CHAPTER 8

Water Policy, Management and Institutional Arrangements: The Fuyang River Basin, China

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Introduction

Faced with a rapidly expanding gap between water supply and demand, and increasing competition among sectors in China, especially in the northern regions, water issues have received increasing attention. In the past, water problems were treated mainly as engineering problems, and most water research focused on improving the efficiency of water use through innovating water-delivery technology (Wu et al. 1986; Chinese Academy of Sciences 1991; Xian Institute of Water Resources 1995). The absence of incentives in the adoption of water-saving technologies at the level of the farm household reveals the importance of water management and institutional arrangements. The growing evidence also shows that water management and institutional arrangements are important measures for dealing with water shortage problems (World Bank 1993; IWMI and FAO 1995). The conflicts among various stakeholders and the inability to implement the water law and policies result in increasing water shortage and inefficient water use in China (Wang 2000). Although China has issued numerous water policies and regulations since the 1980s, many policies are either too general to implement or lack the institutional support system to implement the policies (Wang and Huang 2000a). Recent reforms in the water-management agency reflect that China's government has gradually realized the importance of institutional setting and policy in managing the water sector.

While the importance of institutions and management has received attention from both decision makers and scholars recently, few studies can be found in the literature that systematically examines these issues at the national or subnational level, and at the river-basin level. Based on the case study of "Development of Effective Water Management Institutions" in the Fuyang river basin of China, and general review of national laws,

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The authors thank Scott Rozelle, Zhonghuang Huang, Randy Barker, David Molden, Tissa Bandaragoda, R. Sakthivadivel, M. Samad, Bryan Bruns and Xiaojun Chen. The authors acknowledge the support of the IWMI, ADB, Ford Foundation and the National Natural Sciences Foundation of China (79725001 and 70003011).

institutions and policies in the water sector, this paper explores the possibilities for institutional reforms that can better foster integrated and sustainable use of water at national, regional and river basin levels.

This paper is organized as follows. The first section is the introduction. The second section discusses basic characteristics and water accounting analysis of the basin and irrigation system in the Fuyang river basin (FRB). The next three sections mainly discuss water policy, management and institutional arrangements at national, river basin, and irrigation system levels. The sixth section discusses the empirical research on determinants and impacts of property rights innovation for groundwater irrigation systems. The last section provides concluding remarks on emerging challenges of water management.

Basic Characteristics and Water Accounting Analysis

Location, Climate and Socioeconomic Characteristics of the FRB

Traversing five prefectures (Handan, Shijiazhuang, Xingtai, Hengshui and Cangzhou) of southwest Hebei province, the Fuyang river is one of two branches of the Ziya river, a main branch of the southern part of the Hai river (see figures 1 to 3). The basin covers 22,814 km^2 with a population of 15.64 million in 1998. The FRB has a temperate monsoonal climate and is in a dry subhumid region. The annual average temperature is about 13 °C and the annual mean precipitation for the basin was 543 mm in the period 1956–98. More than 70 percent of the rainfall occurs between June and September. Table 1 summarizes the basic characteristics of the FRB.

Figure 1. China and the location of the FRB.

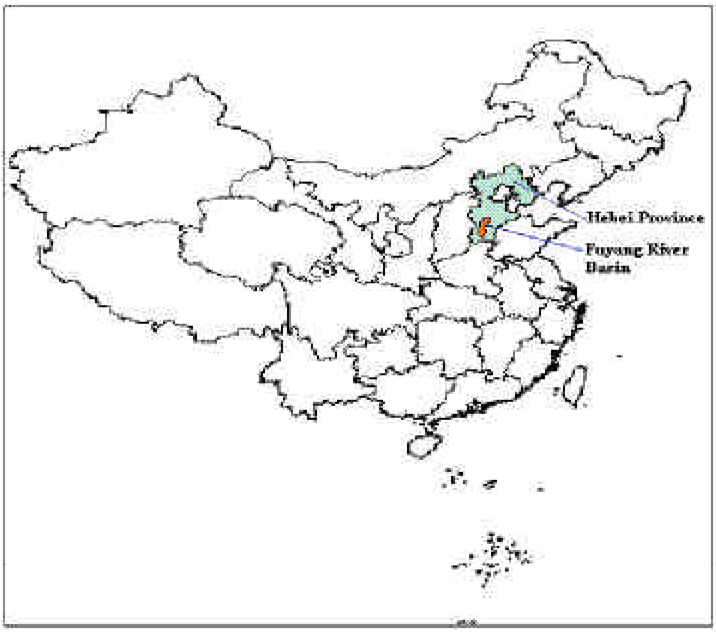


Figure 2. The hydrological Network of the FRB.

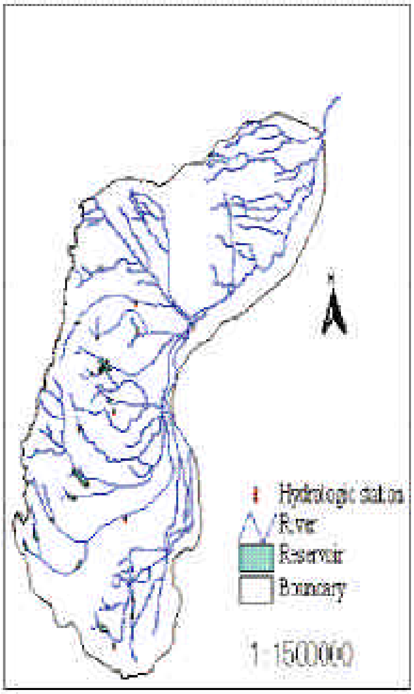


Figure 3. The divisions of the FRB.

