5 An integrated framework for rights management in irrigation districts

Drawing on the discussion above, a broad water rights framework is proposed for HID and other IDs in China. The framework consists of three elements: institutions, irrigation services and regulations. These are described briefly below and illustrated in Figure 3.2.

The institutional component refers to the management institutions responsible for water allocation and delivery, including the relevant river basin management departments, ID management agencies and WUAs. The government river basin management department is responsible for allocating water and issuing water permits to IDs, and auditing their water use plans. No changes to existing allocation arrangements and responsibilities are proposed here.

Irrigation management agencies are mainly responsible for water allocation to WUAs. In this paper, it is proposed that they assume responsibility for the granting and overall management of water rights certificates and water tickets issued to WUAs, in addition to existing responsibilities for collecting water fees, preparing the water use plan of the irrigation district, and monitoring water deliveries to WUAs. Water User Associations, in turn, would assume responsibility for purchasing water tickets within the caps set by GWE calculations, and would manage and monitor allocations under the cap to individual farmers. Field investigations in Hangjin suggest that, where ticket-based payment and contracting systems are already established, the capped arrangements for allocating and purchasing water proposed in this section could be implemented fairly easily.

Irrigation services include the initial allocation of water rights, the issue of water certificates and tickets, water use planning, water delivery and operation of infrastructure. The permitted water abstraction volume of the whole irrigation district is allocated to WUAs through the initial water rights allocation process described, forming the basis for granting water rights certificates and the sale of water tickets. WUAs would purchase tickets within their allocated rights, prepare a water use plan and submit it to the irrigation district management agency for approval. The irrigation district management agency would then complete a water use plan for the whole district and issue delivery instructions to sluice operators, according to each WUAs water use plan and remaining ticket purchase allowance. Deliveries would be monitored and signed-off as they are now, with agency staff and WUA managers entering into seasonal contracts, and jointly monitoring and confirming allocations. The irrigation district management agency would record each WUAs available water, purchased water, and supplied water every year and every watering in their water rights certificates on a continual basis, in order to check the water account and guide water supply in the next period.

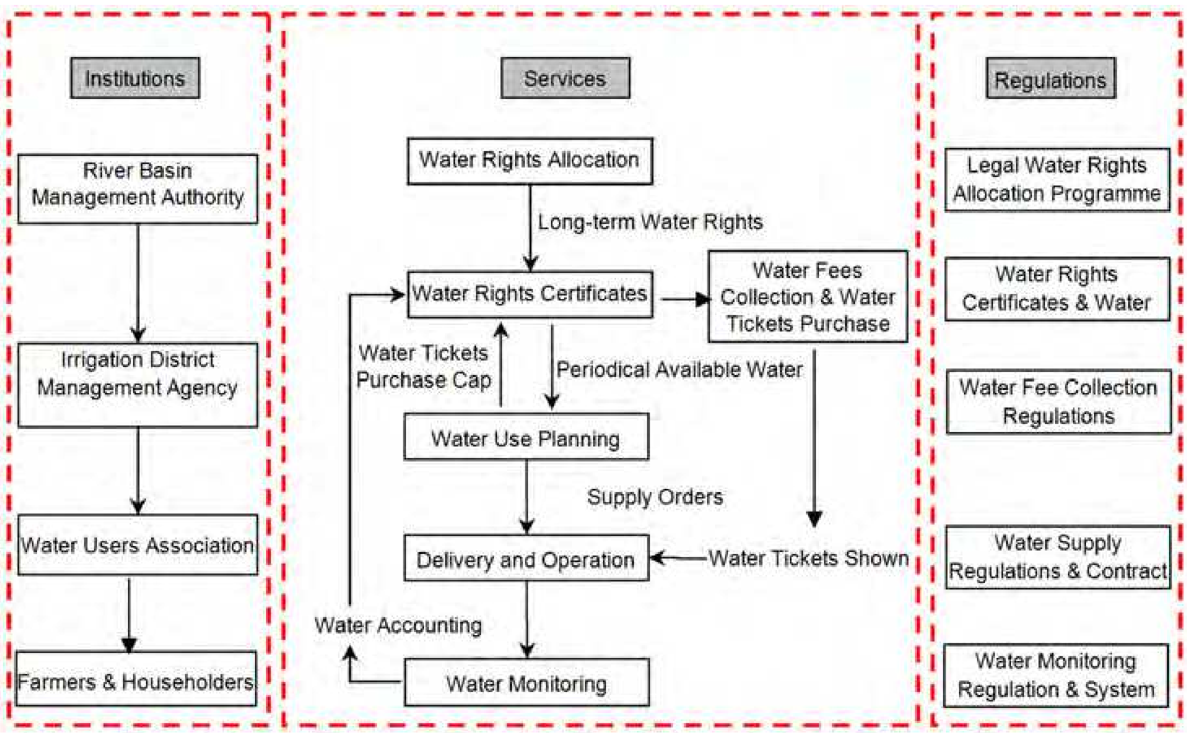


Fig. 3.2 A framework for water rights in an irrigation district

Regulations would then ensure effective implementation and monitoring of the services above, and would need to cover management regulations for the issue and use of water rights certificates and water tickets, water fee collection, water delivery and water monitoring. All management regulations and systems need to be carefully coordinated.

