Pro-poor Intervention Strategies in Irrigated Agriculture in Asia

Poverty in Irrigated Agriculture: Issues and Options

CHINA

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CHAPTER 1

Study Background

INTRODUCTION

China has made great progress in poverty reduction since the late 1970s when the rural economic reform was initiated (LGPR, WB and UNDP 2000). From 1978 to 2000, more than 200 million people in rural areas have escaped from poverty. Based on the government's poverty line, the incidence of poverty declined from 30.7 percent to 3.4 percent (table 1.1).[1] China's poverty reduction has been attributed to the adoption of a broad program of rural economic reforms (Zhang et al. 2002). These reforms, including the adoption of the production responsibility system, the dismantling of the commune system, agricultural product price increase and market liberalization, have been associated with dramatic rural economic growth.

Irrigation, the most important form of investment in the agricultural sector in both the rich and poor areas of the rural economy, is also believed to have played an important role in increasing agricultural productivity and in reducing poverty. China has invested more than 10 times as much in irrigation (35 billion yuan in 2000), as it did in agricultural research (3.4 billion yuan). Investment in water control, more generally, also dominates all other forms of investment. For example, spending in 2000 on water control (83 billion yuan--Ministry of Water Resources 2001), far exceeded the annual budget that was targeted specifically at poverty reduction (22.4 billion yuan--National Statistical Bureau of China 2001).

However, low and declining marginal returns to irrigation investment at the aggregate level are not unexpected, since China has exploited nearly all of the opportunities to irrigate cultivated areas. The proportion of cultivated area under irrigation increased from 18 percent in 1952 to more than 50 percent by the late 1990s (National Statistical Bureau of China 2001). Given the high level of irrigation, the increasing costs of bringing additional land under irrigation, and the severe financial constraints of government budgets, the potential advantage in expanding irrigation areas to increase agricultural productivity and reduce poverty may be fairly limited.

Furthermore, water shortages are threatening China's resource base and agricultural production. Despite ranking fifth in total water resources among the countries in the world, on a per capita basis, China has only 25 percent of the world average. Between 1949 and 1998 total water use increased by 430 percent. China's water utilization rates are already among the highest in the world, and there is little scope for tapping additional sources (Ministry of Water Resources 2002; Rosegrant and Cai 2002). Water demands in industries and urban sectors have risen so fast that the water available to the agricultural sector has declined.

Not just a limited resource base and rising demand, but also a deterioration of the surface water irrigation system and resultant inefficient water use have also contributed to the water crisis in China. Constructed in the 1950s-1970s, the surface water irrigation system has been the

[1] However, based on the World Bank poverty line (US$1/day), China still had a 124 million rural poor population in 1997, though the poverty decline trend is also very obvious.

backbone of the effort to increase agricultural productivity. However, due to lagged investment (which has favored new projects rather than maintenance of old projects) and poor water management, the surface water delivery infrastructure has been deteriorating and water cannot be used efficiently (Lohmar et al 2002). Delivery of surface water efficiency in China is only about 25 - 40 percent.

China's government has identified the nation's rising water scarcity as one of the key problems that must be solved if the nation is to meet its national development plan in the coming years (Zhang 2001). Shortages of water are attenuating efforts to alleviate poverty and are causing environmental problems (World Bank 1998; Zhang 2000). In many regions of the country, a rapidly growing industry and an expanding, increasingly wealthy urban population regularly vie with each other for the limited water resources, thus threatening to curtail growth in food production.

China has made remarkable progress in increasing the standard of living in its rural areas since the onset of economic reforms. Research has documented a rapid rise in rural incomes and reduction in poverty (Lardy 1983; Putterman 1992; World Bank 2001). A number of studies have analysed the impact of institutional changes and the increased use of inputs in production growth during the reform period, as well as attempted to explain the success of China's poverty alleviation efforts (McMillan, Whalley and Zhu 1989; Lin 1992; Fan 1991; Huang and Rozelle 1996).

While several studies have established the links between rural growth and institutional change and input growth, few studies have established the link between policy effort and investments on one hand and poverty reduction on the other. For example, a study on the effect of agricultural research on productivity of farmers in poor areas, has shown that new technology did not benefit poor area farmers (Jin et al. 2002). Rozelle et al. (1998), show how billions of yuan that have been invested in poverty alleviation do not explain income per capita gains in poor areas. Most observers believe China's efforts to invest in micro-credit schemes have generally failed to produce any sustained, positive effect on poverty reduction (World Bank 2001).

Perhaps, more curiously, despite the large investment that China has made in water control, the most important form of investment in the agricultural sector in both the rich and poor areas of the rural economy, previous studies have not been able to identify any strong impact of irrigation on the performance of any part of the rural economy.[2] For example, Hu et al. (2000), find that irrigation did not contribute to the total factor productivity (TFP) growth of rice in China between 1981 and 1995. Jin et al. (2002), extend the work to other crops and cannot find a link between irrigation and TFP growth of any major grain crop (rice, wheat or maize). Fan et al. (2000), illustrate that government expenditure on irrigation has the smallest returns to agriculture output compared to other investments, such as roads, agricultural research and development and education.

While such a finding may be surprising, a survey of the broader development literature shows that this finding is not unique to China. Studies in other countries, frequently, are unable to find a significant effect of irrigation on the performance of the rural economy. For example,

[2]Information on investments are from a number of sources. Water control investment numbers are from the Ministry of Water Resources (2001). Agricultural research figures are from Huang and Hu (2001). Data on the investments for poverty alleviation are from the China National Statistics Bureau (2001).