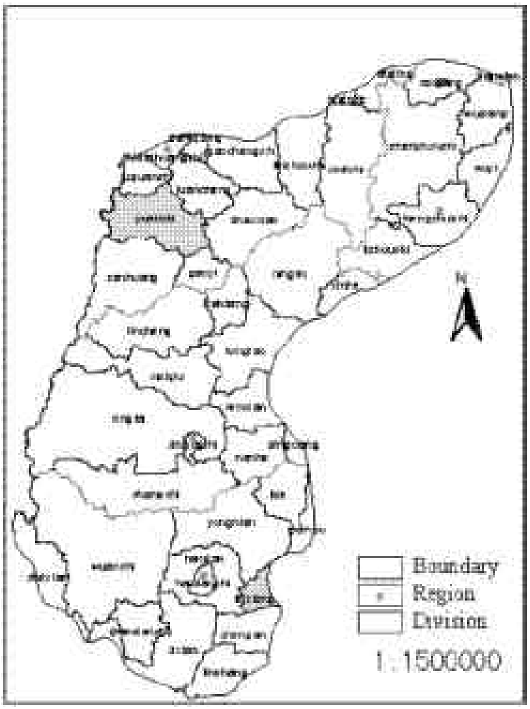


Table 1. Basic characteristics of the FRB.

Variables	Values
Total area (km^2)	22,814
Total population (million persons)	15.64
Population density ($persons/km^2$)	686
Number of major urban centers	4
Number of prefectures	5
Number of villages	9,092
Urban population (million persons)	4.37
Rural population (million persons)	11.27
Per capita water availability (m^3)[a]	868
Share of agricultural employment (%)	67
Proportion of population living below official poverty line (%)	6
Cultivated area (1,000 ha)	1239
Proportion of irrigated area (%)	83
Multiple cropping intensity (sown area / cultivated area)	1.55
Average annual rainfall (mm) (1956-1998)	543
Annual average evapotranspiration over many years (mm) (1956-1998)	1,562
Maximum temperature (^{0}C)(1956-1998)	42.6
Minimum temperature (^{0}C) (1956-1998)	-20
Average temperature (^{0}C) (1956-1998)	13
Average dry months per year (<5 mm rainfall) (1956-1998)	4

Note: If the years are not indicated, the values are for the year of 1998.
[a]Estimated by the authors based on water accounting analysis in the FRB.
Source: Hebei Provincial Water Resources Bureau and Hebei Provincial Statistic Bureau.

The basin is a slightly more agricultural and rural-oriented region with 72 percent of the population in the rural sector in 1998 (compared to 70% for the nation as a whole). The growth of industrialization and urbanization was slower than in the rest of the country, partly due to scarcity of water in this region. Irrigation plays a critical role in the agriculture of the basin and has developed faster in there than in the rest of Hebei Province and China. The share of irrigated land in the FRB reached 83 percent in 1998 (rising from 69% in 1985), which is much higher than in the Hebei Province (67%) and the average national level (54%) in the same year (State Statistics Bureau 1999). Wheat and maize are dominant crops; followed by vegetables, oil crops, soybeans, cotton, tubers and rice.

Hydrological Characteristics of the FRB

Based on our water accounting analysis, per capita water resource availability in FRB is not very high, only 868 m^3 (table 2). Shares of groundwater and surface water were 82 percent and 18 percent, respectively in 1998. Agriculture is the largest water consumer but the share of agricultural water use has been declining over time, from 81 percent in 1993 to 75 percent in 1998, mainly due to increasing domestic consumption (from 5% to 10%). Limited by many reasons, the share of industrial water use increased only one percent (from 14% to 15% between 1993 and 1998).[2]

Table 2. Water accounting for a normal year of 1993 in the FRB.

	Total $10^6 m^3$	Components $10^6 m^3$
Inflow		
Gross inflow	12,290	
Precipitation		12,100
Surface sources from outside basin		190
Storage change	1,053	
Surface water		-34
Groundwater		1,087
Net inflow	13,343	
Outflow	54	
Available water	13,298	
Depletive use		
Process depletion	10,110	
Irrigated crop evapotranspiration		6,431
Nonirrigated crop evapotranspiration		2,567
Orchard evapotranspiration		689
Industrial uses		330
Domestic uses		93
Non-process depletion	1,500	
Forest evapotranspiration		1,500
Non-beneficial depletion	1,690	
Evapotranspiration from uncultivated lands		1,315
Evapotranspiration from lying fallow lands		259
Free water surface evaporation		116
Total depletion	13,300	
Accounting indicators	Value	
Depleted fraction (ratio)		
of gross flow	1.08	
of available water	0.98	
Process fraction (ratio)		
of gross flow	0.82	
of depleted water	0.76	
of available water	0.74	
Productivity of water		
Gross value of production in million US dollars	689	
Gross value of production per unit of		
gross inflow ($/m^3$)	0.056	
available water ($/m^3$)	0.051	
crop evapotranspiration ($/m^3$)	0.077	

[2]In 1998, for the national as a whole, the shares of agricultural, industrial and domestic uses of water were 69%, 21% and 10%, respectively.

With a total length of 403 km in the main river, the Fuyang river has 14 major branches. All branches of the Fuyang river flow into the main river at Aixinzhuang, Ningjin County in Xingtai Prefecture. The outflow of the surface water from the basin is measured at the Aixinzhuang hydrologic station. Figure 4 shows that the outflows from the basin dramatically decreased from an average of more than 500 million m^3 in the 1970s to a discharge of less than 100 million m^3 in the 1980s. It became a nearly closed basin in the 1990s except for 1996.