3.6 Recommendations

Based on field investigations in HID, a water rights framework for IDs in China has been proposed in this section, based on an initial water rights allocation, the issue of water rights certificates, sale of water tickets, water use planning and effective management of farmer-level rights through WUAs. Drawing on this framework, the authors offer the following recommendations:

1. Group Water Entitlements should be defined and allocated to WUAs in HID and other IDs, and could additionally be given legal basis by government so that rights can be legally asserted and defended, providing greater security to WUAs and farmers. In addition, a water rights management system should be developed for all IDs, including regulations that cover water use planning, water delivery, emergency planning and risk management, the collection of water fees and maintenance of infrastructure. Entitlement-based allocation planning underpins future water conservation efforts and the development of a modern, socialist countryside of China.
2. The use of an allocation plan to allocate water to WUAs in HID and other IDs is feasible. The annual allocation process in an ID needs to define and allocate GWEs within the overall permitted allowance of the district, determined by the relevant river basin authority. Allocation planning of this kind is fairer and more transparent than existing arrangements.
3. Existing contract and ticketing procedures operating between HIMB and WUAs are well understood and respected. They provide an excellent platform for the introduction of GWEs and ticket-linked water certificates. Those WUAs that have set up systems of continuous water accounting between irrigations, and volumetric delivery to (and billing of) individual production teams, will be better able to meet new quota obligations in a fair and transparent manner. Such systems are recommended for other IDs in China embarking on rights-based reform.
4. Water trading to downstream industrial users has reduced the revenue available to HIMB. The issue of funding will need to be addressed to ensure the long-term sustainability of the trading programme and channel infrastructure, and to protect farmers' long-term water rights. Management and institutional reforms in the ID should be conducted as soon as possible to improve management of the channels, enhance the financial position of the irrigation agency and secure new investment and financial resources. Most importantly, funding for the maintenance of newly lined channels in Hangjin should be secured from industrial enterprises as soon as possible. Similar channel lining and water transfer initiatives being considered by government agencies for other IDs in China need to learn from the experience of Hangjin.
5. Information and monitoring systems in Hangjin and other IDs need to be gradually upgraded to improve accuracy and reliability and reduce manpower requirements. A key priority is to strengthen monitoring of water deliveries at WUA purchase points, as monitoring here affects both WUA payment and compliance with any new system of GWE-based water rights certificates.

4. Water trading among the irrigation districts under a duration-based water rights system

This section introduces a duration-based water allocation system, which has already existed for over 200 years in northwestern China, and discusses a water trading approach in the manners of exchanging the durations (the number of days) for water extraction. As case study in Taolai irrigation district, Gansu Province, China, the efficiency of the inner-agriculture water trading in the duration-based water allocation system is reviewed. This kind of water trading would provide possible approaches to promote water trading in Chinese irrigation district.

4.1 Introduction

Water resources support critical functions within human societies and ecosystems. Along with rapidly increasing population and improved living conditions, urbanization and industrial growth have led to increased demand, competition and conflicts between different water-use sectors (Liu et al., 2009). Climate change will intensify the situation in many parts of the world. It is very important to develop solution strategies to prepare against future conflicts.

The water rights system has been proved an effective tool for water resources management (Wang, 2009; Brook and Harris, 2008). Generally, water rights are defined in volumetric terms, with a statement of the probability that the nominal volume will be delivered in full in any given year (Productivity Commission, 2003). The predictability is a key requirement of a water rights system, so that users can have a reasonable expectation of the volume of water that will be available to them (Speed, 2009). In Australia, the water management authority announces an available percentage of the water rights volume to each stakeholder seasonally according to current reservoir level and inflows over the forthcoming season (Rebgetz et al, 2009). The announcement of the available water should be transparent and least variable to the stakeholders during the year, who thus take the minimum hydrological risk when using water. In the contrary, the water authority takes most of the responsibility for guaranteeing the water rights, which increases its management and technical cost. How to reduce the hydrological risk and to share it between the water manager and users in water allocation is still an ongoing issue, which raised a lot of studies recently both in the developed (Robertson, 2009; Zaman et al, 2009) and developing countries (Wang and Wei., 2006; Zhao et al., 2006; Hu and Tang, 2006; Zheng et al, 2010).

Some useful techniques and methods were proposed in these studies, including the long-term runoff predication, seasonal water allocation, self-adaptive water operation and so on. While all these techniques were developed to provide more reliable water volume availability under a centralized storage management, due to the hydrological uncertainties and storage capacity constraints, the hydrological risk affecting the volumetric water delivery cannot be completely removed only through these techniques. Moreover in practice, it is unlikely that dam managers will have complete information on user's water demand preferences. With this asymmetric information, a central manager may implement a sub-optimal release (allocation) policy, raising a problem that the intra-seasonal allocation is overly conservative, that is, where early season allocations are low and there is unallocated water available in storage (Hughes, 2009).

Institutional innovation such as redefining water entitlements rather than a share of total volume releases (natural stream runoff) is required. A system of allocating property rights to water from shared storages (as well as a share of inflows and losses), which is called capacity sharing, is established in Australia (Dudley and Musgrave 1988, Hughes, 2009). The capacity sharing proposed a decentralize the process allowing individual irrigators to exercise a degree of control over storage decisions and resulted in water entitlements more closely reflecting the physical realities of the water supply system: constrained storage capacity, variable water inflows and significant storage and delivery losses, and thus provided a solution to address the problems outlined above including hydrological risk and asymmetric information.

Similar with the capacity sharing, a Chinese traditional water entitlement may provide another way for solution. China has a long history of water resources development and management. Water diversions for irrigation dated as far back as 316 BC (Wouters et al., 2004). In 18th Century, the administrative water allocation appeared in some arid rivers northwest China by defining the order and length of water extraction period between upstream and downstream users. This kind of water allocation has been widely adopted in the northwest China for hundred years and is still used currently. This traditional water entitlement, instead of sharing the water extraction volume, allocated water rights based on water extraction duration. Each entitlement holder in the river basin is allocated a share of the total number of water extraction days. This water rights arrangement is named "duration-based water rights" in this paper.

