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RESEARCH ARTICLE

Toward a socio-political approach to water management: successes and limitations of IWRM programs in rural north-western China

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Abstract In rural north-western China, the tension between economic growth and ecological crises demonstrates the limitations of dominant top-down approaches to water management. In the 1990s, the Chinese government adopted the Integrated Water Resources Management (IWRM) approach to combat the degradation of water and ecological systems throughout its rural regions. While the approach has had some success at reducing desertification, water shortage, and ecological deterioration, there are important limitations and obstacles that continue to impede optimum outcomes in water management. As the current IWRM approach is instituted through a top-down centralized bureaucratic structure, it often fails to address the socio-political context in which water management is embedded and therefore lacks a complete treatment of how power is embedded in the bureaucracy and how it articulates through economic growth imperatives set by the Chinese state. The approach has relied on infrastructure heavy and technocratic solutions to govern water demand, which has worked to undermine the focus on integration and public participation. Finally, the historical process through which water management mechanisms have been instituted are fraught with bureaucratic fragmentation and processes of centralization that work against some of its primary goals such as reducing uncertainty and risk in water management systems. This article reveals the historical, social, political, and economic processes behind these shortcomings in water management in rural north-western China by focusing on the limitations of a top-down approach that rely on infrastructure, technology, and quantification, and thereby advances a more holistic, socio-political perspective for water management that considers the state-society dynamics inherent in water governance in rural China.

Keywords integrated water resources management, top-down implementation, inland river basin, water rights, China

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1 Introduction

Perhaps no place demonstrates the tensions inherent in efforts to conserve the environment and the drive for economic growth than rural north-western China. The region has a long and rich history of environmental stewardism, such as the implementation of the ambitious Three-North Shelter Forest Program and the Grain for Green Project; however, population growth and the rapid expansion of the local economy has had a profound impact on the sustainability and management of inland watersheds in the Gansu Province and the Xinjiang Uyghur Autonomous Region. The degradation of these water systems has caused severe water shortage, desertification, and social disability. During the last several decades, China has transformed its water management system from a decentralized system focusing primarily on supply and distribution to a centralized system of laws, decrees, and regulations constituting a complex governance bureaucracy. This transformation is embedded in and runs parallel to a transformation in environmental policy reflected in a wide range of legislation addressing major environmental policy challenges since the 2000s, including pollution, wildlife protection, and natural conservation (Shen, 2014; Moore, 2015). Contrary to the previous era when the decentralized administrative structure could not properly address the nation's growing environmental challenges, a significant portion of water governance programs implemented after 2001 have relied on top-down political mobilization and earmarked funding from the central government to ensure the completion of infrastructure and agricultural structural adjustment projects (Rogers and Crow-Miller, 2017; Mao and Zhang, 2018). However, research has shown that, historically, the participatory water management processes in China are hindered in policy implementation, as the goals of the central state became absorbed by the existing structure of domination in its bureaucracy (Magee, 2013; Moore, 2018). An examination of the elite-driven policy design and the command-and-control implementation process of water systems contributes to the understanding of how market-oriented measures have interacted with existing water governance institutions, advancing insights into the need for a more socio-political focus on water issues in rural China.

This article examines four IWRM programs in rural north-western China where water resource degradation has become a central concern for both the rural inhabitants of the region and for the Chinese central state. We explore the following questions: What were the institutional and historical particularities that constituted the context of water resources management in China? What is the governance structure of the IWRM programs, and how has it shaped the regulatory approaches, expected outcomes, and implementation results in our case studies? How have the institutional and socio-economic factors shaped the hybridized socio-natural processes of watershed management? What can a socio-political approach tell us about the sustainability of IWRM programs in centralized regimes that attempt to balance economic growth and environmental conservation? To answer these questions, we undergird our case studies with a historical timeline of water governance in the region and examine how the implementation of the IWRM programs have resolved and generated uncertainty and vulnerability in water system management. We then provide an analysis of the policy objectives for the Tarim, Shule, Hei and Shiyang IWRM programs and an examination of the implementation process of the Shiyang IWRM program in Minqin County, Gansu. We conclude with a discussion of the institutional constraints that may hinder the sustainability of these programs and thereby generate further uncertainties in the management of inland water systems of north-western China. We argue that the IWRM programs are more than integrated attempts to govern surface water and groundwater resources. Instead, the IWRM programs are fundamentally state-led rural development initiatives that utilize control over water use rights to reconfigure land use and agricultural production patterns. The case studies demonstrate the need for a socio-political approach that incorporates diverse interests and power into the assessment of uncertainty and sustainability of water systems, complementing the dominant hydraulic and social engineering perspectives. Our findings may contribute to the understanding of centralized governance programs of inland rivers in the developing world.

2 Methods and data

This study uses data from government documents, policy papers, reports from state-owned media, and in-depth interviews to examine the formulation and implementation of Integrated Watershed Management Plans for four integral watersheds in north-western China. Engagement with multiple methods allows for triangulation between multiple sources of information for more consistent and reliable results. The watersheds selected for our analysis are the Tarim River, the longest inland river in China, and the Shule, Hei and Shiyang rivers, the most important inland rivers in the Hexi Corridor. These watersheds were selected based on their ecological and geographical similarities and import as well as their comparable levels of economic development. The inland watersheds in our study are essential to the ecological health of the region as they provide ecological barriers against sandstorms and desertification (Yao et al., 2008). The Tarim River provides essential water resources to oases in southern Xinjiang, as the area around the Taklamakan Desert is a major source of sandstorms in China. The Shule, Hei and Shiyang rivers protect the ecosystems around the Hexi Corridor and Alxa League of Inner Mongolia, another source of sandstorms. The Hexi Corridor and Tarim river basin has a long history of agricultural development and is a key producer of agricultural commodities in north-western China. The regions have significant economic and national security importance for Gansu and Xinjiang, and China as a whole. Additionally, the corresponding IWRM plans were all formulated and implemented when the Chinese central government initiated top-down management of water resources. The four IWRM programs examined in our study, therefore, provide an archetypal sample of the management of inland water systems in north-western China.

The authors collected provincial, prefectural, and county-level water management plans announced between 2002 and 2016 as well as official policy reports on water resources, economic development, and agricultural production in the watersheds. These reports aided in understanding the formal approaches to water management, economic growth, and environmental protection, as well as strategies for improving program accountability and public oversights. Given that the lack of water resources has generated nationwide press coverage in China, the authors collected reports from the Chinese Central TV station and publications from national and provincial news outlets to examine media interpretation of the state-sponsored IWRM programs in the selected watershed. The semi-arid oasis ecology of our case studies may limit the generalizability of the study to natural conservation programs in different regions in China, but we emphasize the logic and similarities behind water resource management as well as the similarity of challenges to natural resource management confronted by this logic.

The data for the second part of our findings came from 83 in-depth interviews with farmers, 23 in-depth interviews with the county, township, and village cadres as well as 4 NGO representatives in Minqin County, Gansu (Fig. 1). In-depth interview is a useful research method to understand the hybridized socio-natural processes of resources management because it allows the collection of sensitive and confidential information from critical stakeholders. The qualitative approach also enables researchers to understand how farmers and grassroots state agents interpreted the benefits and challenges of the IWRM programs that subsequently shaped the response from the rural communities. The interview data (Table 1) we collected in Minqin informs the analysis of our article by providing a bottom-up perspective that is integral to the socio-political approach. The first author used snowball sampling to interview village and township cadres as well as their acquaintances who had diverse perspectives on IWRM in the region. The semi-structured interviews were conducted in seven separate field trips between 2010 and 2011 to capture the informants' varied views on natural resource governance and program implementation as the economic and environmental conditions in the oasis evolved.

These interviews were recorded with consent from the informants for later review, which was transcribed, translated, and analyzed based on major themes such as changes in farmers' water usage, agricultural production, land use, environmental awareness, and participation in decision-making. The authors also categorized the divergent interpretations and perceived obstacles of policy implementation in the IWRM program. The analysis of interview data was then cross-referenced with results from policy documents, news reports, and notes from the interviewer's observation. In spring 2013 and summer 2016, the interviewer returned to the oasis and conducted follow-up interviews with 12 key informants to observe how the IWRM program had affected their livelihood since 2012. In December 2016, the interviewer shared the findings of this manuscript with five informants to verify the validity of his interpretations. Furthermore, in May and June 2018, the second and third author joined the project to re-analyze and cross-validate the interview data gathered from government and news reports published after 2015.