Groundwater is the most important water source in the FRB. With the increasing demands of agricultural, domestic and industrial uses of water, groundwater exploitation increased rapidly and the groundwater table (both shallow and deep) fell substantially, at more than 1 m annually in the past two decades (figure 5). Due to the overexploitation of groundwater, cones of depression have developed in all five prefectures, centered in the cities. Urbanization, industry and population growth have also led to increasing pollution of surface water and groundwater, which further sharpened the water-scarcity situation in the FRB.

Figure 4. Trend of discharges at Aixinzhuang Hydrometric Station, 1957-98.

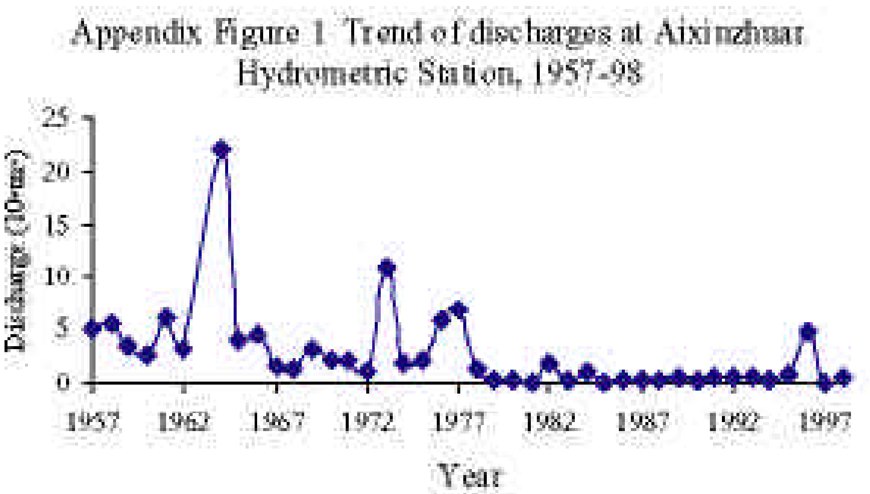
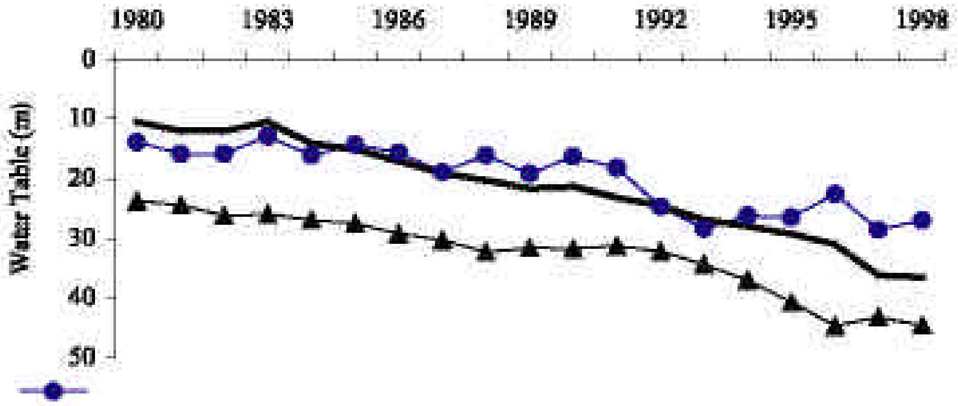


Figure 5. Trends of groundwater table in Bailuobao, Jiuzhou, and Longhua, 1980–98.

[Appendix Figure 2. Trends of groundwater table in Bailuobao, Jiuzhou, and Longhua, 1980-98.]



Overview of the Fuyang Irrigation District

As one of three large surface water irrigation systems in the FRB, Fuyang Irrigation District (FID) is located in the upstream part of the basin. The district includes 30 townships and 731 villages from 6 counties and the Handan city. The maximum irrigation capacity from surface water can reach 43,000 hectares. The average annual irrigated area with surface water in the district was 24,000 hectares in 1962–98, about 56 percent of total surface water irrigated areas in FID or 2 percent of the total irrigated area in the FRB. Total population in the FID is 1.26 million, about 8 percent of the total population in the FRB. The district is relatively rural with a 77-percent rural population, compared to 72 percent for the whole basin, in 1998.

Water-Accounting Analysis

Three representative years in the FRB (1993 for a normal year, 1996 for a wet year and 1998 for a dry year) were selected to conduct the water accounting analysis.[3] The results for a normal year in the FRB are presented in table 2. They show that both the depleted fraction of the available water and the process fraction of the available water are very high, even under the conditions of groundwater overdraft during both the normal and dry years. This suggests that the additional water for further exploitation is very limited.

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[3]Based on water accounting approach presented by Molden and Sakthivadivel.

To achieve sustainable development, the water storage change in the basin over a long-term period should be zero. In the past, groundwater was overdrafted, resulting in a declining groundwater table and other environmental problems. The current outflow from the basin is insufficient to maintain sustainable development in the downstream regions. Agriculture is the primary water user in the basin. Water available for agriculture is expected to decrease in the future as demand for domestic and industrial water uses increases. Generally, industry and domestic sectors have priority over water allocation when there is a water shortage. Increased productivity of water in the agriculture sector will be an important tool for alleviating water shortages in the basin in the future.

Increasing evidence in the FRB shows that existing water problems (such as increasing water shortage, decline groundwater tables, serious water pollution and decline of financial ability of irrigation systems) can be mainly attributed to poor water allocation and management, ineffective water policies and legal system and various water management conflicts among stakeholders and agencies. Any regional and river-basin water problems will be influenced by the national water management and institutional environment. In the next section, we discuss the national water law, management, and institutional arrangement problems, followed by a discussion of the relevant water management problems, based on our field studies in the FRB and irrigation systems in the basin.