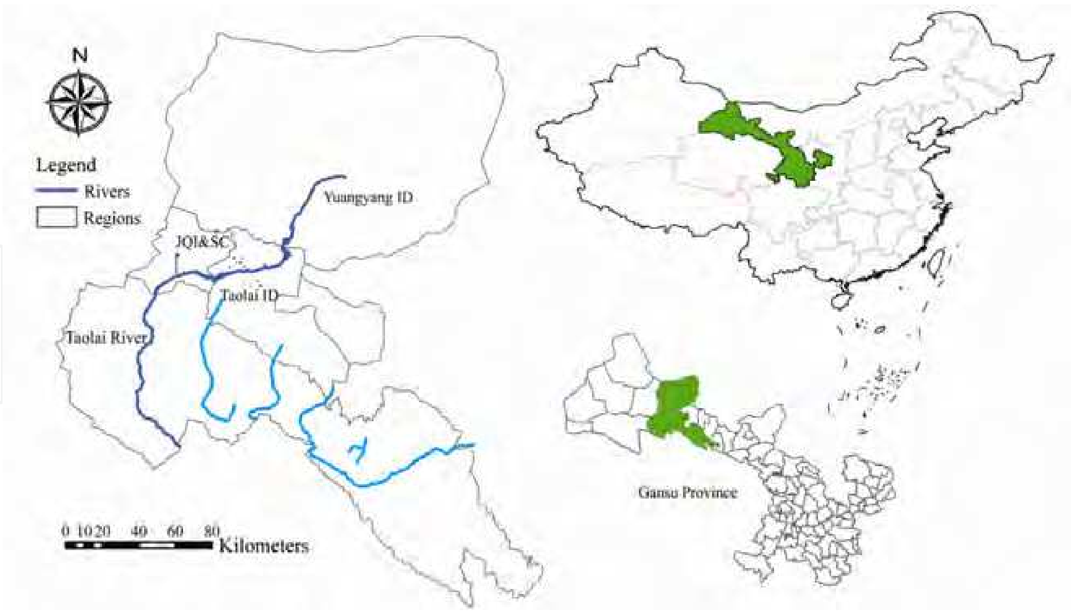
The "duration-based water rights" is defined as a kind of water usufruct which is quantified by the independent duration of water extraction. In "duration-based water rights" system, the water users can store or withdraw the entire natural stream within their permitted extraction period, and manage it independently: determining how much water to use (or sell) and how much to leave in the water course, meanwhile taking all risks from the hydrological uncertainty and variation by themselves. The dam manager does not need to make volumetric allocation announcements and their role becomes in charge of water accounting: recording each user's inflows and withdrawals to monitor the quantity of water in each user's account. However, due to lack of volumetric cap in water use, the surface stream would be likely used out and the ground water would be over extracted in the "duration-base water rights" system.

4.2 Taolai River Basin

Taolai River Basin is an inland watershed located in northwest of China, covers an area of 28,100 km2. The total renewable water resources of the basin are estimated at 1.21 billion m3. It has three main water users: Jiuquan Iron & Steel Corporation (JQI&SC), Taolai Irrigation District (Taolai ID) and Yuanyang Irrigation District (Yuanyang ID) (Figures 4.1 and 4.2). The "duration-based water rights" started in Qing Dynasty about 200 years ago and is still used in this Basin. The stakeholders share the annual water extraction days (365 days in total) in the mainstream of Taolai River: 37 days of water use duration for upstream JQI&SC; 153 days for Taolai ID, and 175 days for downstream Yuanyang ID. These days named as "allocation durations" in this paper are shown as the horizontal length of the slices in Figure 4.3. The users are able to store or use the entire natural stream during their water allocation periods independently, as shown in the right vertical ordinate of Figure 4.3. However, due to lack of volumetric cap in water use in this "duration-based water rights" system, the water resources development ratio in Taolai River Basin is rising and close to 100% recently. An urgent institutional innovation is needed.

4.3 A water allocation-trading framework for duration-based water rights system

An improved "duration-based water rights" system is proposed by (1) introducing the volumetric water use cap in each allocation period, according to the water demand and historical water usage of the users; (2) creating the enabling environment for water trading; (3) promoting the water trading in the valley and (4) setting up an integrated water allocation-trading framework support these improvements (1), (2) and (3).



Note: Data from the National Fundamental Geographic Information System, China.