Fan and Hazell (2000), show that despite levels of investment in water control that exceed those of seven other investment categories, irrigation ranks only sixth in terms of marginal impact on poverty alleviation in India behind investments such as rural roads, agricultural research, and education. Rosegrant and Evenson (1992), also find that irrigation does not have a significant impact on TFP in India.

In facing the emerging water crisis, leaders typically debate about which of the several approaches they should use to address water scarcity problems, although none has been very successful (Lohmar et al. 2002). As discussed above, developing more water resources to increase water supply, historically, has been given the highest priority in resolving water shortages. Recently, the State Council announced plans to allocate more than 50 billion US dollars for the construction of a project to move water from the Yangtse River Valley to North China. Despite such ambitious goals, the high cost of developing new sources of water will make it so that the volume of water that can be added to north China's water equation will still be marginal. Leaders have also promoted water-saving technology and considered whether or not they should use water-pricing policy (Chen 2002; Rosegrant and Cai 2002). Unfortunately, most of their efforts to encourage the use of sophisticated water-saving technologies such as drip and sprinkler irrigation have failed, and in the past several years the Ministry of Water Resources has distanced itself from a water policy based on water-saving technology (Zai 2002). Political considerations will also, most likely, keep leaders from moving too aggressively on raising prices, at least in the agricultural sector (Rosegrant and Cai 2002).

With the failure and infeasibility of traditional methods, in recent years, leaders have begun to consider water management reform as a key part of their strategy to combat China's water problems, since they believe water in agriculture is being used inefficiently. Despite water shortages, users in all sectors of the economy--especially those in agriculture, by far the nation's largest consumer of water--do not efficiently use the water that they are allocated. One study, for example, estimated that due to the poor management of the nation's canal network, only 50 percent of water from the primary canals is actually delivered to the fields (Xu 2001). Farmers also do not efficiently use the water that reaches their fields, wasting roughly 20-30 percent of their water. Hence, overall, only about 40 percent of water in China's Surface Water System, that is allocated to production agriculture, is actually used by farmers on their crops. Others have estimated even greater inefficiencies (Fang 2000). In response, it has been proposed that local leaders reform the institutions that manage water in China's communities (Nian 2001; Reidinger 2002).

Despite the resolve of the current leadership in China to push water management reforms, there is a considerable debate about its appropriateness. International evidence shows that water management and its institutional arrangements are important measures for dealing with water shortage problems (World Bank 1993; IWMI and FAO 1995). Since the 1980s, many developing countries have begun to transfer irrigation management responsibilities from the government to farmer organizations or other private entities, in order to mitigate the financial burden of water projects and to improve the efficiency of water use and supply (Vermillion 1997). Despite decentralizing water resource management a proper structure can provide the incentive needed to stabilize and improve the efficiency of irrigataion and water supply system. However, there have been some cases internationally where these efforts have failed or generated negative influences (Easter and Hearne 1993; Vermillion 1997; Groenfeldt and Svendsen 2000).

In fact, even as early as the 1980s, but more so since the late 1990s, China's policy makers have promoted water management reforms, and like similar attempts outside China, the record seems to be mixed although most evaluations are only based on anecdotes or case studies (Nian 2001; Huang 2001; China Irrigation Association 2002). Even in those areas in which management reforms have been well-designed, effective implementation of the reforms have been difficult (Ma 2001; Management Authority of Shaoshan Irrigation District 2002). Collective action, information problems and getting the incentives right may be among the most important reasons why water management reform has failed. The design of water management reforms themselves may also create a number of negative externalities. Since the reforms provide financial incentives to the manager to more efficiently manage water, it is possible that the manager could take a number of actions that could negatively affect the production, income and the poverty status of certain individuals. For example, managers could deliver less water than demanded by farmers or cut off water deliveries to slow-paying, poor households. Surprisingly, despite the high stakes of the reforms there is little or no empirical-based work that has been conducted to understand and judge the effectiveness of water management reforms.

While there is no doubt that creating new irrigation systems will bring about significant increases in productivity and decreases in poverty levels in the limited areas which can still be irrigated, the overall extent of future poverty alleviation through irrigation expansion is certainly circumscribed. Hence, in those areas that are in regions that will never be irrigated, poverty reduction strategies must rely on policies that have nothing to do with constructing new irrigation facilities, or improving the delivery of water and water-related services. There may be, however, considerable poverty and a need for poverty alleviation efforts, inside irrigated areas. It is less clear how much poverty exists within irrigated areas, since in irrigated agriculture areas there are few studies conducted that have explored the magnitude of poverty and the alternatives for poverty reduction through pro-poor intervention.

To understand the need for attention to poverty problems in irrigated areas, several critical questions need to be addressed:

What is the incidence of poverty in China's irrigated areas and non-irrigated areas? What has been the contribution made by irrigation in increasing agricultural productivity and reducing poverty as regions have become irrigated? Within irrigated areas, what formal and informal irrigation-related institutions exist and how have they affected productivity? Finally, to what extent has the rise of certain institutions and creation of certain water management policies contributed to poverty reduction in irrigated agricultural regions?

In other words, in the rest of this report we seek to understand the magnitude of poverty inside irrigated areas and analyze the factors that contribute to making the life of the poor better and/or worse. In particular, we want to understand how recent innovations in water institutions and the creation of water regulations have affected the poor inside irrigation districts.

STUDY OBJECTIVES AND HYPOTHESES

The overall goal of the proposed research is to promote performance and sustainable development of irrigation systems, and equity development of rural areas through effective management policy, institutional arrangement and incentive mechanisms in China. In order to realize the overall goal of the research, five specific related objectives will be pursued in our studies:

1. Review poverty situations, changes and socio-economic and environmental constraints; synthesize pro-poor interventions and their effectiveness at national, river basin and local levels in China.