3 The socio-political perspectives on water systems

The complexity of water resource management lies in its intersection with both natural conditions and human activities. As human activities increasingly affect the quantity, quality, and access of water resources, the risks to water resource systems have been further amplified, leading to more uncertainties in the understanding and prediction of system outcomes (Taylor and Sonnenfeld, 2017). Traditionally, hydraulic and social engineering perspectives approach water management as a technical and scientific issue and tend to perceive uncertainties as embedded within the hydrological cycle and the hydraulic structures with solutions dependent upon economic feasibility and data reliability of the operational system (Fassnacht et al., 2018). However, major human-induced threats to nature such as climate change necessitate approaches that take account of the interconnectedness of society with the natural world. As such, the assessment of uncertainty and environmental sustainability for water systems should incorporate perspectives that analyze the socio-political aspects of water resource management.

The literature on the sociology and politics of water recognizes that water access, use, and governance is fundamentally an issue of property rights and decision-making rights, which are, subsequently, connected to the

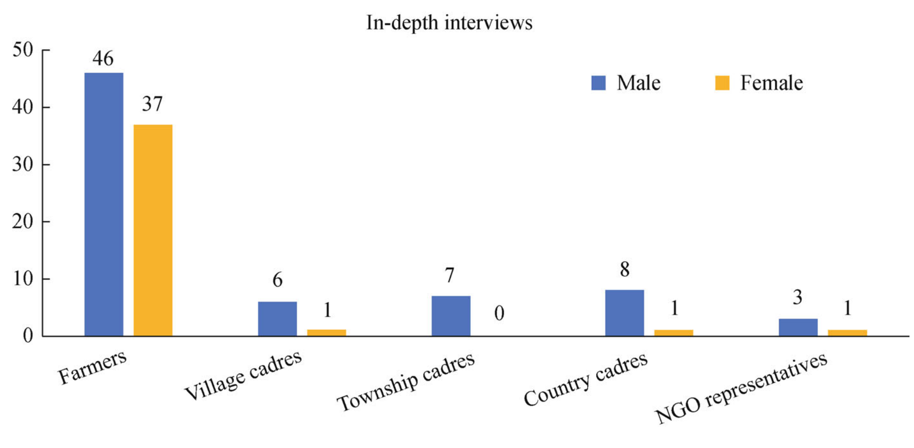

Fig. 1 Background of Interviewees.

Table 1 Summary of interview questions used in Minqin County

Major themes	Sample questions
Changes in agricultural production	Has the IWRM program affected how you farm the land?
	In what ways has the IWRM program affected the patterns of water consumption in your village?
	How much money have you invested in water-saving infrastructure such as horticulture greenhouses and drip-irrigation?
	How has the IWRM program shaped the allocation of land resources and the scale of agricultural production in your village?
	How have the application of technology and subsidies affected the dominant ways of production in your village?
	How have out-migration, capitalization, and stratification shaped the implementation of the IWRM program?
Environmental awareness and conservation of natural resources	What have been the environmental and economic benefits of the IWRM program in Minqin?
	Have there been any changes in the environment in vicinity of your village/township?
	In what ways has the IWRM program changed how you utilize water and land resources in your household and village?
	Would you be willing to change how you utilize water and land resources after the completion of the IWRM program?
	How successful is the IWRM program in Minqin?
Opportunities & obstacles of IWRM implementation (grassroots cadres & villagers)	How was the IWRM program implemented in Minqin?
	What were the major obstacles for the state's drive to reduce cultivation areas?
	How did the local government promote the construction of horticulture green houses and drip irrigation infrastructure?
	In what ways has the local government ensured accountability of program outcomes?
	What have been the main obstacles to the sustainability of the IWRM program? How has the local government addressed these obstacles?
	How have the central and local governments shared the cost of program implementation in Minqin?
Public participation & decision making (grassroots cadres & villagers)	How have the county government, irrigation districts, and townships determined allocation of water resources?
	How have the Water Users' Associations operated in Minqin?
	How have the construction of metered wells and the expansion of water-saving infrastructure shaped decision-making at the grassroots level?
	What have been the major mechanisms to ensure public participation in the formulation of program goals and the implementation process?
	How have the restrictive goals of the IWRM program shaped the implementation process?

allocation of the natural and social resources that sustain the operation of the water system (Mollinga, 2008; Swyngedouw, 2009; Meehan, 2014). By highlighting the social relations in which water users and state policies are enmeshed, the socio-political perspective demonstrates that technical and organizational control of water is conditioned by institutional constraints embedded within the broader social structure as well as the changing natural conditions in the ecological system (Mollinga, 2008; Rogers and Crow-Miller, 2017). Water systems, therefore, should be viewed as "hybridized socio-natural processes" by which the flow of water and the relations of power co-produce each other over time (Loftus, 2009; Linton and Budds, 2014). The advancement in water control technology and infrastructure create ecological changes that affect the availability of water resources, which, in turn, influence the organization of distribution regimes that implement the technology and infrastructure (Loftus, 2009; Meehan, 2014). The human-water dynamic has multi-scalar dimensions where access to water in a locality is structured by institutional practices, market mechanisms, rationalities, and discourses at the regional, national, and international levels of governance. As such, the management of water resources becomes a politically contested process shaped by interaction between multiple stakeholders operating across socially constructed scales of power and space (Norman et al., 2012; Norman et al., 2015).

The complexity of water control and uncertainty in resource availability has led to global development institutions and national governments promoting the management of water resources through an ecosystem services approach at the watershed and river basin levels since the 1980s (USAID, 2007; Schneider, 2010; Taylor and Sonnenfeld, 2017). The integrated water resources management (IWRM) approach requires a coordinated development of surface water, groundwater, catchment areas, and land resources due to interactions between the hydrologic cycle and land use, which determine the quantity and quality of water available for human consumption and ecosystem services (Mukhtarov, 2008). Within the IWRM approach, "triple-bottom-line" issues including environmental risk, social equity, and economic benefits require the involvement of multiple stakeholders across scales in policy planning and implementation in the management of water resources (Reed, 2008). Yet, critics have shown that successful public participation and program accountability can be lacking due to variability in water flow, differences in political and environmental contexts, and institutional barriers that prevent the representation of stakeholders' interests; gaps in water management institutions complicate the inclusion of decision-making at multiple levels of water governance (Mostert, 2003). A further complication hinges on the fact that IWRM projects are often designed and implemented by state policymakers and outside experts occupying hegemonic positions who designate the types of practices that should be interpreted as "integrated," "participatory," and "good governance" (Cornwall, 2004). As such, decision-making power remains in the hands of techno-elites whose cooptation of IWRM reinforce existing organizational mandates and expand state power (Cornwall and Brock, 2005).

Since the amendment of its Water Law in 2002, IWRM has become the dominant approach to water management in China, and, subsequently, has encountered serious challenges due to miscalculation of water needs, partial implementation and enforcement, and conflicting interpretations of policy goals (Yu et al., 2010). As the issue is multi-faceted and rooted in all scales and domains of water management, it requires a holistic approach. However, most state publications on uncertainty for Chinese water systems focus on the variability of water flow and conflicting demands by competing users in the watershed, underestimating the difficulty of stakeholder coordination in an authoritarian environmental policy context. Therefore, the socio-political perspective on water systems management provides an alternative approach as it focuses on the intersection of the environment and human systems and understands the multi-scalar domains and complexity of institutions involved in water management.