Fig. 4.1 Location of the Taolai River Basin, Gansu province, China

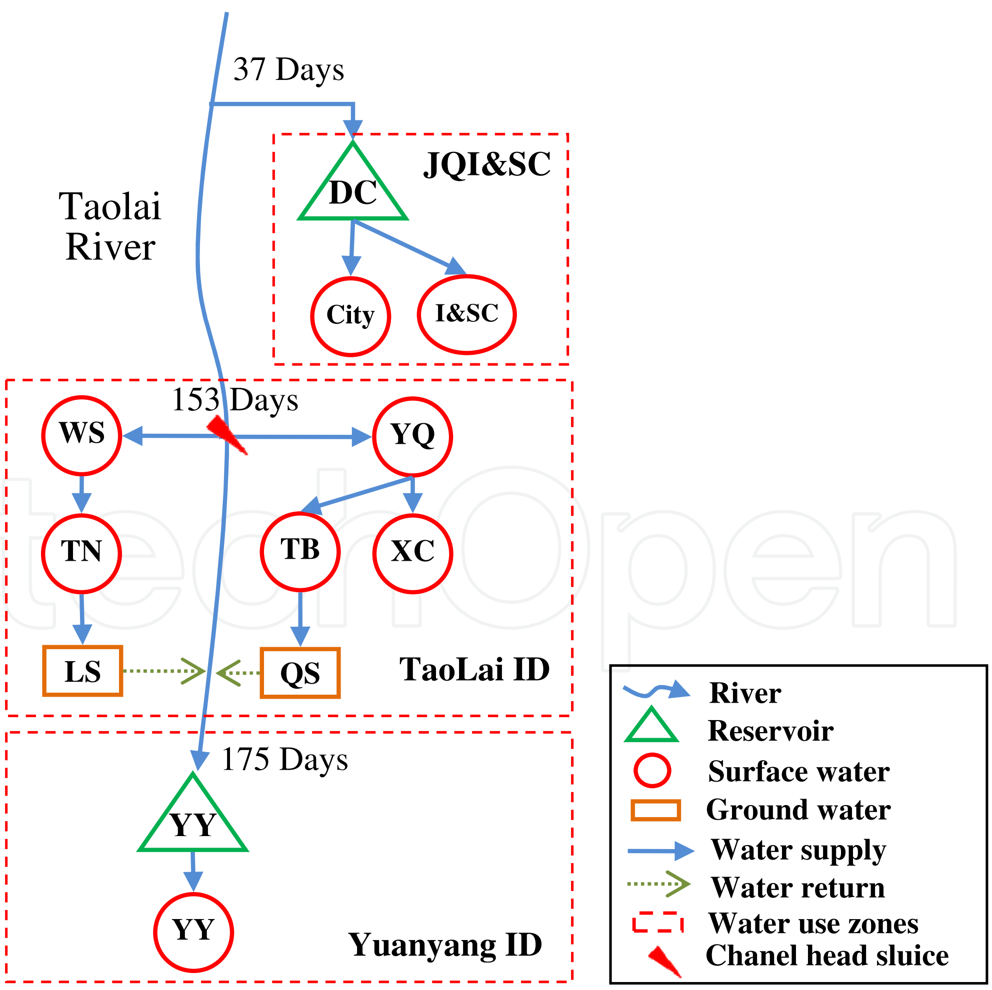


Fig. 4.2 Schematic diagram of Taolai River Basin, Gansu province, China

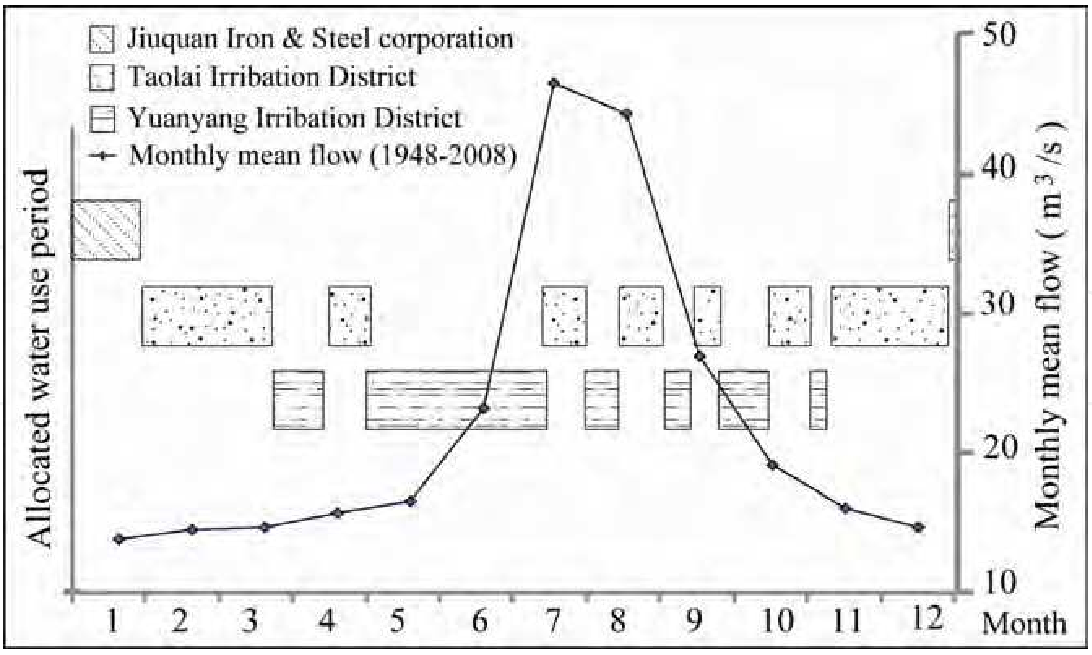


Fig. 4.3 Intra-year allocations of the “duration-based water rights” in Taolai River Basin, China

1. Introducing the volumetric water use cap

The discharge volume within a specific allocation period provides the maximum available water for the user who is authorized to withdraw water in that period under the “duration-based water rights”, which is shown in Figure 4.4. The shaded area under the flow curve indicates the available water volume for Yuanyang ID in its first allocation period of the year. The annual available water can be identified by accumulating all the available water in the allocation periods across the year.

The annual available water and historical water use of Taolai and Yuanyan ID under their “duration-based water rights” are shown in Figure 4.5 and Figure 4.6. The water volume is ranked descendingly by the total annual runoff of the Taolai River 1980-2008, and plotted versus the hydrology frequency of the years. The year with hydrology frequency of n% means that the annual runoff of the year will be exceeded in n years out of 100. The annual available water of the IDs is the accessible water within their allocation periods so that is part of the total annual runoff; therefore, the available water in a dry year may be larger than that in a wetter year for the inter-annual variability of the runoff process, which can be found in Figure 4.5 and 4.6.

In Figure 4.5, the historical water use of Taolai ID is stable and less than its available water, which indicates that there is some water didn’t or can’t be used by Taolai ID in its “duration-base water rights”. Actually, this unused water is mainly made up of the flood in July and August, which can hardly be stored by Taolai ID without enough reservoirs in it, and was spill out to the ecosystem and downstream Yuanyang ID. For the ecological benefit from the flood water, involving the stream flow maintenance and groundwater recharge, the annual water use limit is introduced underneath the available water of Taolai ID and portrayed by the upper cap line of historical water use for satisfying the current water demand.