National Water Law System, Management Institutions and Policies

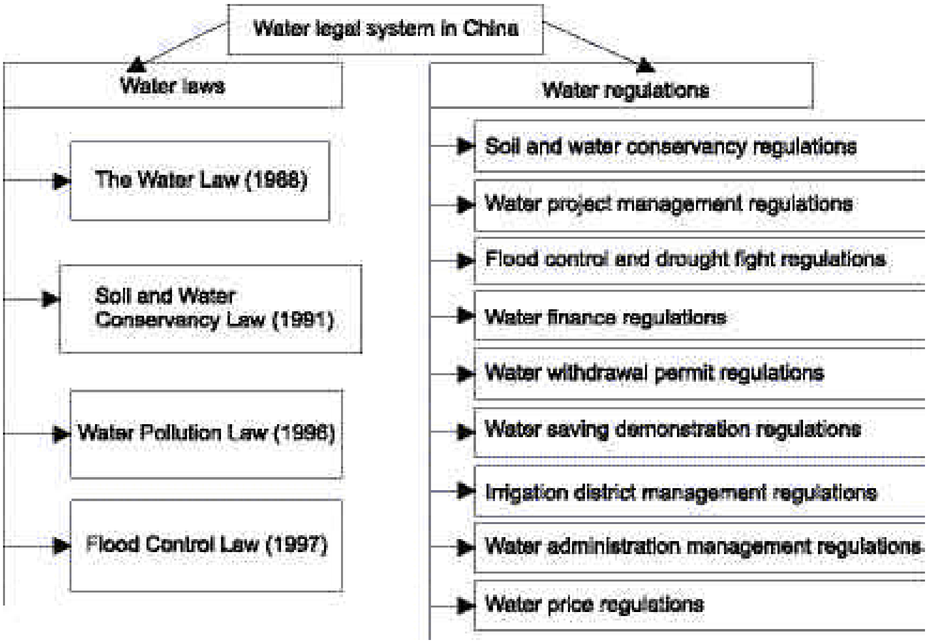
The Legal System

The emerging water shortage and environmental problems associated with social and economic development in China have accelerated the development of the water law system since the 1980s. In recent decades, four water laws and nearly 50 water management regulations have been issued. According to the contents of these regulations, we grouped the latter into 9 kinds (figure 6). However, the water law and regulations were always too general to be implemented, and amending existing legislation and issuing necessary new legislation were both very slow, which reflect sharp conflicts among various stakeholders.

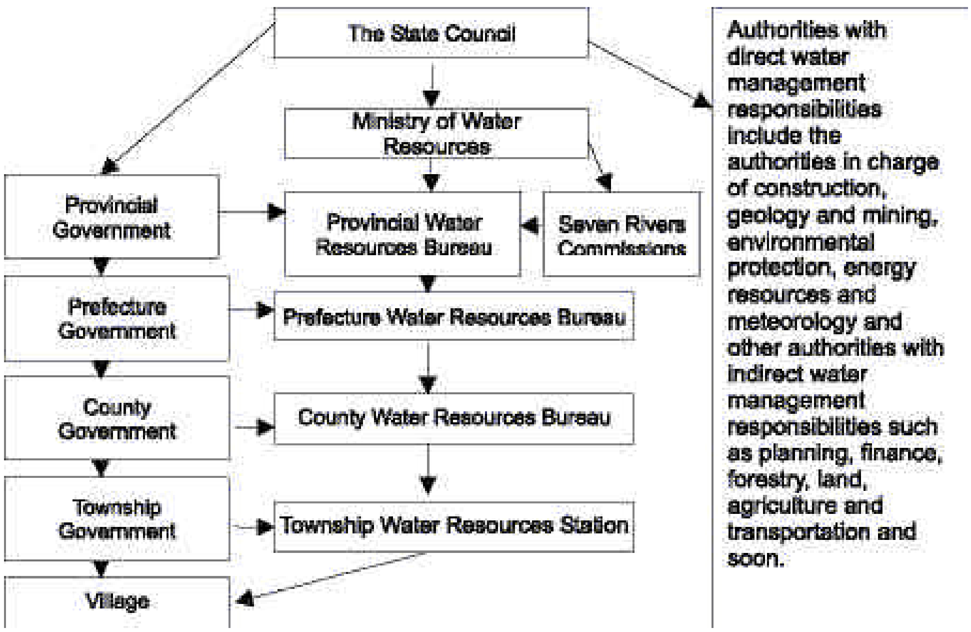
Structure and Conflicts of Water Management

In China, water resources are administered by a nested hierarchical administrative system. Figure 7 presents the structure of water management institutions in China. The Ministry of Water Resources (MWR) is at the highest central level directly under the State Council, with Water Resource Bureaus at the province, prefecture and county levels. Water management stations at the township are the lowest levels of state administration. The MWR not only provides technical guidance, issues water policy and regulates subnational water resource bureaus but also influences the local bureaus through allocating investment on water infrastructure from the central government.

Figure 6. Legal system for water in China.



Fgure 7. Structure of water management institutions in China



This system of water administration is supplemented by seven river commissions under the MWR that are responsible for coordinating water allocation among provinces through implementing the MWR policies. However, these cross-provincial river commissions have little decision-making power (Lohmar et al. 2001). Besides the two main water management systems of the MWR, there are several other government authorities, such as the ministries, bureaus or agencies of construction, geography and mining, environment protection, energy resource, meteorology, finance, and so on, which have some direct or indirect responsibilities in managing water resources (figure 7). The diverse functions of water use and diverse objectives and interests of many water management authorities result in various water-management conflicts present in rural and urban water use, surface water and groundwater balance, water quantity, and water-quality controls. Water management conflicts between management agencies, horizontal and vertical systems and between the upstream and downstream have not only accelerated water shortages, but also contributed to poor management, allocation and utilization efficiency of water resources (Wang and Huang 2000a).