4 The institutional and historical context of water resources management in China

Institutional transformation in environmental governance has shaped the management and protection of water resources in China and provides perspective for understanding China's contemporary water management issues. Before the dissolution of the Collective Era in the early 1980s, China had a highly decentralized model of water governance, as there were no laws regulating the distribution and utilization of water resources at the national level. The 1988 Water Law was the first attempt by the Chinese central government to establish a national water governance system by designating water as a property of the central state and the rural collectives (Nickum, 2010; Magee, 2013). However, as the 1988 Water Law was designed to promote water resource utilization, it was deficient in environmental protection and did not recognize the mismatching scales of watershed geography and administrative jurisdictions. The resultant ambiguities concerning the regulatory limitations of central government ministries and sub-national authorities contributed to water resource conflicts between local and regional governments. The division of governance functions between differing administrative apparatus in the central bureaucracy also led to fragmented enforcement and penalties, directly contributing to increased water pollution and the deterioration of water resources in the 1980s and 1990s (Yu et al., 2015; Yao and Zhou, 2016). The rapid decline of China's water systems prompted the National People's Congress Standing Committee to redesign the regulatory framework in 1997, and the revised Water Law was promulgated in 2002.

The 2002 Water Law incorporated several important organizational, regulatory, and legislative changes to address China's water system's crisis. The law established a national principal department for water resources governance utilizing IWRM principles to consolidate watershed management with regional administration (Yu et al., 2015). To control water pollution and groundwater overdraft, the law delineated a chain of administrative authority between local, prefectural, provincial and national departments within the hierarchical bureaucracy, enabling the central government to impose restrictive targets to discipline water governance at the sub-national level. It tied the size of the watershed directly to the implementation and enforcement of water regulations by placing the Ministry of Water Resources (MWR) directly over water conservation and pollution regulation in watersheds that span across provinces. At the regional level, it created provincial watershed committees, consisting of heads of provincial departments and prefectural-level cities, to manage water resources within each watershed. At the local level, it designated the departments of water resources and environmental protection at prefectural and county levels of governance as responsible for enforcing regulations on water resources (Magee, 2013).

Since 2002, the State Council of China and the Ministry of Water Resources have issued a series of national laws and ministry-level regulations to create basin-wide water allocation and zoning plans to improve water-supply capacity and water-use efficiency. To reduce the growth of demand for water resources, the MWR issued the "Suggestion of Implementing the Strictest Water Management System" in 2012, setting three national "Red Lines" for total water use, water use efficiency, and ambient water quality. According to the State Council, subnational governments must incorporate centralized water targets into their five-year development plans with responsibility of successful target implementation tied directly to the annual work evaluations of head bureaucrats (Nickum et al., 2017; Wang et al., 2017). During the same period, the Chinese central government also began experimenting with market-based solutions to water shortage by implementing water users' associations and water rights trading schemes at the grassroots level (Wang et al., 2007; Moore, 2015). In line with the 2002 Water Law, the 2015 Environmental Protection Law also adheres to the IWRM approach by mandating better public access to environmental policymaking and implementation. The 2015 Law attempts to improve water governance by imposing systemic regulatory measures and administrative punishment on polluters. These legislative and policy transformations reveal an unambiguous shift toward more comprehensive and robust environmental policymaking, making water management in China more centralized and integrated (Moore, 2014b; Shen, 2014).

However, alongside these legislative and regulatory accomplishments, there remain significant governance issues with fragmentation in the domains of implementation and enforcement, policy philosophy, and development. There are more than 11 major laws concerning watershed management as each central government ministry has attempted to exercise its policy agenda (Nickum, 2010; Yao and Zhou, 2016). As a result, the distinction of legal authorities over regulation enforcement are murky and tend to generate contradicting expectations of policy outcomes and implementation procedures. For example, Article 32 of the 2002 Water Law stipulates that the provincial water resources departments or the river basin management agencies have the authority to set the types and amounts of pollutant discharges in watersheds under their jurisdiction. Yet, the 2015 Environmental Law delegates the same responsibility to the provincial departments of ecology and environment, causing inconsistent measurements and enforcement for water pollution. Though the 2002 Water Law has granted legal status to river basin management agencies, the prescribed powers are principled and not operational, leading to contradictory interpretations of legal authority between watershed management agencies and subnational governments in the management of trans-provincial rivers (Yang et al., 2016). Moreover, in the current legal system, the pollution and over-extraction of groundwater are not treated as suitable for criminal charges, and there are no national policy guidelines for the enforcement of water conservation policies. Instead, local governments are tasked to issue policy instruments, contributing to the lack of coordination and the under implementation of water regulations (Shen, 2015; Yao and Zhou, 2016).

In the domain of policy philosophy and development, the Chinese government's attempt to improve water governance remains mostly dependent on state investment in engineering projects, which relies on the building of large-scale infrastructure to control water resources, representing a supply-side approach to water shortage that has little effect on improving water quality and user efficiency (Liu and Yang, 2012). This technocratic interpretation of national development and the discourse of water scarcity legitimizes supply-side solutions that assert the construction of infrastructure as the most important policy approach (Crow-Miller, 2015; Crow-Miller et al., 2017; Moore, 2019). The pre-eminence of infrastructure in water governance, in turn, shapes the organizational networks and institutional practices of the hydro-bureaucracy, resulting in an elite-driven policy process deficient in the social equity aspects of water management (Pohlner, 2016; Webber and Han, 2017). At the same time, market-oriented approaches in rural water governance have encountered profound institutional barriers as the complete control of water resources by the administrative system interferes with the legal provisions on the water rights system. The lack of efficiency and transparency increases the transaction cost of water rights trading and reduces incentives to participate in water governance for stakeholders in non-state sectors' (Magee, 2013; Moore, 2015). In addition, while the 2002 Water Law, the 2015 Environmental Protection Law, and numerous ministry-level regulations all call for public involvement and oversight in water governance, no national guidelines have been issued to specify who constitutes "the public" or appropriate ways of engagement, making public participation unfeasible in practice (Spijkers et al., 2018). This historical process of bureaucratic centralization and the development of regulatory frameworks over water governance in China have generated the institutional context in which the IWRM projects in our case study operate and serve to position the case study within the particularities inherent in a hierarchically structured bureaucratic state.

5 Governance structure, regulatory approaches, expected outcomes of IWRM programs in the Tarim, Shule, Hei, and Shiyang watersheds

Since 2001, the Chinese central government has made substantial fiscal investments in its implementation of integrated water resources management plans for four inland watersheds in North-western China, the Tarim, Shule, Hei and Shiyang rivers. These four river basins suffer from severe water shortage, pollution, and ecological deterioration in the downstream region, as they are located in arid climate zones with annual precipitation below 120 mm. Before the implementation of the IWRM programs, desertification and the over-extraction of groundwater in these watersheds posed dire threats to the ecosystem, economic development, and community health. The Chinese central government responded to these severe ecological challenges by establishing river basin organizations (RBOs) for these watersheds similar to the Yellow River Conservancy Commission (Shen, 2014). The Hei River Watershed Management Bureau was founded by the MWR and incorporated into the Yellow

River Conservancy Commission in 1999 (Ministry of Water Resources, 2002). The Tarim, Shiyang, and Shule River water management commissions were established by the Xinjiang Autonomous Region and Gansu provincial governments in 1997, 2002, and 2004 respectively. Table 2 details the MWR approved IWRM programs examined in our case study.

The establishment of RBOs has promoted coordination between upstream and downstream governments in the watersheds as well as the implementation of localized regulations on water allocation and distribution plans. To ensure the timely realization of policy goals, all four IWRM programs have adopted the local administrative chief responsibility system (*di fang shou zhang fu ze zhi*) and, after 2016, the river chief system, which utilizes "the hierarchy within the party-state structure to overcome the territorial mismatch for transboundary governance" (Chien and Hong, 2018). While program implementation was delegated to subnational and local governments, the MWR played an essential role in the "top-level design" (*ding ceng she ji*) of the IWRM programs, ensuring an integrated management approach that includes forestry and grassland conservation in the headwater regions, reduction of agricultural land size in midstream areas, and restoration of endorheic lakes and wetlands (Fig. 2). Three major themes, hydraulic projects, top-down implementation, and market-oriented mechanisms emerged from our critical analysis of the designs of the IWRM programs and the supplementary regulation guidelines drafted by the RBOs in these watersheds.