2. Understand water legal and regulation system, water management policy, institutional arrangement and their influences on the performance of the irrigation systems at national, river basin and local levels.

3. Assess the performance of irrigation systems in terms of efficiency, equity and sustainability, and identify its physical, socio-economic, institutional and policy causes.

4. Explore the linkage between the performance of irrigation systems and its impact on the poor farmers, identify other socio-economic and environmental constraints to equal development of rural areas.

5. Develop the analytical tool and alternative policy, management and institutional options that can promote the performance and sustainable development of irrigation systems and equal development of rural areas.

In order to reach our research objectives, six hypotheses will be tested in our study:

1. Command areas of specific canal reaches receiving less irrigation water per hectare have lower productivity and a higher incidence of poverty (poverty and irrigation).

2. Under existing conditions, small, marginal and poor farmers receive less benefits from irrigation than large and non-poor farmers.

3. The greater the degree of O&M (Operations and Maintenance) cost recovery, the better the performance, of irrigation management.

4. Effective implementation of PIM/IMT leads to improved irrigation system performance, which in turn reduces poverty.

5. An absence of clearly defined water allocation and distribution procedures, and an absence of effective and clear water rights (formal and informal), adversely affect the poor more than the non-poor.

6. There is scope for improving the performance of irrigation systems under existing conditions, with effective and improved institutional arrangements.

Table 1.1. Estimates of the number of poor in rural China, 1978-2000.

Year	Estimates by the Government of China ($0.71/day)			International standard ($1/day)	
	Poverty line (current Yuan)	Number of rural poor (millions)	Incidence of poverty (%)	Number of rural poor (millions)	Incidence of poverty (%)
1978	100	250	30.7	na	na
1980	na	218	27.6	na	na
1982	na	140	17.5	na	na
1984	200	128	15.1	na	na
1985	206	125	14.8	na	na
1986	213	131	15.5	na	na
1987	227	122	14.3	na	na
1988	236	96	11.1	na	na
1989	259	102	11.6	na	na
1990	300	85	9.4	280	31.3
1991	304	94	10.4	287	31.7
1992	317	80	8.8	274	30.1
1993	350	75	8.2	266	29.1
1994	440	70	7.7	237	25.9
1995	530	65	7.1	200	21.8
1996	580	58	6.3	138	15.0
1997	640	50	5.4	124	13.5
1998	635	42	4.6	na	na
1999	625	34	3.7	na	na
2000	625	32	3.4	na	na

Note: na = not available
Data sources: State Statistical Bureau (2001) and World Bank (2001).

CHAPTER 2

Poverty and Irrigation Development in China—An Overview

POVERTY IN CHINA

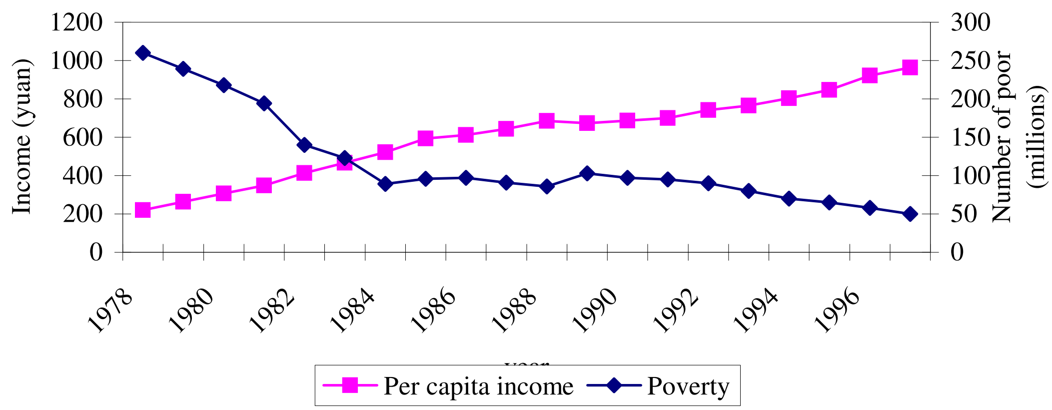
Poverty measurement and poverty line

Poverty is a multi-dimensional phenomenon, encompassing various types of deprivation that constrain the lives of poor people (Stern 2001). Income has always been treated as the major poverty measurement by many international organizations and governments due to its convenient operation and rationality. While there is no one-to-one correspondence between income and other measures of human welfare, Wang and Zhang (1999), and the World Bank (1999), show that there is a fairly high degree of correlation between areas with low income and those that do poorly on measures such as illiteracy, infant mortality, etc. The poverty line fixed by the World Bank is US$1 per day per capita. When China's government decided to set up a large-scale poverty alleviation plan in 1986, a standard was necessary for determining which counties would receive the specially allocated funds (Park et al. 1998). The Leading Group of the State Council initially adopted a mixed set of poverty lines to choose poor counties. The basic standard for selecting nationally designated poor counties was net income per capita below 150 yuan, in 1985 (Rozelle, Zhang and Huang 2000). However, a higher poverty line was applied to counties in old revolutionary base areas and counties with large minority populations. For some counties in important revolutionary base areas and for several minority counties in Inner Mongolia, Xinjiang, and Qinghai, the poverty line was raised to as high as 300 yuan. Three hundred poor counties were chosen as counties to be supported by national poverty programs based on these standards, which used 1985 State Statistical Bureau data. In 1988, 37 pastoral counties were added (Tong et al. 1994). Some 370 additional counties were also designated for provincial government support in 1986. By 1988, the Leading Group and its provincial counterparts were running a program targeting 698 counties (about 1/3 of China's counties).