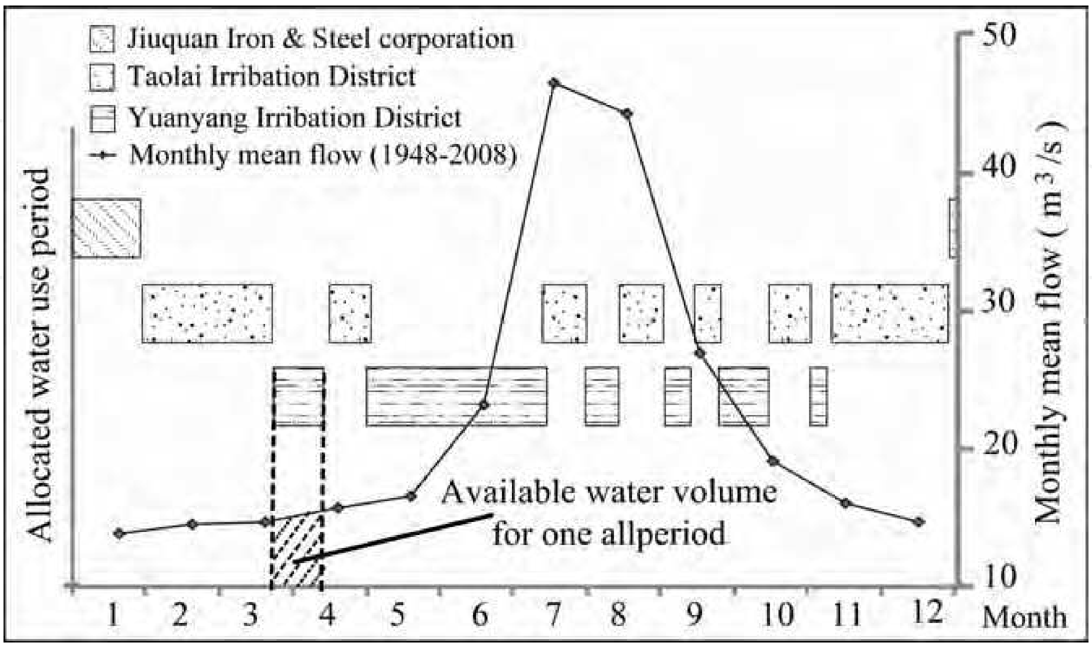
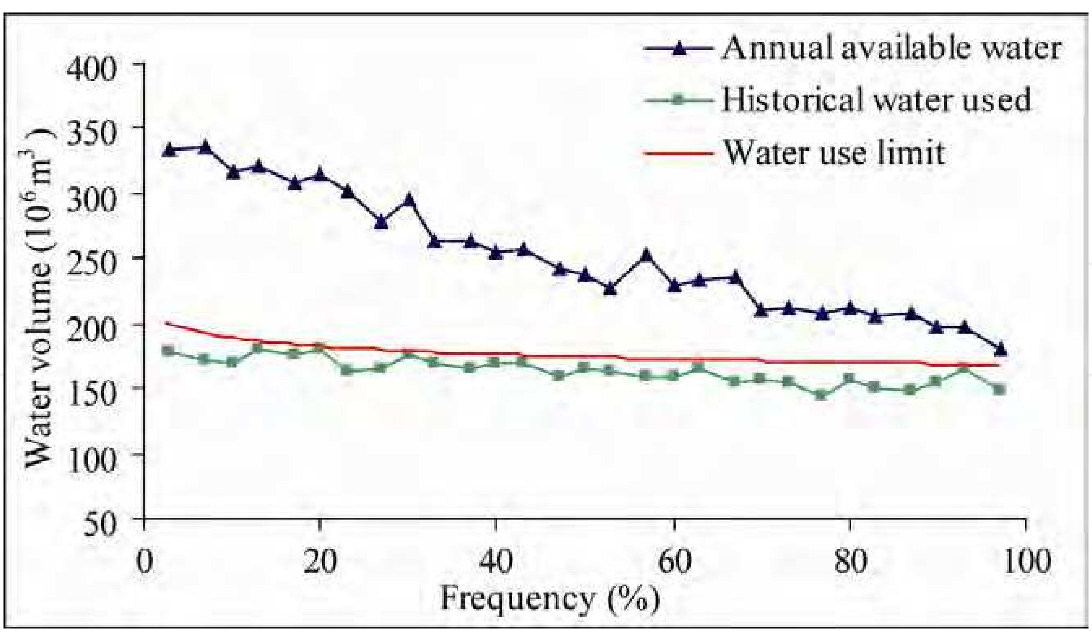
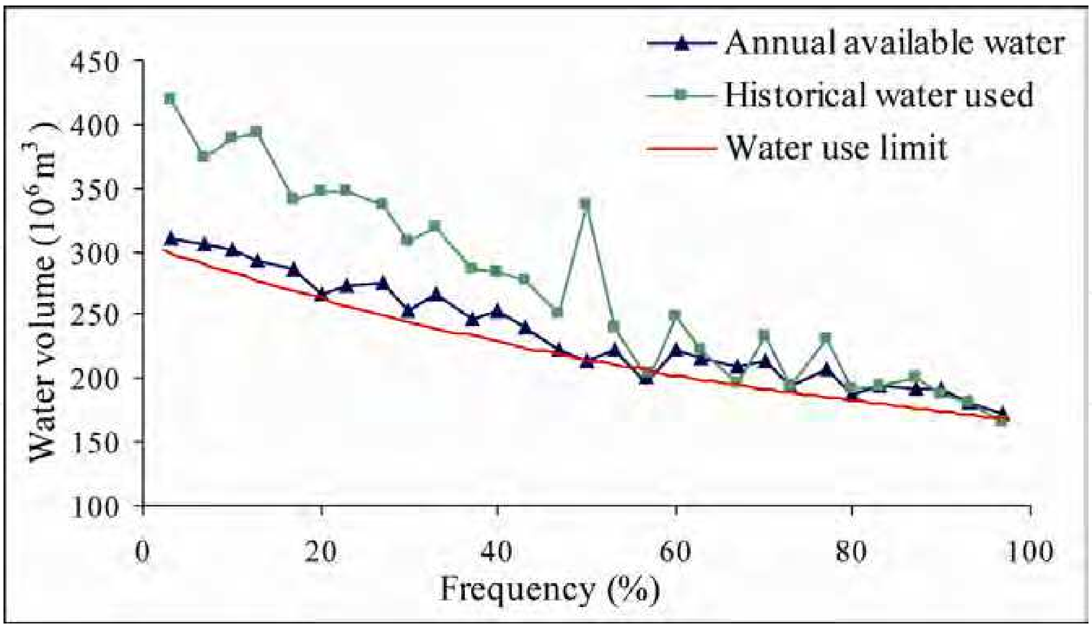