Table 2 The IWRM programs of Tarim, Shule, Hei and Shiyang watersheds in Western China

Watershed	**Hei River**	**Tarim River**	**Shiyang River**	**Shule river**
Province	Gansu	Xinjiang	Gansu	Gansu
River basin organizations	Hei River Basin Management Bureau, Yellow River Conservancy Commission (for surface water), MWR 1999	Tarim River Basin Management Bureau, Xinjiang Uyghur Autonomous Region Water Resources Bureau 1997 (reformed in 2011)	Shiyang River Basin Management Bureau, Gansu Provincial Water Resources Bureau 2002	Shule River Basin Management Bureau, Gansu Provincial Water Resources Bureau 2004
Plan examined	Short-term Governance Plan of Hei River Watershed (The next phase of the Hei River IWRM program is still being reviewed by MWR as of October 2018)	Short-term Governance Plan of Tarim River Watershed (The next phase of the Tarim River IWRM program is still being reviewed by MWR as of October 2018)	Key Governance Plan of Shiyang River Watershed	Integrated Plan on Rational Water Resource Use and Ecological Conservation of Dunhuang (The IWRM of Dunhuang also includes the Dong River Watershed)
Plan duration	2002–2011	2001–2017	2007–2020	2011–2020
investment (billion yuan)-	2.35	10.739	4.749	4.722
Water-saving irrigation and diversion projects	Y	Y	Y	Y
Wells and cultivated land reduction	Y (Implemented by Zhangye Prefecture Water Resources Bureau)	Y	Y	Y (Implemented by Guazhou County Water Affairs Bureau)
Crop adjustments	Y	Y	Y	
Pollution control	Y	Y		Y
Ecological restoration	Y	Y	Y	Y
Ecological migration	Y		Y	
Administrative chief Responsibility system	Y	Y	Y	Y
Local watershed regulations	Y	Y	Y	Y
Water rights allocation	Y		Y	Y
Water resources fees	Y	Y	Y	Y
Water users' association	Y	Y	Y	Y

Source: Integrated Plan on Rational Water Resource Use and Ecological Conservation of Dunhuang, 2011; Key Governance Plan of Shiyang River Watershed, 2007; Short-term Governance Plan of Hei River Watershed 2002, Short-term Governance Plan of Tarim River Watershed 2001.

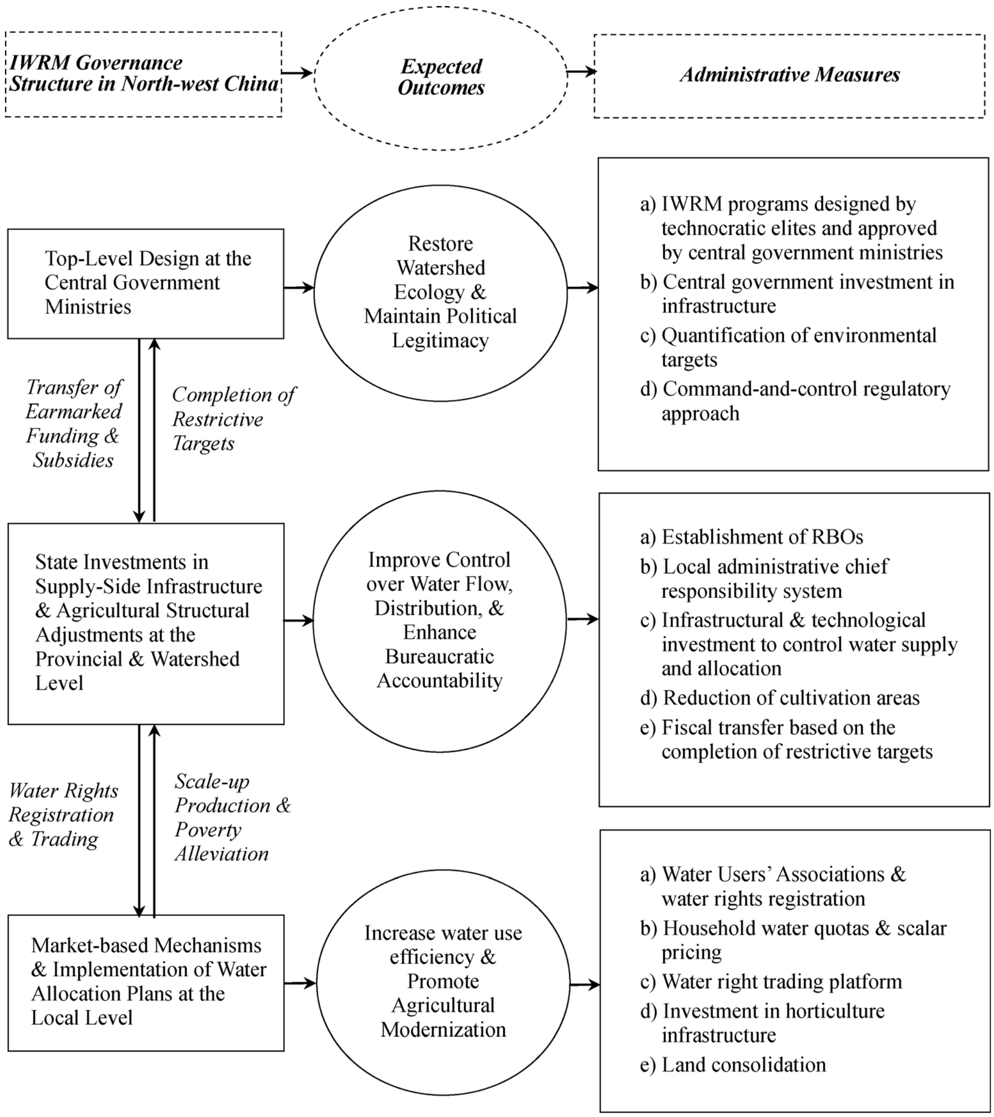

Fig. 2 Governance structure, expected outcomes & administrative measures of IWRM programs in north-western China.

5.1 The construction of hydraulic projects in the Tarim, Shule, Hei, and Shiyang watersheds

Although the 2002 Water Law and the 2012 No. 1 Central Document champion a demand-side solution to water shortage, the Chinese central government has relied on building supply-augmentation infrastructures to maintain the water supply in northern China (Crow-Miller et al., 2017). The 13th Five-Year Plan included the construction of 172 water diversion and conservancy projects that are expected to save 26 trillion cubic meters of water used in agricultural production, increase total water supply by 80 trillion cubic meters, and expand total irrigated area by 78 million *mu* (Xinhua News, 2014). As such, the IWRM programs we examined all included significant investments from the central government in dam expansion to increase water supply and water-saving conveyance systems to improve water use efficiency in irrigation. Table 3 details major water control projects implemented in the Tarim, Shule, Hei and Shiyang watersheds between 2002 and 2018.

The building of dams and diversion structures are essential to the management of the water systems we studied due to severe water shortage and the disappearance of terminal lakes in these watersheds. Since the 1960s, the length of the Tarim River has shortened by 363 km and its terminal lakes, the Lop Nor and Taitema lakes, disappeared completely in the 1970s. East Juyan Lake, the endorheic lakes of the Hei River, started to shrink in the 1980s and dried up entirely between 1995 and 2000. The natural river courses and terminal lakes of the Shiyang River and Shule River also disappeared from the 1970s to 2010. The extinct lakes and dry riverbeds became conduits of the surrounding sand dunes and caused severe desertification to the

Table 3 Flow-control infrastructure and water saving irrigation implemented by the IWRM programs in north-western China

Watersheds	Hei River	Tarim River	Shiyang River	Shule River
Dam construction & expansion	Huangzangsi Water Control Project	Expanding eight small reservoirs in the Watersheds	Expanding and heightening Hongyashan Dam from 99 million to 148 million m^3	Building Changma Reservoir
Water saving irrigation	Implemented on 0.46 million *mu* cultivated lands, but the amount of water use increased by 20 million m^3 for 0.35 million *mu* new cultivated land	Implemented on 0.44 million *mu* cultivated land with water saving irrigation, including 8160 km seepage prevention channels	436.23 km of anti-seepage canals, 18,833 hectares of drip irrigated fields, and 1873 hectares of greenhouses	Implemented on 1.00 million *mu* cultivated lands, including 405 km seepage prevention channel
Diversion structures	Langxin Mountain Water Diversion Hub, Anci River Water Diversion Hub	Patamu Diversion Hub	Jintaichuan Diversion Project Phase II Extension	Haleteng River Diversion Project

Source: Integrated Plan on Rational Water Resource Use and Ecological Conservation of Dunhuang, 2011; Key Governance Plan of Shiyang River Watershed, 2007; Short-term Governance Plan of Hei River Watershed 2002, Short-term Governance Plan of Tarim River Watershed 2001.

downstream oases. As a result, the IWRM programs conducted large-scale channelization of the river course to reduce water seepage and built flow-control structures to re-establish seasonal inflow of “ecological water” to restore the extinct lakes. In addition, the vast majority of distributary and tertiary canals in each watershed were lined with concrete or compacted clay to increase water use efficiency in irrigation, and hundreds of ancillary structures were added to enhance flow monitoring. The reemergence of the East Juyan, Taitema, and Qintu Lakes in the last decade and the reintegration of the Dong and Shule rivers at Hala Nor Lake in 2017 attest to the effectiveness of the river restoration projects.