Reforms of the Water Management Agency

To strengthen water management and resolve the water conflicts discussed above, China has been trying to reform its water management system since the late 1980s, particularly through a recent reform initiated after the mid-1990s. The reform took a bold move in division of the water-management functions among various stakeholders, though the ability to implement the reform is questionable (Wang 2000). By the reform policy, the MWR is provided with an exclusive right to manage water resources. If the reform is successfully implemented, some relevant water-management responsibilities currently controlled by other authorities are expected to be transferred to the MWR. By mid-1999, about 7 percent of the counties in Shanghai, Shananxi, Shanxi, Hebei, Henan, Anhui, Heilongjiang, and Shenzhen had established Water Affairs Bureaus (WABs) to consolidate the water management system. For the rest of China, the implementation of the reform has not been initiated, but is expected to shift to the WAB management system.

Water Withdrawal Permit System, Water Resources Fee and Water Markets

According to the 1993 regulation on the Implementation Method of Water Withdrawal Permit System, any individual or organization that draws water from a river, lake or groundwater over a certain levels must apply for a water withdrawal permit from the WRBs at various government levels. However, implementation of the above policies has proved to be problematic. The monitoring costs are high and the conflicts among various stakeholders and sectors make it almost impossible to follow the national water permitting system. In China’s agricultural sector, there are millions of small farmers and many individually owned groundwater irrigation wells, so effective implementation of water management arrangements at the individual level (such as water withdrawal permitting, policy and fee collection) is a serious problem. Unlike some countries such as America, Mexico and Chile that allow the trading of legal water rights, transferring a water withdrawal permit or water use rights is currently prohibited in China. But with rising water shortage problems over time, informal groundwater markets have emerged spontaneously in some water shortage areas (Wang 2000).

Reform of Water Finance and Pricing

After the rural institutional reform was initiated in the late 1970s, the planned financing system in the water sector has been gradually decentralized. The major reform has been focused on the responsibility of water management and finance between the central and local governments and between the government and farmers. The central government has focused its responsibility on the operating costs of the institutions directly under the MWR and the finance for special and nationwide projects, such as large flood and drought-control projects. The finance and management of small-scale rural water- conservancy projects have been transferred from higher to lower-level governments. Since the early 1980s, with progress in the financial reform, the share of investment in water projects in the total investment in the national infrastructure has declined from 5–7 percent to less than 3 percent (table 3).

Table 3. The share of government investment in water projects.

Year	Water Infrastructure Investment / Total National Infrastructure Investment (%)
1951–1957	5.3
1957–1965	7.6
1965–1975	7
1975–1982	5.9
1982–1986	2.7
1986–1990	2.2
1990–1997	2.8

Source: Wang 2000.

Declining public agricultural and irrigation expenditures attracted attention to the sustainability of agricultural development and future domestic food supply. Investment policy reviews led to increased investment after the early 1990s (table 3). However, due to the weaknesses of the fiscal system, the new policy to increase public investment in agriculture and irrigation has hardly been implemented. There are many policies and regulations that have been promulgated regarding the provision of a minimum level of agricultural and public goods, but there is no budget to back them up. Without sufficient budgets, policies cannot be effectively carried out.

Although the central government has encouraged local governments to increase water prices and improve methods of collecting water fees, such as extending volumetric water pricing, the actual collected water fees can only cover project operation, management and normal maintenance, while there is no capacity for irrigation management to complete large-scale repairs, rehabilitation and reconstruction. Further, the rate of actual collection of water fees is always lower than 70 percent in most regions (Wang and Huang 2000b).

Water Regulations, Management Institutions and Financing in the FRB

The local governments in the FRB issued water management regulations mainly focusing on water pricing, water finance, collection of water resource fees, water withdrawal permit systems, and water-saving measures. Several water regulations aimed at increasing the efficient use of water were issued earlier than the corresponding national regulations, which reflect the water-scarcity situation and local government's attention to economic measures in solving water-shortage problems. On the other hand, management regulations of the river basin have not been formulated.

Unlike the seven large river basins, the FRB has no special river-basin management organization. In principle, water in the FRB should be allocated by the Hebei Province Water Resources Bureau (HWRB) through coordinating five prefectures within the basin. In practice, the HWRB has very limited power in allocating water among prefectures and counties in the basin. Water management in the basin is administered mainly by the local governments at prefecture or county levels. Lack of integrated management in the FRB results in inconsistent local economic structure and water endowment.

In addition to the management conflicts between horizontal and vertical agencies, local water resources bureaus, urban construction bureaus, environmental protection bureaus and other relevant bureaus also have many conflicts in managing rural and urban water, surface water and groundwater, water quantity and quality. To implement the State Council's 1998 organizational and management reform, local governments in the FRB declared that they would complete the water management reform especially in realizing urban and rural integrated water management by the end of 2000. By 1999, about 49 percent of counties in the FRB had established Water Affairs Bureaus compared with the national level of 7 percent in the same period (Ministry of Water Resources 1999).

Reforms in Water Allocation, Finance and Pricing in the FID

Water Allocation in the FID

Five seasonal Fuyang river branches flow into the Dongwushi reservoir that plays an important role in surface water supply for the FID. Table 4 shows that the annual inflow of surface water in the FID has a general declining trend and the share of agricultural water use has

Table 4. Total annual surface water inflow and allocation in the FID.