These official poverty lines were soon criticized by both researchers and local officials (Park et al 1998). First, there was no explanation as to why 150 yuan was chosen as the basic poverty line. Second, the line was not uniform. Political criteria played an important role in county selection. Third, because incomes in poor, agriculturally dominated areas are influenced by weather, using income data from one year may not reflect the average income levels of different counties. Finally, there was also nearly no adjustment in the late 1980s or early 1990s (except for the addition of 3 Hainan province counties). The Leading Group had no set way to graduate those counties that developed rapidly or support those that fell into poverty during the first few years of implementation.

In response to these complaints and in preparation for the new push to eliminate poverty in the mid-1990s (called the 8-7 Plan), the Leading Group asked the State Statistical Bureau to calculate a new poverty line based on nutritional criteria (Zhu 1998). With this new criteria, national officials made their first (and only, so far) wide-sweeping adjustment to the designations of poor counties in 1994 (Piazza and Liang 1997). The distinction between national and provincial was eliminated. And, despite the large reduction in poverty counts, the number of nationally-supported poor counties was established at 592. Park, Wang, and Wu (1998), provide a detailed province by province listing of the new poverty counties.

Figure 2.1. Trends of income and poverty in China.



Income growth, poverty reduction and inequality

Per capita rural income in China was very low prior to the reform. In 1978, average income per rural resident was only 220 yuan per year, or about US$150 (figure 2.1). During the 29 years from 1949 to 1978, per capita income increased by only 95 percent, or 2.3 percent per annum (Fan, Zhang, Zhang 2001). China was one of the poorest countries in the world. However, since rural reforms in 1978, the per capita income increased to 552 yuan in 1984, a growth rate of 15 percent per year (figure 2.1). During the second stage of reforms (1985-89), rural income continued to increase, but at a much slower pace of 3 percent per annum. This was mainly due to the stagnation of agricultural production after the reforms.

Evidence shows that poverty reduction is greatly related to rural income growth and agricultural development, especially in the 1980s. In 1978, China's poverty population was as high as 260 million. However, in 1984, poverty population reduced to 89 million, poverty reduction was exceptionally rapid in this period. The incidence of rural poverty (poor as proportion of rural population) decreased from 30.7 percent in 1978 to 15.1 percent in 1984. This was also the quick growth period of rural income and agricultural production in China. Because of the equitable distribution of land to families, income inequality, measured as Gini coefficient, increased only slightly, from 0.21 in 1978 to 0.26 in 1984 (Fan, Zhang and Zhang 2001)).

The effects of fast agricultural growth on rural poverty were largely exhausted by the end of 1984 (Fan, Zhang and Zhang 2001). Over the period of 1985-1989, rural income distribution became less egalitarian, and the Gini index rose from 0.264 to 0.301. The ratio of per capita rural income in coastal regions to that in other areas also increased, from 1.21 to 1.51. These changes in income distribution probably resulted from the changed nature of income gains and the growing differential in rural non-farm opportunities among regions (Rozelle 1994). As a result, the number of poor increased from 89 million in 1984 to 103 million in 1989, a net gain of 14 million in five years (figure 2.1).

Only in 1990 did rural poverty begin to decline once again. The number of poor dropped to 9 percent per annum; from 103 million in 1989 to 50 million in 1997 (figure 2.1). Moreover, the rate of rural poverty reduction was faster than that of income growth (5% per annum) during the period, indicating that factors other than income growth were at play (Fan, Zhang and Zhang 2001).

Poverty distribution

In the 1980s, aside from those in counties under special military administration, most of China's poor lived among the more than 200 million residents, who resided in officially designated poor counties (Piazza and Liang 1997). These poor counties were distributed across 23 of China's 27 provinces, but 78 percent of them were concentrated to the west of a north-south line that runs through the central mountainous parts of the country from Heilongjiang, Gansu, and Inner Mongolia in the north to Guangxi and Yunnan in the south. The remaining "poor" counties, generally better-off among all poor counties, were located in the less contiguous islands in the hills of eastern and south-eastern China.

Poor counties in the first wave of officially designated counties were normally characterized as being poorly endowed by geographic location (remote and mountainous) and at a disadvantage in terms of agricultural resources (such as soil, rainfall, and climate (Tong et al. 1994). Many of these areas suffer from severe ecological damage such as deforestation and erosion (Li 1994). Poor counties also tend to have more variable yields (Weersink and Rozelle 1997). Partly as a result of these poor natural conditions, and partly as a result of poverty itself, farmers in poor areas suffer from below average irrigation facilities, fertilizer use, and general infrastructure (Tong et al. 1994). Poor counties in the 1980s were still highly subsistent in their grain needs, and in net terms, often needed to procure grain to meet household demand (Piazza and Liang 1997). Participation in non-farm labor markets in the 1980s lagged far behind the national average (Rozelle et al. 1999).

PRO-POOR STRATEGIES AND THEIR EFFECTIVENESS

Subsidizing before 1986

Though the leaders had not formulated an explicit national policy on poverty alleviation prior to 1986, this did not mean that the rural poor did not receive special attention. With little to lose, given the marginal contribution of poor areas to the overall economy, reformers permitted communes in poor areas to de-collectivize earlier than other areas (as early as the late 1970s). The central government was already subsidizing poor areas, both through direct budgetary transfers (Park et al. 1996) and through subsidized grain sales and other assistance to farmers in need (Park, Rozelle, and Cai 1994). With fiscal decentralization and increasing scarcity of budgetary resources, however, these forms of support were reduced over time. Market reforms led to widespread increases in production specialization, yields, and income (Weersink and Rozelle 1997). These changes helped many escape poverty, especially those in central and coastal China that had been hurt most by grain-first policies, because they lived in areas not well-suited for grain production (Lardy 1983).