The documents associated with the IWRM programs we studied all stated that to rescale the spatial and temporal allocation of water resources, it is essential to construct large-scale flow-control projects in the headwater region as well as water-saving structures in mid and downstream areas. This infrastructure-heavy approach is a manifestation of the existing power relations of water governing institutions embedded within the Chinese environmental policy framework. To ensure the prompt realization of policy goals, the RBOs and the county governments were given tight timelines and quantifiable benchmarks in program implementation. For instance, in 2001, the State Council commanded the Hei River Watershed Management Bureau as well as the Gansu and Inner Mongolia subnational governments to complete all water usage and distribution goals of the IWRM program within three years (State Council of China, 2001). Similarly, every prefectural and county government in the Tarim, Shule, and Shiyang watersheds had to complete the water distribution goals within the first couple of years of the IWRM programs’ implementation. Compared to the ‘wicked problems’ of engaging with multiple stakeholders to reduce demands, the expansion of hydraulic infrastructures provides an efficient way to achieve project outcomes and reliable empirical data to evaluate local bureaucrats’ performance. Moreover, the construction of hydraulic projects could bring major central government funding to the cash strapped coffers of local governments. For example, the initial implementation of the Short-term Governance Plan of Hei River Watershed included 84 infrastructure projects, which led to a 54% increase in national fixed asset investment and a 28% increase in the total fiscal revenue in Zhangye Prefecture in 2002. Throughout the duration of the IWRM program, the central government consistently increased its support for other infrastructure and economic programs to compensate for economic losses caused by water diversion (Zhong et al., 2014).

As such, the expansion of the hydraulic infrastructure not only reconfigured the flow of water and transformed the ecosystems in these watersheds but also indicated a profound rearrangement of the socio-political landscape of water governance. Engineering projects turn water resources into calculable units that can be used to reduce uncertainty in the management of water systems. The ability to collect, use, and distribute data enables the RBOs to formulate annual allocation plans and allows for the delegation of water-saving responsibilities to lower-level governments. The state’s expanding control of water resources also serves as an essential precondition for water rights registration and trading (Shen, 2014). As they become increasingly dependent on fiscal transfer payments to construct the hydraulic infrastructure and the implementation of the IWRM programs, the subnational and local governments must abide by the restrictive targets and timelines set by the central state, which constitute a key aspect of center-local relations. Consequently, hydrosocial relations at the watershed and county levels became subsumed by the rationality of the technocratic elites of central government ministries, and top-down implementation became the dominant governance approach in IWRM programs. Therefore, while the IWRM approach is intended to coordinate between multiple types of resources to maximize social and economic welfare, in China, it articulates through a hierarchical bureaucracy and multi-scalar structure combined with economic imperatives that can create contradictory outcomes.

5.2 Top-down implementation approach in the Tarim, Shule, Hei, and Shiyang watersheds

The IWRM programs examined in our case study can be viewed as examples of authoritarian environmentalism utilizing the authoritarian state's relative autonomy from non-state actors to provide rapid responses to profound environmental challenges and disasters (Beeson, 2010). In this model, the technocratic elites of central ministries and national research institutions determine the design and expected outcomes of the IWRM programs, while the RBOs draft the annual water allocation plans and promulgate administrative orders at the provincial and prefectural level to deliver the policy goals of the central government (Moore, 2014a). The central government exerts its influence on the downstream implementation stage through its application of the local administrative chief responsibility system that incorporates restrictive environmental targets into the evaluation of individual cadres and controls the transfer of earmarked funding to local governments. The top-down policy implementation approach eventually became the "river leader" (*he zhang*) system in 2016, which delineated cadre responsibilities for inter-jurisdictional pollution and conservation issues to reduce uncertainty and risk in the management of water systems (Chien and Hong, 2018; Moore, 2019).

The Chinese central government framed the ecological deterioration in the Tarim, Shule, Hei and Shiyang watersheds as critical national security issues that required urgent responses and viewed the successful implementation of the IWRM programs as crucial to the legitimacy of its environmental governance. For example, the 2011 Integrated Plan on Rational Water Resource Use and Ecological Conservation of Dunhuang states that "the management and the protection of (the Shule and Dang Rivers) not only promote regional socioeconomic development, maintain the social stability of the oasis…but also profoundly influence the stability and development of China's western region…The rational utilization of water resources and ecological protection is necessary and require immediate actions" (Development and Reform Committee of Gansu Province, Water Resources Bureau, and Government of Jiuquan City, 2011). As such, the IWRM programs treat the reduction of water usage in agriculture as the foremost implementation priority and stipulate stringent deadlines for total cultivation area reductions. For instance, local governments in the Shiyang River and Hei River watersheds had to reduce farmland by 90,346 and 21,333 ha, respectively, within the first two years of IWRM programs, and the Tarim RBO planned to convert 22,000 ha of farmland into natural enclosures within four years. Moreover, to reduce water usage, the IWRM programs all stipulated plans for agricultural structural adjustments. Subsequently, local governments in the watersheds promulgated administrative orders to ban high water-consuming crops and irrigation practices. According to the IWRM programs, the water conserved from agriculture use would become ecological water (*sheng tai shui*) used to restore the terminal lakes and wetlands in downstream areas (Table 4).

Nevertheless, the central government's ecological conservation objective has run counter to the interests of local bureaucrats who must fulfill economic development and poverty alleviation quotas set by the subnational governments. This conflict of interest between central and local governments directly resulted in a lack of integration between surface water and groundwater management at the prefectural and county levels, significantly weakening the authority and functions of RBOs (Aarnoudse et al., 2017). For example, before its reorganization in 2011, the Tarim River Basin Management Bureau was unable to prevent the over drafting of surface water used to power hydroelectric stations in upstream areas, and, as a result, the Taitema Lake dried up again between 2006 to 2009 (Shi, 2014; Huang, 2007). Worse, in the Tarim, Hei, and Shule watersheds, the implementation of surface water allocation plans caused local governments to encourage groundwater extraction tacitly and led to rapid depletion of groundwater resources. For example, the Short-term Governance Plan of Tarim River Watershed stated that the IWRM program would bring a total investment of 418 million yuan to construct 3272 electric wells and increase groundwater extraction by 458 million m^3 (Water Resources Bureau, Development and Reform Committee of Xinjiang Autonomous Region, 2001). As a result, the total cultivation area in the Tarim watershed increased by 859.7 km^2 from 2001 to 2017 (Chen et al., 2017). From 2000 to 2012, more than 3000 electric wells were drilled in the Hei River watershed and the groundwater extraction rate increased by an average of 100 million m^3 every year, adding more than 200 million m^3 of total irrigation water usage (Xiao et al., 2017). In the Shule watershed, the construction of upstream water-control structures reduced surface water supply to downstream settlements, and groundwater use increased dramatically from 2006 to 2014, reaching 180 million m^3 per year (Aarnoudse et al., 2019). The short-term economic focus of the fragmented bureaucracy created an institutional barrier that constrained the effectiveness of the top-down, administrative approach in water system management. While extensive restructuring of water management in China was intended to increase water use efficiency, increase control over water flow and distribution, and increase bureaucratic accountability in regulatory outcomes, the process has had mixed results, even leading to opposite outcomes in some cases.