Fig. 4.4 Water available volume in the allocation periods of Taolai River Basin



Note: Source from Zheng, 2011.

Fig. 4.5 Annual available water and water use limit for laolai ID



Note: Note: Source from Zheng, 2011. .

Fig. 4.6 Annual available water and water use limit for Yuangyang ID

In the downstream, Yuanyang ID stored and used part of the flood which was spilled by Taolai ID in its allocation periods, by a large reservoir in it. Therefore, the water used by Yuangyang ID was more than the water available in its allocation periods during 1980-2008. Water use limit of Yuanyang ID is established as the lower cap of its annual available water so that the Yuanyang ID's water extract can follow its "duration-based water rights" strictly and all the flood water can be released for ecosystem, as shown in Figure 4.6.

2. Water use plan and information exchange for water shortage

The objective of water use planning is to schedule water diversion, storage, delivery and use in an ID according to the requirements of farmers, available supply from the river, and flow through the irrigation channel system. A water use plan is a guideline for the rational delivery and use of water within an ID, and can help improve irrigation efficiency and save water (Zheng and et al, 2009). It is proposed that the water use plan takes the water use limits discussed previously as a starting point, and then translates them into a periodical irrigation schedule for water users associations (WUAs) or farmers.

Prior to each irrigation (or allocation period), the period water use plan for the ID would be prepared by the Irrigation Management Agency, based on the plan submitted by each WUA, and submitted upwards through the irrigation agency to the higher-level department for approval, such as the River Basin Management Department, who would then revise and approve the water scheduling of the ID, in term of the water use limit of the ID. Afterwards, the Irrigation District Management Agency would adjust the plan accordingly, and announce it to WUAs and farmers.

If the irrigation water demand is not fully satisfied in the approved plan, on the agreement of the farmers, the Irrigation District Management Agency would release its water shortage information to the valley and search for the water sellers to promote a water trading. This process is proposed to occur through an on-line information exchange system that can balance demand and supply, guide pricing and help manage water trading in a quick and transparent manner, such as the "watermove" system in Australia (Available at https://www.watermove.com.au/Default.aspx).

3. Water trading

The predictability and transferability can be satisfied more strongly in the "duration-based water rights" system due to the stable water allocation periods and the decentralized management of the runoff within them. The economic efficiency of the water trading is described from Equation 4.1 to 4.4.

$$W_a = \int_0^{D_a} Q_a \cdot dt \tag{4.1}$$

$$W_j = \int_0^{D_j} Q_j \cdot dt \tag{4.2}$$

$$MU_a \succ MU_j \tag{4.3}$$

where, W_a and W_j describe the exchanged water volume in April and July between Taolai and Yuanyang IDs (m^3); Q_a and Q_j are mean stream flow in the two months (m^3/s); D_a and D_j are the number of exchanged days. MU_a and MU_j indicate the marginal utility of the water in April and July. From Figure 4.4, it is shown that $Q_a < Q_j$ and $D_a = D_j$. Therefore, $W_a < W_j$ which indicates Taolai ID obtained less water from Yuanyang ID in spring and gave more water back in summer. Due to the serious runoff insufficiency and irrigation competition in spring, the water is more valuable then, as shown in Equation 4.3. So, there is a possibility that the benefit gained by Taolai ID from the allocation period exchange in spring can be equal to its benefit loss in summer. If this balance happens (Equation 4.4), the water trading will be efficient.

$$MU_a \cdot W_a = MU_j \cdot W_j \tag{4.4}$$

In practice, water trading in the manner of exchanging water extraction days between upstream and downstream users has existed in the Taolai River Basin for years. This kind of water trading has being carried out in Taolai River Basin for yeas (totally 10 times, 2005-2009) and reallocated water effectively, with no need of seasonal water allocation, lower transaction cost and thus higher accessibility. In 2008, to solve the upstream water shortage caused by the mismatch between the irrigation schedule and allocation period distribution, the allocation period of Taolai ID was extended in April for 9 days, with the equivalent number of days reduction for Yuanyang ID simultaneously; while in summer when there is excess water for Taolai ID, the allocation period changed in the opposite directions as the same amount of days as in spring, shown in Figure 4.7.

4. Towards an integrated framework for water allocation-trading in the system

Drawing on the discussion above, broad water rights framework, combining the volumetric water use cap and the "time-based water rights", is proposed. The framework consists of three elements: institutions, water allocation-trading services and regulations. These are described briefly below and illustrated in Figure 4.8.