Year	Total Inflow (million m^3)	Total Water Use (million m^3)	Water Losses in Rriver Canal (million m^3)	Water Supply for Downstream Irrigation Districts (million m^3)	Share of Agricultural Water Use (%)
1960s	475	190	71	214	52
1970s	398	225	56	117	44
1980s	276	165	45	65	51
1990s	294	183	46	65	36

Source: Management Authority of the FID.

also decreased over time. Industrial and domestic water uses have priority in water allocation; downstream water users received declining water inflow from upstream.

Water Finance in the FID

In 1962, the Management Authority of the FID (MAFID) under the Handan prefecture water resources bureau was set up with 9 irrigation subdistricts (branches). Government investment was a dominant financial resource for the surface water system of FID before 1981 but it has been almost fully replaced by the revenue generated by MAFID (table 5). Before 1983, all income came from the collection of water fees, though the amount was very small. With the reform of the financial system in the water sector initiated after the 1980s and to improve the financial capacity for maintaining surface water system, the MAFID started to run its own enterprises and businesses such as fishing, plastic firms, and metal-processing firms.

Table 5. Investment in surface water systems of the FID.

		Investment sources (%)				Expense shares (%)	
Year	Total Investment (Million Yuan in 1990 prices)	Government Fiscal	MAFID's Revenue	Farmer	Labor Input (000 days)	Maintenance	Construction
1955–58	2.37	96	4	0	70	0	100
1962–69	2.22	96	4	0	593	43	57
1970–79	1.48	68	29	4	3,588	40	60
1980–89	1.23	69	32	0	190	29	71
1990–98	0.62	0	100	0	2	100	0
1955–98	1.46	74	25	1	1,044	47	53

Source: MAFID.

Table 6. Income and expenditure in the surface water systems of FID management division.

		Income sources (%)			Expense shares (%)		
Year	Income (Million Yuan)	Water Fee	Others*	Expenditure (Million Yuan)	Engineering Input (000 days)	Management	Others[a]
1962–1969	0.25	100	0	0.18	56	44	0
1970–1979	0.45	100	0	0.37	44	56	0
1980–1989	4.42	96	4	2.87	7	10	83
1990–1998	6.19	93	7	5.63	12	15	72
1962–1998	2.88	94	6	2.28	13	16	72

Note: Income and expenditure are real values in 1990 prices.
[a] Means incomes through operating enterprises in the FID.
Source: MAFID.

However, the income generated from these commercial activities was not sufficient to offset the decline in government investment (tables 5 and 6). Our field interviews also reveal that the income from the commercial sources is mainly used to compensate for the lack of core funding for the local staff salaries in the surface water system of MAFID (Wang and Huang 2000b).

Before the early 1980s, farmers' contribution to the surface water system was mainly through their contribution of *yiwugong* (obligatory labor) in the maintenance and construction of water projects at the local community level (table 5). Yiwugong has declined significantly since the 1980s. On the other hand, the water fees paid by farmers have increased rapidly over the same period. In terms of investment priority, investment in the surface water system has shifted from new construction projects to maintenance over time.

Water Price Reform and Water Fee Collection Approaches in the FID

Although the local government tried to implement volumetric water pricing measures for surface water, it has hardly been implemented due to measurement difficulties. At the local level, the water fees based on crop areas were collected by village leaders or people appointed by the MAFID. Recently, the water fees have been merged with the other payments that farmers have to pay for the services provided by the local village and township such as education, rural infrastructure development, and other public services as well as agricultural taxes. In most areas, these merged or aggregated payments are often linked with the government grain-procurement system that allows the farmers to pay all these merged fees in grain equivalent (in kind). In 2000, learning from some other irrigation districts, one subdistrict in the FRB established water user associations to overcome the difficulties in collecting water fees and to improve the management of field canals.

Table 7 shows the trends of water fees (prices) in both nominal and real prices (in 1990) for use in industry, domestic water supply, and irrigation from 1971 to 1998. Water prices for various uses had been kept constant until the late 1970s, then raised significantly in nominal terms thereafter. Despite the significant rise in water prices in the past three decades,

Table 7. Delivery prices of surface water from water suppliers in the FID.

	In nominal prices (yuan/m^3)			In 1990 real prices (yuan/m^3)		
Year	Industry	Domestic	Irrigation	Industry	Domestic	Irrigation
1971	0.006	0.001	0.002	0.013	0.003	0.004
1975	0.006	0.001	0.002	0.013	0.003	0.004
1980	0.010	0.002	0.003	0.019	0.004	0.006
1985	0.050	0.010	0.007	0.081	0.016	0.011
1990	0.232	0.051	0.019	0.232	0.051	0.019
1995	0.278	0.064	0.054	0.161	0.037	0.032
1998	0.365	0.128	0.069	0.204	0.072	0.039

Source: MAFID.

the water prices for various uses are still much lower than the true productive value of water. Indeed, water prices in real terms for industrial and domestic uses had declined in the first half of the 1990s. While the agricultural water prices kept rising, though at a slower rate after the late 1980s, they were much lower than the prices of other uses.

Property Rights Innovation in Groundwater Irrigation

There are different management systems for surface water irrigation and groundwater irrigation. The surface irrigation system has been mostly controlled by government agencies, such as the FID, though a contract management system was implemented in some periods. Compared with groundwater irrigation, surface irrigation has basically not changed in property rights since the 1980s. Therefore, we will focus on the evolution of property rights in groundwater irrigation systems. In this section, we present the results of our recent surveys from a randomly selected sample of 30 villages and 87 sample groundwater irrigation systems [4] in three counties (2 counties in FRB and the other in the nearby basin) of the Hebei Province.