Table 4 Ecological restoration and economic structural adjustments of the IWRM programs in north-western China

Watersheds	Ecological restoration		Structural adjustments in local economy	
	Measures	**Expected policy outcomes**	**Measures**	**Results by 2018**
Hei River	•Transfer of ecological water through the Huangzangsi Water Control Project	•Upstream: 40% increase in grassland coverage area; 20%–35% increase in forest coverage •Midstream: reducing water shortage in dry seasons •Downstream: Increase the size of East Juyan Lake to 35 km^2 by 2010	•Reduce water use in agriculture •Introduction of water-saving crop cultivation	•Water use in agriculture decreased by 1%–2% •Ratio of water use between Irrigation and other use in agriculture decreased by 1%–2%
Tarim River	•Release 6 billion m^3 of ecological water to the terminal lakes in 18 consecutive years •Channelization of the river course	•4 meter increase of Underground water table •Protection of shelter belts along the river course •Restoring terminal lakes and expansion of wetlands in downstream areas.	•Introduction of water-saving crop cultivation Decreasing area of cultivated land by 330,000 *mu* •Water fee price system	•Area of cultivated land increased significantly from 2001 to 2014
Shiyang River	•Protecting and restoring forest and grassland areas •Release of 3800 m^3 of ecological water •Reduce its agricultural water usage to 170 million m^3 a year by 2020 •Annual Inflow to Minqin's Caiqi observation point increase to 290 million m^3 by 2020	•70 km^2 wetland area where the groundwater level would be less than 3 m deep by 2020 •Annual groundwater extraction in Minqin reduced to 86 million m^3 by 2020 • Restoration of forest and grassland coverage in headwater region	•Expansion of greenhouse horticulture •Reducing per capita cultivation areas to 2.5 *mu* •Installing scalar pricing system for groundwater and surface water •Promotion of husbandry •Expansion of large-scale farms	•Cultivation area in the watershed reduced by 6023 hectares •Expansion of large-scale farms and husbandry operations
Shule River	•Release ecological water to the terminal wetlands and Crescent Spring •Expansion of anti-seepage canals •Channelization of the Shule and Dong River courses	•Reemergence of wetlands near Hala Nor in Xihu National Reserve •Protecting Crescent Spring by establishing Xihu National Reserve of Dunhuang in Gansu Province	•Building Water rights management institutions •Promotion of greenhouse horticulture •Establishing scalar pricing for surface water and groundwater resources	•Water use efficiency increased •Irrigation engineering projects covered 93% of the cropland •Expansion of cash crops cultivation

Source: Integrated Plan on Rational Water Resource Use and Ecological Conservation of Dunhuang, 2011; Key Governance Plan of Shiyang River Watershed, 2007; Short-term Governance Plan of Hei River Watershed 2002, Short-term Governance Plan of Tarim River Watershed 2001.

5.3 Market-oriented mechanisms in the Tarim, Shule, Hei, and Shiyang watersheds

Since 2001, the MWR has promoted water rights registration and compensated water rights transfer to improve water use efficiency and resolve water scarcity (Moore, 2015). All the IWRM programs we studied included measures to expand use rights registration to farming households, increase surface water tariffs, and impose a scalar pricing mechanism for groundwater. The valuation and trading of water use rights are central to reducing demand in IWRM programs because price signals are intended to guide rational choices in consumption and incentivize water-saving societies by increasing bottom-up behavioral changes. The implementation of market-oriented measures requires the transformation of water resources from abstract entities into quantifiable units that fit into annual water distribution plans, which is dependent on the construction of flow control infrastructure and the establishment of coordination and oversight institutions such as RBOs. In 2014, the Chinese central government designated Gansu as one of the seven pilot reform sites for agricultural water pricing. The integration of market mechanisms into water governance was designed to ensure the "rational allocation and efficient utilization of water resources, the adequate development of irrigation engineering projects, the modernization of agriculture, and the implementation of poverty alleviation in the construction of well-off society in China" (Song, 2016). To accomplish this goal, the provincial government commanded the RBOs and local governments to obtain funding from various sources to establish comprehensive water supply metering, develop an in-time water pricing system, initiate a water rights trading (WRT) platform, expand water-saving fields, and design water-saving incentives in agricultural production (Gansu WRB, 2017). Every farming household in the watersheds was granted water usage permits (*qu shui xuke zheng*) that guarantee a defined quota of water in a specified period. Water Users' Associations (WUAs) were established at the grassroots level and given water use rights certificates (*shui zi yuan shiyong quan zheng*) to promote collective decision-making on water usage. As such, the market-oriented measures listed in the IWRM programs should be considered as a critical part of the macro-level restructuring of agricultural production and the reconfiguration of rural landscapes in these watersheds.

Though WRT and agricultural water price reform have been prominently promoted by the Chinese central government, the actual implementation of these measures has encountered significant institutional barriers (Shen, 2014; Moore, 2015; Aarnoudse et al., 2018). Foremost, the application of WRT has conflicted with the command-and-control regulatory approach used in the IWRM programs to resolve water shortage. Rather than utilizing market-oriented mechanisms to allocate water resources between upstream and downstream users, the RBOs in Gansu and Xinjiang set stringent inflow targets for each prefectural and county government in their water distribution plans. The viability of terminal lake and wetland restoration in these watersheds has been dependent on the water flow quotas designed and enforced by the central government through the local administrative chief responsibility system, not by WRT. Additionally, since there have been no national guidelines for institutional arrangements in multi-level water governance, the RBOs of the inland watersheds in north-western China have divergent sectoral authorities and utilize distinctive approaches to define and regulate surface water and groundwater rights. For example, the Shiyang River Basin Management Bureau has control over both surface irrigation and groundwater extraction and imposes a strict per capita water quota system. At the same time, the Hei and Shule River Basin Management Bureau have delegated groundwater regulation to prefectural and county-level water management authorities, and their different enforcement approaches to groundwater extraction have resulted in severe depletion in both watersheds and the erosion of trust for the WRT regime (Moore, 2015; Aarnoudse et al., 2019). In addition, subnational and local governments must balance the conflicting tasks of water resources conservation and poverty alleviation, and local authorities have limited space to increase the price of water used in irrigation. As such, the scalar pricing scheme has limited effects in reducing agricultural water usage (Aarnoudse et al., 2017).

In sum, to reduce the uncertainty in the management of the inland water systems, the IWRM programs have invested heavily in flow-control infrastructures to increase supply, utilized restrictive targets to ensure project completion, and encouraged water use rights registration and trading to promote agricultural structural adjustments to reduce demand. However, the elite-driven process does not consider how the IWRM programs may generate profound transitions in hydrosocial relations in local communities and how differing interests between bureaucrats and farmers may affect the interpretation and outcomes of the IWRM programs. These concerns are integral to a comprehensive understanding of water system management. Below, we use the case study on the implementation of the Shiyang River Integrated Management Plan in Minqin County to illustrate how socio-political factors may create uncertainties that will affect the sustainability of IWRM programs in north-western China.

6 Institutional and socio-economic constraints of the IWRM program in Minqin County, Gansu

Minqin County, located in the downstream region of the Shiyang River Watershed, experienced severe desertification in the 1980s and 1990s as the mismatching administrative and water management scales caused prolonged water conflicts between upstream and downstream oases. During this period, the watershed was designated as a provincial base for commodity grain, and local governments began encouraging groundwater extraction to increase agricultural production and tax revenue (Mao and Hanley, 2018). As a result, the peasants in Minqin reclaimed at least 30 thousand hectares of grassland to plant cash crops, and the number of mechanized wells in Minqin increased from 16 in 1965 to 9519 in 2005. The acute ecological and socio-economic crisis became the impetus for the formulation and implementation of the Key Governance Plan of the Shiyang River Watershed. In December 2007, the State Council of China approved the Shiyang River IWRM plan and provided 4.74 billion yuan to the Gansu provincial government for program implementation (MWR and NDRC, 2007).