Investment on increasing growth of Income

After 1986 the government unleashed a major set of investments to increase growth of incomes in poor areas. Between 1986 and 1997 the government invested over 96 billion yuan through its main poverty alleviation loan, food for work, and grants programs. Nominal investments in poor areas increased every year except in 1992 and 1996. In real terms (after adjusting for the impact of inflation), however, the picture is still impressive though the trend is worrisome. In 1985, total expenditure reached 46 billion yuan. After increasing steadily between 1986 and 1990, however, real expenditure in poor areas have fallen (when comparing, for example, the first three years of the 1990s (1990-92) to the most recent three-year period (1995-97).

Grants and Loans to Households

In 1986, the State Council formed an inter-ministerial Leading Group for Economic Development in Poor Areas, at the national level, to administer a new investment program allocating 4 billion yuan per year to 300 nationally designated poor counties. Provincial governments also designated additional poor counties to receive provincial support. By 1988, 698 counties received public help through these programs. Poor Area Development Offices (PADOs) were established at the provincial and county levels to administer funds from both national and provincial sources.

China's multi-level poverty alleviation network was funded by grants and loans approved by the State Council. In the first few years, most funds came from programs such as *laoshao bianqiong diqu daikuan* (subsidized credit for supporting old revolutionary bases, minority areas, and remote areas) and *bu fada diqu fazhan zijin* (development capital funds (DCF) for supporting under-developed areas). As the real value of grants declined due to inflation (the nominal level of funding for DCF remained largely unchanged from 1986 to 1993), new subsidized loan programs became the main form of poverty investment. In its initial years local PADO offices controlled most of the loan portfolios (Li and Li 1992). Agricultural Banks, which disbursed and collected the loans, exercised little decision-making authority, according to interviews with PADO and banking officials.

Policies during the period 1986-1988 stressed that funds should be allocated directly to poor households to support agricultural production and other income-generating projects (State

Council 1989a to 1989e; World Bank 1992). Program rules often required local poverty officials to allocate up to 80 percent of their funds for agricultural loans to households (Li and Li 1992).

After these first few years of implementation, poor area policies came under closer scrutiny. There was a general perception that much of the assistance was not spurring growth but was being used to support consumption directly (State Council 1989a to 1989e). As is typical for formal subsidized loan programs, loan repayment rates were low. Estimates of timely repayment on subsidized poverty loans range from 30-65 percent (Park, Wang, and Wu 1998). The main problem, as described in an important policy document, was that the long-term development of "social productive forces" in poor areas was being neglected (Zhou 1988; State Council 1989a to 1989e). Even after four years of targeted programs, there were still over 100 million rural poor in 1989. Interestingly, these conclusions were drawn based on limited data and observation. No systematic, large-scale evaluation of China's poverty program was ever conducted.

Targeting Development Projects

By the late 1980s, the widespread belief that economic growth in poor areas had stagnated led to a major policy shift. New directives ordered local officials to turn their attention away from poverty alleviation through direct transfers to households in favor of projects that would better promote economic development (State Council 1991). The new measures encouraged poor area officials to direct loans away from households and towards "economic entities" (*jingji shiti*) that could better coordinate activities requiring new technology, greater input use, and marketing support (State Council 1991). In recognition of the need for local governments to generate fiscal revenues, local officials were allowed to allocate more funds to enterprises. A new poverty loan program was established to support county state-owned enterprises. The Food-for-Work Program to support basic infrastructure construction, which had previously focused on roads and drinking water, was expanded to include infrastructure projects in agriculture designed to help spur long-term productivity increases (Zhu and Jiang 1994).

Local officials welcomed these changes. By the end of the 1980s, fiscal decentralization, which tied budgetary expenditure more closely to local revenues, had created a budgetary crisis in nearly all poor counties (Park et al. 1996). This created a strong incentive for local officials in poor areas to invest in revenue-producing enterprise rather than other growth-oriented activities, or to divert earmarked investment funds to meet fixed expenditure obligations such as wage payments to government cadres (Wu 1994; Park et al. 1996). Investment funds and loans were commonly channeled to county-run enterprises regardless of the investment's projected rate of return; this infusion of cash allowed government officials to transfer funds to the county budget (through fees and remittances or tax payments) or to shift fiscal burdens to enterprises (such as for hosting guests or paying travel costs).

Banking reforms in the late 1980s also affected the allocation of investment funds. Reforms made bankers more responsible for their profits and losses (Park and Rozelle 1997; Li and Li 1992). In response, bank managers began to assert more influence on loan decisions, including subsidized poverty loans. Conflicts arose between bank managers and PADO officials over proposed projects. Given the excessive demand for low interest loans, bankers also began to target borrowers with less risky projects or larger projects that made loans less costly to administer (Du 1994). As is common in rural settings, banks sought to ration out the poor, who have fewer assets, demand small loans with high transaction costs, and face greater uncertainty over crop yields (Carter 1988). Thus, the poverty policy shift in emphasis from household to enterprise, and from agriculture to industry, was re-enforced by changing incentives caused by fiscal and banking reforms.

Shifts in the 1990s

There was a growing consensus among some of those interested in poverty work that, by the mid-1990s, the subsidized credit directed at jingji shiti for integrated agricultural/rural development had not met any of its goals. Repayment rate on loans did not increase markedly. In one interview by the authors with banking officials in northern Shaanxi, we were told that repayment rates of subsidized loans in the northernmost prefecture of the province were less than 40 percent. A provincial leading group project officer in Sichuan revealed that only about 25 percent of the loans to jingji shiti were ever repaid in full, and partial repayments made were only slightly more than 50 percent.