Investment in Groundwater Irrigation Systems

Groundwater irrigation investment was mainly financed by the local villages and townships with varying extents of government financial subsidies, prior to the implementation of the household production responsibility system (HRS) initiated in the late 1970s. Farmers always contribute family labor for constructing a groundwater irrigation system. Collective ownership dominated all groundwater irrigation systems. With the implementation of HRS, the declining collective role in the local economy and growing private (farmers) involvement in groundwater irrigation, investment from collectives and the government has dropped considerably, while farmers' investment has increased significantly since the early 1980s (table 8).

Table 8. Groundwater irrigation investment in the 30 sample villages in Feixiang, Yuanshi and Qinglong counties, Hebei Province.

	Sources of Groundwater Irrigation Investment (%)					Total Investment (Million Yuan) [a]
Year	Total	State	Collective	Farmers	Others	
1983	100	21	12	67	0	203
1990	100	10	11	69	11	85
1998	100	3	5	92	0	170

Note: Feixiang and Yuanshi counties locate in FRB, Qinglong county located in neighboring basin of FRB.
[a] Real price in 1990.
Source: Authors' surveys in 30 randomly selected 30 villages from 3 selected counties of the Hebei Province.

[4]One tube well and its relevant facilities are defined as a unit of groundwater irrigation system.

Characteristics of Property Rights Innovation

In this study, we divide groundwater irrigation systems into two groups with different property rights: collective and noncollective. For collectively owned irrigation systems, we further classify them into purely collectively owned and quasi-collectively owned irrigation systems; the latter is for those irrigation systems in which both collectives and farmers or other organizations jointly owned the system. Noncollectively owned irrigation systems are also classified into two subgroups: individual privately owned and shareholding by several individuals.

The most significant change in the property rights of groundwater irrigation systems in our study area is shifting from collective to noncollective. The share of noncollectively owned irrigation systems increased from 17 percent in the early 1980s to 69 percent in 1998 (table 9).

Table 9. Changing structure of property rights in groundwater irrigation systems, 1983–98.

Year	Collective v Noncollective		Within Collective		Within Noncollective	
(%)	Collective	Noncollective	Pure	Quasi	Shareholding	Private
1983	83	17	52	48	100	0
1990	56	44	24	76	99	1
1997	32	68	16	84	87	13
1998	31	69	18	82	86	14

Source: Field survey in 30 villages in three counties, Hebei Province.

Within the collective property-rights system, pure collectively owned irrigation systems have been gradually replaced by quasi-collective systems (table 9). The noncollectively owned groundwater irrigation systems were dominated by the farmers' shareholding in the initial stage of property-rights changes due to credit constraints of individual farmers. However, the individual privately owned irrigation systems have been growing rapidly since the early 1990s, increasing from only1 percent in 1990 to 14 percent in 1998.

Determinants and Impacts of Property Rights Innovation

Econometric analyses of the determinants of property rights innovation[5] show that the noncollective property rights of the groundwater irrigation system are induced by many factors, including changing resources endowments, environmental stress, weakening local collective economy, market development, improving human capital, and financial policies (table 10, and Wang et al. 2000). Among these factors, increasing water scarcity, overexploitation of groundwater, and increasing population pressure are major factors that led to rapid expansion of noncollective groundwater irrigation activities.

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[5]Data from 30 sample villages are used in this model.

Table 10. Determinants of property rights innovation in groundwater irrigation.[a]

Variables	Share of Noncollective Property Rights of Groundwater Irrigation System (%)		
	OLS		Random effect
	Case 1[b]	Case 2[b]	model
Constant	-132.022	-404.156	-111.367
	(-0.69)[c]	(-4.55)***	(-1.99)**
Water resources endowments			
Groundwater table level in the last year (log)	4.817	66.031	13.246
	(1.39)	(3.33)***	(2.64)***
Share of surface water use in irrigation (%)	0.430	0.435	0.455
	(2.72)***	(3.07)***	(3.21)***
Environmental stress			
Per capita cultivated area (log)	-3.262	-83.075	-31.740
	(-0.27)	(-2.54)**	(-1.90)**
Local community economic power			
Per capita real net income of farmers (log)	-9.370	-11.570	-11.740
	(-1.11)		
	(-0.91)	(-1.23)	
Per capita income of village collective (log)	-4.074	1.340	0.250
	(-1.82)*	(0.72)	(-0.13)
Human capital in local community			
Share of agricultural labors who received middle school or higher education (%)	1.979	0.038	1.595
	(5.54)***	(0.07)	(4.06)***
Policy dummy variables			
With fiscal subsidies for water project	9.359	13.479	13.873
	(1.25)		
	(2.06)**	(2.12)**	
With subsidized loan for water project	-27.680	-62.107	-30.018
	(-4.14)***	(-2.10)**	(-2.90)***
Road condition dummy	13.383	21.947	19.037
	(1.84)**	(2.24)**	(2.29)**
29 village dummy variables[d]	-[e]	omit	-
R^2	0.458	0.833	0.619
Adjusted R^2	0.413	0.755	-
F	10.31	10.63	-
Chi^2	-	-	137.77
Degree of freedom	110	81	110

[a] The sample size is 120.
[b] "Case 1" does not include the village dummy variables while "case 2" includes village dummy variables.
[c] Numbers in parentheses are t statistics (case 1 and case 2) or z statistics (random effects model); "*", "**" and "***" represent statistically significant at 10%, 5% and 1%, respectively.
[d] Coefficients for village dummy variables have not been listed.
[e] "-" indicates the variable has not been included in model.

Table 11. Estimated results of stochastic water production frontier model.