The implementation of the IWRM program and the formation of the RBO improved coordination and consolidated state resources for a rapid response to restore the watershed's ecology. The IWRM program increased surface water tariffs and imposed a scalar pricing mechanism for groundwater in the region to reduce agricultural water usage in Minqin. Restrictive environmental targets were set to limit the Shiyang River's inflow to the oasis and groundwater extraction in Minqin. To achieve the targets, Minqin had to reduce its agricultural water usage from about 400 million m^3 a year in 2000 to 170 million m^3 a year by 2020 and reduce its cultivation area by 26,667 ha. Subsequently, Minqin shut down more than 3,800 deep-bore wells and installed electronic meters on the remaining pumps. The IWRM program estimated that these combined measures would create a 70 km^2 wetland area where the groundwater level would be less than 3 m deep by 2020 (MWR and NDRC, 2007). In 2014, the Gansu Water Resources Bureau announced that Minqin had achieved the restrictive targets of the IWRM program in 2012, eight years ahead of the targeted completion date, and created a 106 km^2 wetland in the Qingtu Lake area (Fan, 2018).

Central to the Shiyang River IWRM program was the expansion of flow-control infrastructure to store and channel the "ecological water" used for restoring the extinct Qingtu Lake. The IWRM program expanded the Hongyashan Dam and Phase II of the Jintaichuan Electric Lift Irrigation Extension that connected the Yellow River to Minqin Oasis across the Tenggar Desert. From 2001 to 2006, the Extension did not function as planned as the Gansu provincial government faced strong resistance from downstream provinces in the Yellow River watershed as the average annual inflow to Minqin was only around 61 million m^3, far below the volume necessary for irrigation and wetland restoration. The IWRM program removed the institutional barriers to water transfer and increased the amount of Yellow River water diverted to Minqin in 2010. In 2017, the Extension delivered more than 120 million m^3 of Yellow River water to the expanded Hongyashan Dam, which enabled the Shiyang RBO to release 3830 m^3 of "ecological water" to restore the terminal lake (Fan, 2018). During this period, Minqin also expanded its water-saving conveyance and irrigation system, retrofitting 4542 deep-bore wells with electronic meters and constructing 436.23 km of anti-seepage canals, 18,833 ha of drip irrigated fields, and 1873 ha of greenhouses (Minqin County Government, 2015b). As a result, the effective utilization coefficient of irrigation water in Minqin increased from 0.589 in 2009 to 0.614 in 2014, saving an estimated 178 million m^3 of water every year (Fan, 2018).

The water-saving infrastructure and technology fundamentally transformed the productive conditions and relations of agriculture, and, consequently, generated significant resistance from the community. Our analysis of the interviews with farmers in the oasis revealed some of the key issues. The first issue was that the infrastructure could not provide efficient and timely allocation of surface irrigation water. The farmers stated that they still had to rely on groundwater for agricultural production because Minqin only received the diverted water during the non-growing season, and the cost of lifting water across 120 km of barren desert land raised the price of surface water threefold (Interview, March 2011, and April 2013). Many also questioned the logic behind transporting large quantities of water through open canals and maintaining surface lakes in an arid climate zone with a 2644 mm annual evaporation rate (Hook, 2013; Interview, October 2011, April 2013, and May 2016).

The second issue was the implementation of drip irrigation and greenhouse horticulture, which also caused strong community backlash. As described by a farmer in the Dam District of Minqin, "Drip irrigation is not practical because of high installation and operation costs. The sprayers often get clogged with compounded fertilizer, and the compressors cannot pump enough water to the fields located at the end of the pipe, resulting in major strife in our village" (Interview, November 2011). This issue is linked with the ecological characteristics of the region. Since the groundwater in Minqin has high mineral concentration, the farmers' perceived that the application of drip irrigation might worsen soil alkalization in cultivated areas (Interview, May 2013). Land fragmentation prevented mechanization and lowered the utilization and efficiency of drip irrigation, which eventually led some farmers to haphazardly damage irrigation infrastructure (Minqin County Government, 2015b). Finally, to promote agricultural structural adjustments, the Minqin County government ordered every farming household to build a horticulture greenhouse, which became a heavy expenditure for farmers even with state subsidies (Minqin Bureau of Agriculture and Husbandry, 2008). Minqin's remote location and the lack of a procurement network made horticulture highly unprofitable, causing rampant abandonment of the greenhouses (Minqin County Government, 2016b; Shi, 2010). These concerns demonstrate the unintended social impacts of the IWRM program, which not only changed the allocation of water but also transformed agriculture and rural communities in the watershed.

Nevertheless, the drive to make Minqin a national model forced the provincial and county government to rely on top-down political mobilization to implement the conservation program through stringent timeframes for task completion on the local bureaucracy. Instead of the collaborative governance structure specified in the IWRM program, the actual policy implementation processes reverted to the command-and-control system emphasizing the fulfillment of quotas regardless of the practicality of the assigned tasks. Facing the conflicting demands of economic development and resource conservation in a community severely weakened by out-migration and capital depletion, the grassroots cadres in

Minqin had no choice but to utilize existing patterns of dominance to exclude public deliberation and ignore longstanding informal institutions in the local community (Mao and Zhang, 2018). Since the IWRM program designated 55.2% of the total infrastructure investment to the construction of greenhouse, the expansion of horticulture became the most important political task in local governance. Every cadre was responsible for the timely construction of greenhouses at the administrative level below their positions in the bureaucracy (Gansu WRB, 2008). The allocation of water resources became the disciplinary tool used by grassroots cadres to ensure the completion of quotas.

This heavy-handed approach was later applied to almost every objective in the IWRM program of the Shiyang River watershed and is exemplified in the 2018 Water Allocation Plan of Minqin, which delineates the disciplinary measures placed on farmers. One passage of the Plan states, "Every township needs to link the operation of drip irrigation to the designation of water rights. Special oversight will be paid to villages that do not actively implement water-saving infrastructure and technology, proactively monitoring crop choices and cultivation areas, or failing to follow the orders of the WUAs. We will assign cadres to impose control on every village and revoke the violators' rights to water" (Minqin County Government, 2018). Additionally, water use rights were used as disciplinary tools for policy targets not specified in the IWRM program. To enforce the ban on non-water-saving crops, the 2015 Water Allocation Plan of Minqin stated that "we will revoke the water rights of those who plant onions and seeding corns, prohibiting their water and electricity usage. For those who use the greenhouses as nursery for onion crops, we will block their access to water and electricity, and the violators will be responsible for the loss incurred. Cadres need to monitor and report the cultivation pattern daily and will be punished if there are any onion planted in their assigned villages" (Minqin County Government, 2015b). The imposition and subsequent disciplinary nature of the water use rights, therefore, became one of the most powerful factors shaping state-society relations in the rural governance of Minqin.

The need to rapidly achieve restrictive targets set by higher level governments led to discrepancies between reported and actual policy results. By 2016, at least 1583 greenhouses had been abandoned by local farmers, and the county government stated that other than the ones built by funding from the IWRM programs, the rest of the greenhouse operations could be torn down and returned to field production or be transferred to large-scale operators (Minqin County Government, 2016b). At the same time, costs related to the administrative control of water and ecological restoration projects exceeded beyond the initial funding from the central government and the Minqin county government started to experience difficulties in balancing its budget. A December 2018 report by the Minqin Bureau of Finance demonstrates this tension between project goals and implementation cost: "…the costs related to infrastructure building, social welfare, and administrative staffing continued to increase, and combined with the stress generated by interest and principle payments, the government faces severe challenges to balance its budget and ameliorate the deficit. It is getting more and more difficult to prevent and resolve a fiscal crisis in Minqin" (Minqin Bureau of Finance, 2018). To reduce costs, the local government began encouraging private investment in the expansion of water-saving infrastructure and high-efficiency fields (Minqin County Government, 2015b). The High-efficiency Field Construction Plan of Minqin stated that "State investment in water-saving irrigation should prioritize the construction of facilities for high-efficiency agriculture, focusing on large-scale land leasers, large farm operators, and villages in close proximity." Moreover, operators who were financially capable of utilizing greenhouse horticulture and drip irrigation in field cultivation would enjoy 30% and 50% discounts for the prices of surface water and groundwater respectively, and those who continued to cultivate traditional crops in standard fields would be punished by a 30% and 50% increase in surface and groundwater pricing respectively (Minqin County Government, 2015a and 2016a). Therefore, the IWRM program's plan to control water flow, delineate water rights, and implement market-oriented measures inadvertently became tools to promote scale-up and capital-intensive models of agricultural production, squeezing out subsistence farmers who could no longer sustain their operations. The case study demonstrates that the infrastructure-heavy, top-down, and market-oriented components of the IWRM program in Minqin was lacking in a full consideration of the diverse and conflicting interests between environmental conservation, social equity, and economic benefits of water system management which is exemplified in the socio-political dynamics of the local region.