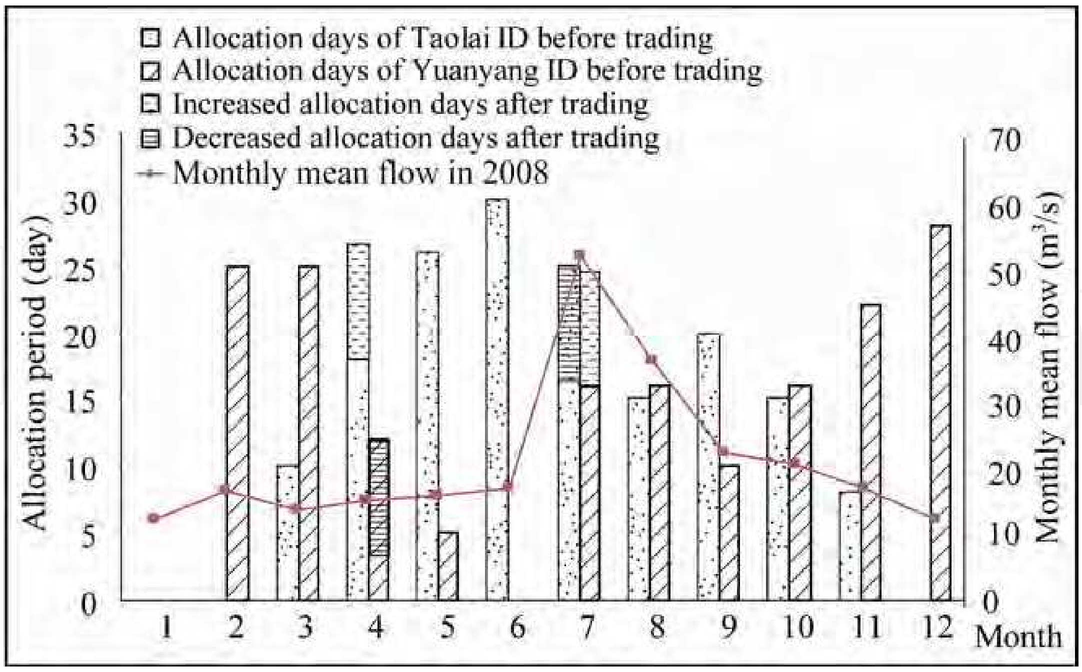


Fig. 4.7 Allocation period exchanges between Taolai ID and Yuanyang ID in 2008

The institutional component refers to the management institutions responsible for water allocation, trading and delivery, including the relevant State Water Resources Management Department, River Basin Management Authority, Irrigation District Management Agency and WUAs. The Water Resources Management Department of state government takes charge of administrative management for River Basin Management Authority. The authority is then responsible for allocating water and issuing water trading permits to IDs, and auditing their water use plans. Irrigation Management Agencies are mainly responsible for water allocation to WUAs and organizing a democratic decision making process for water trading. In this paper, it is proposed that they assume responsibility for preparing the water use plan of the irrigation district, and monitoring water deliveries to WUA. Water User Associations, in turn, would manage and monitor allocations under the cap to individual farmers.

Water allocation-trading services include issue the available water and water use limit, water use planning, water delivery and operation of infrastructure, as well as the information support, application approval, contrast and publicity for water trading. Prior the irrigation, the available water volume and water use limit for current allocation period would be issued to the irrigation district according to the duration of its allocation period and the forecasted runoff. Then, the rationing water volume of the whole irrigation district is allocated to WUAs through the normal volumetric water allocation process, providing the cap for water use planning of the WUAs. The Irrigation District Management Agency would then complete a water use plan of the whole district accordingly and check whether there are water shortage and the necessity for buying water. After the democratic consultation with farmers, if the irrigation district decides to buy some water and extend its allocation period, the management agency would publish its requirement to other irrigation districts and seek the water seller. If the buyer and seller get an agreement on water trading, they would submit a trading application to the River Basin Management Authority for approval.

The water trading will be legally effective only after the trading application is approved by the government and passed through by publics.

Regulations would then ensure effective implementation and monitoring of the services above, and would need to cover management regulations for the issue and use of volumetric water use cap together with the "duration-base water rights", and the information exchange, decision making, third-party impacts assessment and approval for water trading, as well as water delivery and water monitoring. All management regulations and systems need to be carefully coordinated.