Variables	Water Production(log)[a]			
	Case 1[b]		Case 2[b]	
	Coefficient	T statistic	Coefficient	T statistic
Constant	2.410	(16.24)***[c]	2.408	(16.79)**8
Fixed cost (log)	0.080	(2.85)***	0.081	(2.88)***
Variable cost (log)	0.255	(5.95)***	0.254	(6.00)***
Labor (log)	0.389	(7.16)***	0.389	(7.38)***
Average water table level (log)	0.049	(0.92)	0.056	(1.04)
Dummy for 1997	0.034	(1.52)	0.033	(1.46)
Dummy for 1998	0.026	(1.21)	0.027	(1.23)
County dummy: Feixiang	-0.196	(-2.51)**	-0.208	(-2.64)***
County dummy: Yuanshi	-0.106	(-2.02)**	-0.110	(-2.07)**
Variables influencing technical efficiency				
Constant	0.459	(7.77)***	0.460	(8.38)***
Dummies for property right				
Noncollective	-0.084	(-2.44)**	-[d]	-
Shareholding	-	-	-0.088	(-2.87)***
Private	-	-	-0.028	(-0.40)
Dummy for management with bonus	-0.085	(-1.99)**	-0.101	(-2.59)***
Irrigation system scale:				
Annual maximum irrigated area (ha)	-0.023	(-12.57)***	-0.022	(-13.89)***
Management ability of manager				
Schooling years (years)	0.001	(0.16)	0.001	(0.17)
Irrigation system age				
Founding years (years)	-0.014	(-2.19)**	-0.013	(-2.19)**
d^2	0.019	(4.64)***	0.018	(6.12)***
r	0.912	(24.98)***	0.907	(26.56)***
Max. likelihood value	155.09		155.72	
Average value of technical efficiency	0.818		0.819	

[a]The sample size is 189.
[b]Property right dummy variables in "case 1" are divided into two kinds: collective and noncollective; while those in "case 2" are divided into three kinds: collective, shareholding, and private.
[c]"*", "**", and "***" represents statistically significant at 10%, 5%, and 1%, respectively.
[d] "-"variable not included in model.

Econometric results (table 11) show that in case 1 (dummy variables for property rights are divided into collective and noncollective) the coefficient of noncollective property rights is statistically significant and positively related with technical efficiency. It implies that the changes of property rights in favor of noncollective and market-oriented mechanisms in irrigation have significant impacts on the technical efficiency[6] of the water-supply sector after controlling for all other impacts[7] (Wang and Huang 2000a). Further, innovation of noncollective property rights for groundwater irrigation was also found to have statistically significant impacts on cropping patterns and agricultural production (Xiang and Huang 2000).[8] In particular, the expansion of private or noncollectively owned irrigation stimulates cropping pattern changes in favor of high- value cash crops and against grain crops. This change raises farmers' income as the former are more profitable and the additional water is available for later crop cultivation through the increase in water use efficiency, due to the changes in irrigation property rights.

Policy Implications

The above findings have strong policy implications for raising water productivity and farmers' income. The ongoing expansion of private and shareholding groundwater irrigation should be encouraged and integrated into the government irrigation investment programs. The current government fiscal and financial/credit policies that favor collectively owned irrigation as well as the large irrigation projects owned by the state should be revisited and reevaluated.

However, our study also warns that if water prices do not fully reflect the marginal value of water use (including externalities affecting other water users), then, property rights innovation toward privatization might lead to overexploitation of groundwater and water table declines. Therefore, to promote sustainable development of water resources, future water resources policy should emphasize on property rights innovation, rationalizing water prices, and better groundwater management institutions.

Concluding Remarks

Declining groundwater levels, reduced surface water discharges, and increasing water competition among stakeholders with growing water demands have been presented in China, one of the most water-short countries in the world. If these trends continue and the government does not respond to these trends with proper policies in the future, water shortage could threaten China's economically and environmentally sustainable development.

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[6]Technical efficiency is defined as the ratio of observed water output to potential water output (water frontier output).

[7]Data of 87 samples of groundwater irrigation system are used in estimation.

[8]In this research, we assume institutional variables to be exogenous variables.

Although limited water endowment is one important reason for an expanding water demand and supply gap, the existing legal system, regulations, management and other water-related policies add to the unbalanced and unsustainable use of water in China, particularly in the northern regions. The water management and organizational conflicts between rural and urban water allocation, between surface water and groundwater, and between horizontal and vertical management authorities will hardly be solved if the system is not reformed. A better-enforced system of laws and regulations, and a more effective institutional setting that facilitates the implementation of integrated water management at national, regional and water-basin levels need to be established.

Although the seven large-river commissions were established to coordinate water allocation and flood control across provinces, the impacts of these commissions are more on flood control than on water allocation due to the limited power of the commissions. Generally, there is no interregional water management authority in the small water basins. The local governments based on administrative jurisdictions often separately manage the water in the small water basins. Within the administrative jurisdictions, water supply and demand are controlled and managed by too many authorities that have different interests and, therefore, resulting in various conflicts in balancing water use in the region. Increasing conflicts, unbalanced and inefficient water allocation among sectors and between upstream and downstream within the river basin have made integrated river basin management very essential.

Although central and local governments have successfully developed surface water and groundwater resources through mobilizing every possible financial and human capital by administrative measures that greatly supported national and local social and economic development, growing evidence shows that administrative measures alone cannot solve increasing water shortage problems. Market-oriented water management measures, such as rational water price, water market, water rights transfers and property rights innovation for water facilities, should be emphasized and introduced into central and local water management systems.[9]

Our study on property rights innovation also suggests that the private and shareholding groundwater irrigation system can improve the efficiency of water use. The existing government fiscal and financial policies in irrigation investment need to be revised to encourage the development of this market-oriented irrigation management system.

[9]Farmers' responses to water prices, water markets and water rights transfers need to be studied in the future.

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