The effectiveness in stimulating local development of subsidized poverty loans also became increasingly suspect. Field work frequently uncovered cases in which farmers were forced into collective projects in pursuit of scale economies that they did not want to participate in. In other cases, loans were taken out by jingji shiti managers for projects that were not appropriate for the local economy; projects that often ended in failure and unpaid debts. Loans were often diverted into economic entities that had political and fiscal importance (Park et al. 1996). A later section describes the results of one study that measures the ineffectiveness of loans to counties and townships, and the greater impact on growth of loans to farm households.

The largest problem of lending to economic entities was that there was less effort to direct the funding to poor households. Many of the loans were given to township and village enterprises (TVEs) or county-owned enterprises, which increased the local revenue base for local governments but did not greatly benefit poor households (Wu 1994). Wu's work shows how very few poor farmers in investment sites get access to loans at all, and when they do, how they receive much smaller ones than their non-poor counter parts. The failure of the program in reaching the poor was criticized by researchers and some local leaders. At the National Work Conference on Poverty in September, 1996, the Chinese Government decided to return the focus of lending to providing direct loans to poor households.

With the slowing of poverty reduction, the government introduced several anti-poverty programs between 1984 and 1986. It also established the Leading Group for Poverty Reduction (LGPR) under the State Council to coordinate those programs and expedite economic development in poor areas. Economic growth did revive, and since 1991 another 40 million residents escaped poverty -- about 49 million, or about six percent of the rural population, remained in absolute poverty at the end of 1997. By the end of 1998, 42 million people were officially reported to live under absolute poverty. The government has a strong commitment to poverty reduction, and most government agencies and ministries have special poverty reduction responsibilities, including, education and health programs administered by their respective ministries. The LGPR coordinates special development grant funds, administered through the fiscal system, and the Poverty Reduction Fund, which provides subsidized loans for developing poor areas. The regional office of the State Development Planning Commission administers a Food for Work (FFW) program that supports the construction of roads, potable water systems, irrigation, terracing, and other work in rural infrastructure. Subsidized credit through the Poverty Reduction Fund has become the most important element of the poverty program. During the late 1980s these funds were allocated primarily to households to support agricultural production and other income-generating activities (World Bank 1992). However, by the early 1990s, borrowed funds were generally conceived as financing consumption rather than production, repayment rates were very low, and economic growth in poor areas had stagnated, as evidenced by the lack of reduction in the number of absolute poor. As a result, leaders shifted the focus of the poverty alleviation programs from households to "economic entities" or enterprises that could better coordinate activities requiring new technology, greater input use, and marketing support (State Council 1991). Fiscal decentralization, however, had created a budgetary crisis in nearly all poor counties (Park et al. 1996), which, in turn, created strong incentives for local officials in poor areas to invest in revenue-producing enterprises rather than in growth-oriented activities, or to divert earmarked investment funds to meet fixed expenditure obligations, such as wage payments.

By the mid-1990s, it became clear that subsidized credit directed to enterprises was not meeting rural development and growth objectives. The credit did not appear to stimulate local development and loan repayment rates did not markedly improve. The investment approach was often "top-down" as local officials identified collective projects without due consultation with farmers in pursuit of economy of scale. Rozelle, Park, Wong, and Ren (forthcoming) have empirical evidence of the failure of China's subsidized credit program in Shaanxi during the early 1990s.

When leaders reassessed the poverty reduction effort in the mid-1990s, the focus of subsidized loans returned to poor households. Since then, a debate has raged about how to create an effective system to reach the poor households. Officials are searching for a program that will lead to growth, reduce poverty, reduce lending costs, and improve repayment rates. This has led to widespread experiments of micro-finance programs, which to date, have had mixed results and has stimulated a great deal of debate in terms of its effectiveness and sustainability.

Evidence on effectiveness of pro-poor strategies

Rapid economic growth has led to extraordinary success in reduction of poverty in rural China. Few studies have analyzed the causes of this success. A 1992 World Bank country study represents the first comprehensive analysis on the incidence and correlates of rural poverty in China. The study concluded that rural economic reforms have contributed tremendously to the rapid reduction of rural poverty, and that poverty is now almost entirely restricted to resource-constrained, remote, upland areas. In more recent years, rural household survey data have been used to re-estimate the incidence of poverty and changes over time for four provinces in Southwest China (Jalan and Ravallion 1996; Jalan and Ravallion 1997; and Chen and Ravallion 1996). A large effort was made to construct a panel dataset at the household level from 1985 to 1990. The analyses from this panel dataset reveal that consumption variability accounts for a large share of observed poverty, and is likely to be a severe constraint on efforts to reach the long-term poor. Therefore, effective insurance and credit options for poor people are critical to alleviate persistent inequality problems. Gustafsson and Li (1998), analyzed the structure of Chinese poverty for 1988. One significant finding from this study is that the rural poor are not limited to remote resource-poor areas, in contrast with the World Bank (1992) report. Using a small sample of 500 rural households, Wu et al. (1996), attributed rural poverty to low levels of factor endowment and immobility of labor and demographic characteristics of households. Khan (1997), updated the trend and pattern of Chinese poverty in a recent article. One contribution of his study is to adjust the poverty measures at the provincial level, and his measures are sharply different from those of the Chinese government. Rozelle et al. (2000), recently comprehensively reviewed the government policies regarding poor area development, concluding that such policies have generally failed to reduce rural poverty in these poor areas.

Using provincial level data for 1970-97, Fan, Zhang and Zhang (2000), has developed a simultaneous equation model to estimate the effects of different types of government expenditure on growth, regional inequality, and rural poverty in China. The results show that government spending on production enhancing investments, such as agricultural R&D and irrigation, rural education and infrastructure (including roads, electricity, and communication) has contributed to agricultural production growth, regional inequality and reduction in rural poverty. But differences in their distributional effects and production effects are large among different types of spending as well as across regions.