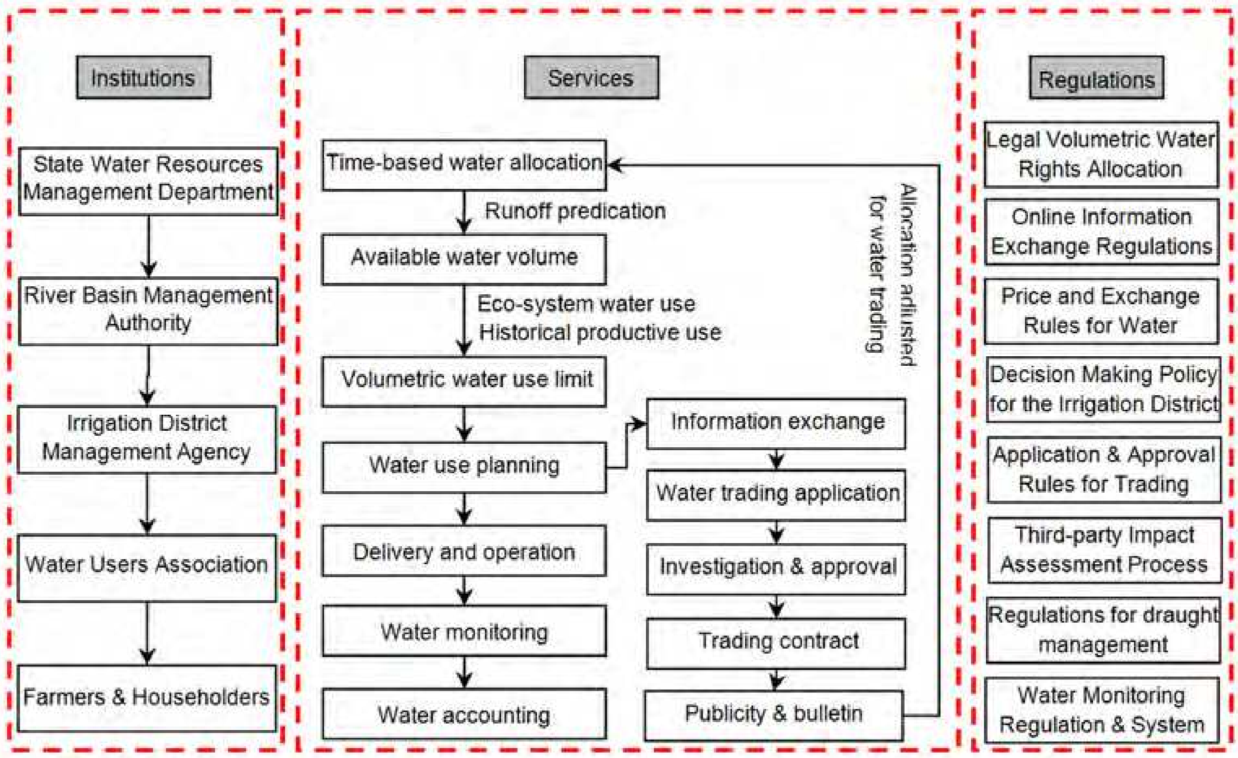


Fig. 4.8 Water allocation-trading frameworks for duration-based water rights system

4.4 Recommendations

A water allocation-trading framework based on the "duration-based water rights" was proposed in this section. Comparing with the normal volumetric water rights system, the framework is supposed to reduce the management cost of the water authority by introducing a decentralised and semi-independent water management to the stakeholders. In the framework, water entitlement is indicated by the fixed amount of water extraction days and would hardly be affected by the hydrological uncertain. The water users can manage the stream flow and storage independently during their allocation period under the volumetric water use cap. The water authority is just responsible for the water use planning and accounting, making sure the water use of the stakeholders not over their limit. The hydrological risk is shared mostly by water users while they get more flexibility to make their own storage decisions, taking into account their private information on water needs.

The idea of "duration-based water rights" is similar with the capacity sharing in Australia to a certain extent. Capacity sharing is a system of allocating property rights to water from shared storages proposed by Dudley (Dudley and Musgrave 1988, Dudley and Alaouze 1989, Dudley 1990, Dudley 1992). Each entitlement holder in an irrigation system is allocated a share of the total system storage capacity, as well as a share of total inflows (spill water and losses). Users are able to manage these capacity shares independently, as well as take the hydrological risk and losses. The duration-based water allocation-trading framework suggests a property rights system by sharing the water extraction duration, rather than storage capacity. But both of the systems suggest a decentralize the process by designing some system of property rights allowing individual irrigators to exercise a degree of control over storage decisions, which is helpful to address some of the problems of centralized water management, such as the hydrological risk, asymmetric information and transaction costs in water delivering. The proposed duration-base water allocation framework could provide a comparison reference for capacity sharing, and the success of the capacity sharing practice in Australia could be helpful to understand the feasibility and practicability of the proposed framework.

Volumetric water use limit was introduced and combined with duration-based water allocation in the study, which suggested a mechanism to integrate the international contemporary water rights system with the Chinese traditional water management. In recent decades, with the introduction of the global experiences of water rights reform, volumetric water right and its allocation system have been implemented across the China to a varying degree (Gao, 2006; Shen & Speed, 2009), and replaced the traditional water allocation system in most of the rivers. This has raised many conflicts in the reforms. The integrated mechanism proposed in this chapter would be helpful to buffer the conflicts when establishing a volumetric water rights system in valleys where the traditional water allocation is still working. Moreover, the integrated water allocation-trading framework could be used in the upcoming process of establishing the water market in Taolai River Basin, which would probably become the first water market in China and also a significant improvement in China's water rights reform. The framework would be feasible for the arid river, especially the valley which has uneven spatial distribution of the storage capacity.

For the limitation of the data and practices, the proposed framework just provides a conceptual framework of integrating the volumetric and time-based water rights without enough data verification. As noted, to transform this result based on one case study into the business of managing water catchments on a daily basis requires considerable further research, policy development and investment. Some future researches are still required to improve the framework, involving (1) defining the volumetric ground water cap in Taolai valley; (2) pilot study to verify the feasibility and validity of the framework; (3) modelling the irrigation water use planning which is constrained by the volumetric cap and time-based allocation in the irrigation districts and farmers level; (4) the technique for monitoring and accounting the water use and trading volume.

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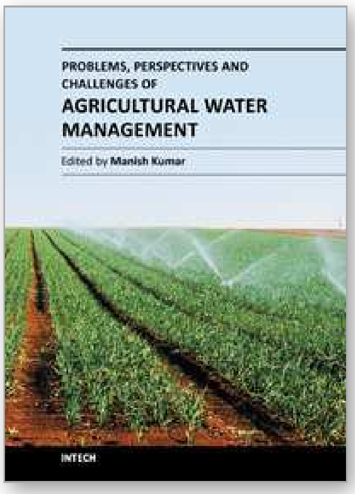

Problems, Perspectives and Challenges of Agricultural Water Management
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Food security emerged as an issue in the first decade of the 21st Century, questioning the sustainability of the human race, which is inevitably related directly to the agricultural water management that has multifaceted dimensions and requires interdisciplinary expertise in order to be dealt with. The purpose of this book is to bring together and integrate the subject matter that deals with the equity, profitability and irrigation water pricing; modelling, monitoring and assessment techniques; sustainable irrigation development and management, and strategies for irrigation water supply and conservation in a single text. The book is divided into four sections and is intended to be a comprehensive reference for students, professionals and researchers working on various aspects of agricultural water management. The book seeks its impact from the diverse nature of content revealing situations from different continents (Australia, USA, Asia, Europe and Africa). Various case studies have been discussed in the chapters to present a general scenario of the problem, perspective and challenges of irrigation water use.

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