7 What can a socio-political approach contribute to the study of inland water systems in China?

Our examination of the Tarim, Shule, Hei, and Shiyang IWRM programs demonstrates the complex and interconnected components of socio-political factors that shape the design and management of inland water systems in north-western China. The water crisis in China provides a unique focus on these issues as it contends with both economic growth guided by a strong centralized state as well as ensuing environmental degradation. In addition, the use of a centralized state to mitigate environmental resource degradation provides important insights into the shortcomings and limitations of dominant approaches in water system management and shines light on the regulatory debate that undergirds many approaches to environmental conservation strategies. To rapidly address the severe water shortage and ecological degradation, the IWRM programs utilized the construction of infrastructure to transform unregulated usage to quantifiable units, relied on restrictive targets to effectuate policy implementation, and promoted WRT to generate structural adjustments in local agriculture. The changes in the management of these watersheds represent more than basin-wide attempts to regulate water resources. They should be perceived as the culmination of state-led initiatives in rural development. The control over water resource allocation has directly reconfigured patterns of land use, agricultural production, social stratification, and, most importantly, state-society relations. The assessment of uncertainty and sustainability for water systems, therefore, must include an understanding of how institutional relationships embedded within the broader context of environmental and rural governance interact with the "hybridized socio-natural processes" of water resource management.

The findings of this study indicate that the IWRM programs' emphasis on infrastructure building and the top-down implementation approach may negate the objective to promote demand reduction through water use rights registration and trading. The elite-driven policy formulation process has failed to adequately address the different conservation and economic objectives of the local bureaucracy, and the fragmented implementation of IWRM programs also complicates the enforcement and oversight of water regulations at the grassroots level. The stringent timeline to achieve restrictive targets generate uncertainty in program sustainability as the administrative chief responsibility system propelled local state agents to utilize their control over water access to enforce compliance, thereby exacerbating social stratification and reducing the legitimacy of the IWRM programs (Fig. 3).

The arbitrary implementation of IWRM programs has resulted from the unique dilemma faced by the central state. The central government must provide immediate policy responses to the ecological deterioration and resource extraction caused by the rapid growth of the Chinese economy. China's profound regional variations make resource governance immensely complicated, and no one-size-fits-all approach exists. As a result, the IWRM programs designed by the MWR primarily rely on measurements of changes in natural conditions, such as water flow and groundwater table, and the amount of structures built to ensure policy efficacy. Since hinterland regions in China have become increasingly dependent on fiscal transfer funds from the central government, the completion of infrastructure projects and the meeting of restrictive targets are essential to local governments' budgets, thereby encouraging the prioritization of quota fulfillment over the development of a participatory approach that may fit into local customs. This approach to resource management is inherently unstable because the

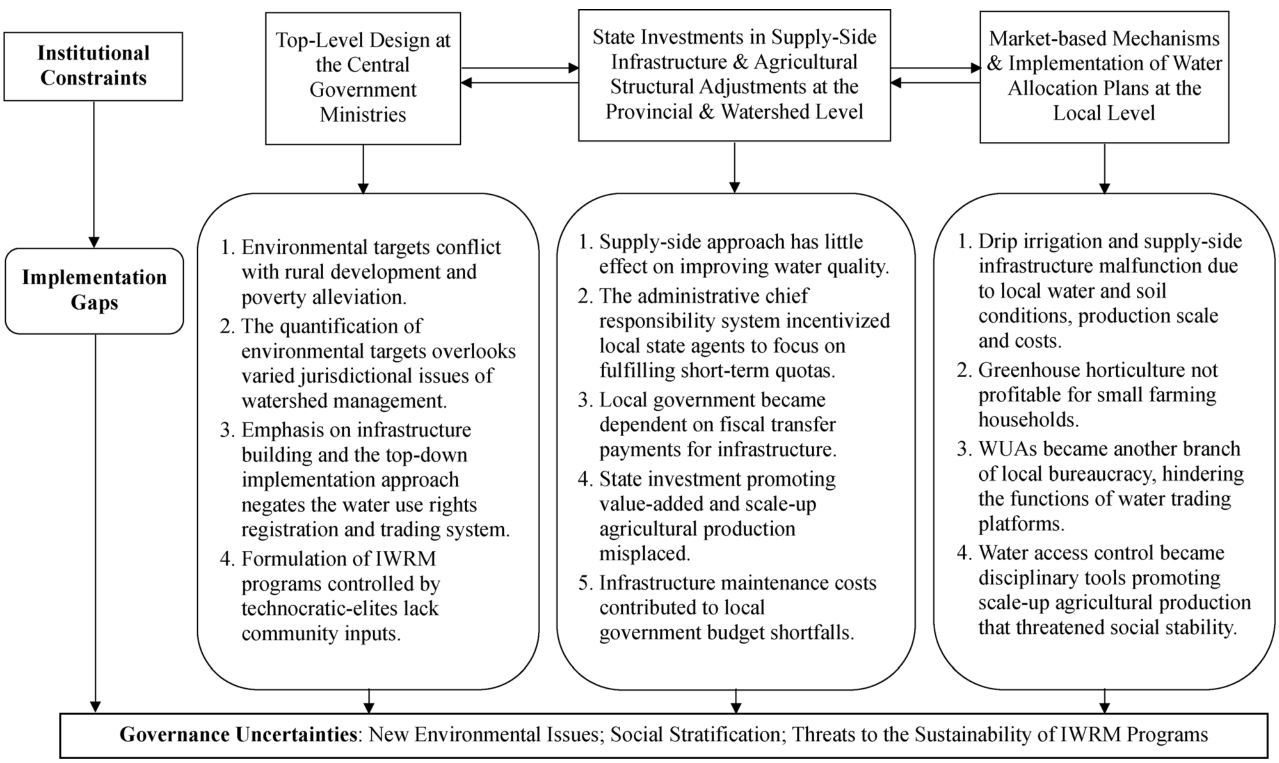

Fig. 3 Institutional constraints, implementation gaps and governance uncertainties of IWRM programs in north-western China.

top-down implementation approach is costly in terms of human resources and management expenditures. The realization of intended outcomes primarily depends on the political interests of the local bureaucracy shaped by center-local relations. As a result, the duration and intensity of state intervention are mainly determined by the preference of the current party leadership, not by legal institutions and market mechanisms. In other words, without sustained engagement with stakeholders across political and geographical scales, the IWRM programs we examined may only succeed in a specific political and spatial-temporal context as their long-term viability depends on the central government's willingness to provide fiscal transfers and maintain the intensity of its political campaigns. To remedy the shortcomings of infrastructure-heavy and quantity focus of the IWRM programs, the Chinese central government implemented the "river chief system" in 2016, which attempts to transform the divergent rationalities of water resource management to fit into the incentive structure of the party-state administrative apparatus. However, the new system has also confronted the challenge of sustainability and accountability in implementation, which requires more time to observe the institutional dynamics and evaluate the policy outcomes.

By examining the formulation and implementation of the Tarim, Shule, Hei, and Shiyang IWRM programs, this article provides further insights into the socio-political aspects of water system management in north-western China. Our study finds that the administration of inland watersheds is structured by the divergent rationalities and interests of political actors at multiple levels of governance. The continuing consolidation of land rights and the capitalization of agricultural production in hinterland China continue to shape the political, social, and economic contexts of water allocation and utilization. As such, this article proposes a socio-political approach to examine the human-nature, state-society dynamics in water system management in China.

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