Government expenditure on education has the largest impact on both poverty reduction and growth in the overall rural economy. Among all types of investments, more investment in education in less-developed areas (the west region) also contributed most to greater regional equality. Government spending on agricultural research and extension has improved agricultural production substantially. In fact, this type of expenditure has fetched the largest returns to agricultural production. Government spending on rural communication, electricity, and roads have the second, third and fourth largest impact on rural poverty reduction. These poverty reduction effects mainly come from improved non-farm employment and increased rural wages. In particular, road investment has the largest impact on the non-farm economy, and the second largest impact on the overall rural economy, only slightly lower than education investment.

Irrigation investment has had only a modest impact on growth in agricultural production and an even smaller impact on rural poverty reduction even after allowing for trickle- down benefits. This is consistent with the results found by Fan, Hazell, and Thorat (1999), for India. China and India have invested heavily in irrigation in the past. Large-scale irrigation facilities have been built, and a high percentage of the arable land is now under irrigation. Therefore, the marginal returns from further investment may be declining and small, and the more limited funds should be used for improving the efficiency of existing public irrigation systems.

Why are the marginal returns of irrigation investment less than other public investments? How can irrigation play an important role in poverty reduction? Can irrigation management, especially surface water irrigation management reforms be beneficial to the poor people? are some issues that need to be addressed.

IRRIGATION DEVELOPMENT

Since the establishment of the People's Republic of China, emphasis of the rural water conservancy is to increase effective irrigated area and improve the agricultural production conditions. Based on increased characteristics of effective irrigated area in China, development of rural water conservancy in China can be divided into six stages to analyze the changes of basic infrastructure investments of water conservancy in various periods (Wang 2000). For Development of irrigation area, see table 2.1.

Table 2.1. Change in trend of effective irrigated area and cultivated area in China.

Year	Cultivated area (10,000 ha)	Effective irrigated area (10,000 ha)	Share of effective irrigated area (%)
1949	9,788	1,593	16.3
1952	10,792	1,934	17.9
1957	11,183	2,500	22.4
1962	10,290	2,870	27.9
1965	10,359	3,204	30.9
1975	9,971	4,612	46.3
1978	9,939	4,805	48.3
1979	9,950	4,832	48.6
1982	9,861	4,866	49.4
1983	9,836	4,855	49.4
1984	9,785	4,840	49.5
1985	9,685	4,793	49.5
1986	9,623	4,787	49.7
1987	9,589	4,797	50.0
1988	9,572	4,791	50.1
1989	9,566	4,834	50.5
1990	9,567	4,839	50.6
1991	9,565	4,895	51.2
1992	9,543	4,946	51.8
1993	9,510	4,984	52.4
1994	9,491	4,994	52.6
1995	9,497	5,041	53.1
1996	9,497	5,116	53.9
1997	9,497	5,227	55.0

Data source: Wang (2000).

First stage (1949-1957): Rapid growth period of rural water conservancy

In the land revolutionary period, comrade Zhedong Mao proposed a scientific judgment that "water conservancy is the lifeblood of agriculture". Three years before establishment of the People's Republic of China were resume periods of national economy, when resume and construction of water conservancy were treated as an important link of the national economy resume. In 1950, the Ministry of Agriculture held a working conference of rural water conservancy; the working guidelines of rural water conservancy was: "Extensively mobilize masses, greatly resume rural water conservancy construction, apply state investment, loan with plan and emphasis, greatly organize masses' fund and absorb private capital to invest in rural water conservancy, help improve original management institution, strengthen irrigation management and gradually realize rational utilization and establish and perfect various institutions". In 1953, the Central Government proposed general guidelines for the transition period. At the same time, national economic construction entered into the first five-year plan period. Emphasis of rural water conservancy had shifted from resume previous irrigation and drainage engineering, to construct new engineering facilities according to national economy development requirements step-by-step in a planned way and gradually improve and enlarge natural disaster resistance ability and play water resources benefits more effectively.

Water conservancy in this period developed very quickly; effective irrigated area increased from 15,930 thousand hectares in 1949 to 25,000 hectares in 1957; the average annual increase rate was 5.8 percent, share of effective irrigated area increased from 16.3 percent to 22.4 percent. Water infrastructure investment (real price in 1990) steadily increased from 500 million yuan in 1951 to 18 billion yuan in 1957; average annual increase rate was 20.1 percent and it was the quickest period since 1949. Increased rate of water infrastructure investment and national water infrastructure investment was almost in the same period, average share of water infrastructure investment over national infrastructure investment was 5.3 percent.

The second stage (1957-1965): *Continue increase period of rural water conservancy.*

Although influenced by progressive errors of "Great Leap Forward" and "People's Commune Movement," effective irrigated area still increased at an annual 3.1 percent; share of effective irrigated area reached 30.9 percent in 1965. Compared with the first stage, increase rate of water infrastructure investment (real price in 1990) of this period was relatively slow, average annual increase rate is only 2.4 percent, which was still higher than the national infrastructure investment (real price in 1990) of 1.5 percent; while share of water infrastructure investment over total national infrastructure investment reached 7.6 percent, the largest share period in history. This indicated that rural water conservancy still received high attention of the government.

The third stage (1965-1975): Relatively rapid increase period of rural water conservancy

"The Great Cultural Revolution" begun in 1966 plunged the state into a disturbance status of ten years, when development of rural water conservancy was not lashed much. Effective irrigated area in this period increased from 32,040 hectares in 1965 to 4,612 hectares in 1975; average annual increase rate is 3.7 percent, which was only lower than that of the first period development rate. Average annual growth rate of water conservancy was also very quick at 10.1 percent, which was higher than that of the national total infrastructure investment of 8.8 percent; share of water conservancy investment reached 7 percent.

The fourth stage (1975-1982): *Slow increase period of rural water conservancy.*

In this period, rural water conservancy was slow, share of effective irrigated area was only 0.8 percent, water infrastructure investment (real price in 1990) reduced from 5.6 billion yuan in 1975 to 3.2 billion yuan in 1982; average annual decrease rate was 7.6 percent; share of water infrastructure investment over total national infrastructure investment was 5.9 percent.

The fifth stage (1982-1986): *Backward period of rural water conservancy.*

Although rural reform policies have greatly promoted rural and agricultural development of China, rural water conservancy fell into a never-before-experienced backward period. Effective area annually decreased from 48,660 hectares in 1982 to 47,870 hectares in 1986; 790,000 hectares of effective irrigated areas were reduced; average annual reduce rate was 0.4 percent; the only decrease period of effective irrigated area since 1949. From water conservancy investment, average annual growth rate (real price in 1990) of water infrastructure investment was 2.1 percent, only 2.7 percent of the national infrastructure investment. Obviously, compared with other industries' development in this period, water conservancy was overlooked.

The sixth stage (1986-1990): *Stagnation and slow resume period of rural water conservancy construction.*

Continued decrease in effective irrigated area from 1982 to 1986 captured the attention of government and society. In 1986 and 1987, two successive rural water conservancy symposiums were held by the rural water policy research house of the Central Committee of the Communist Party of China, and the Ministry of Water Resources and Electric Power, which fully confirmed achievements of rural water conservancy in the past 30 years; existing crises were also pointed out such as:

1. Considerable quantities of water conservancy are aging, poorly maintained and benefit decreased; drainage and flood resistance ability of canals also decreased obviously. Urban industry construction occupied irrigated areas and water source and water facilities were also destroyed and stolen by people.
2. Water resources are very short especially in North China and coastal regions. Groundwater was over-drafted greatly which made a sharp decline in the groundwater table and land subsidence and disorder of the ecological system. Pollution of water sources also reached a shocking degree.
3. Construction scale of rural water conservancy was somewhat small; accumulated labor in some provinces could only supply 1-2 labor in winter while water investment in some provinces continued to decline.

As a result of lack of attention by society and government, rural water conservancy construction shifted from backward to stagnant, and slowed increase; average annual growth rate was only 0.3 percent; increased from 47,870 thousand hectares in 1986 to 48,390 thousand hectares in 1990, still equal to effective irrigated area in 1978 and lower than that in 1982. For water infrastructure investment, growth rate of water infrastructure investment (real price in 1990) was quicker than that in the early 1980s, reached 8.6 percent, while ratio of water infrastructure investment declined to the lowest level in history at 2.2 percent.

The seventh stage (1990-1997): *Relatively rapid increase period of rural water conservancy construction.*

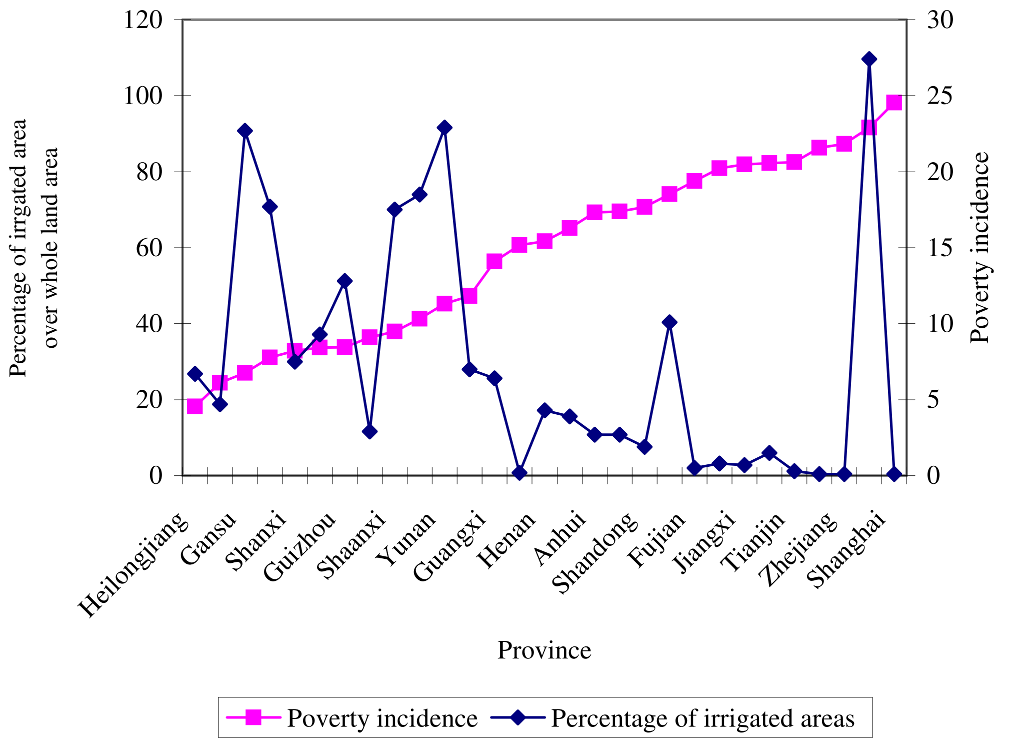
In the 1990s, China's economic system reform had gradually deepened and rural water conservancy had gradually freed away from a stagnant situation and increased relatively quickly. In this period, the average annual growth rate of effective irrigated area reached 1.3 percent, the quickest development stage since rural reform. Annual growth rate of water infrastructure investment (real price in 1990) was as high as 19.7 percent, only second to that in the first stage, and only in this stage, the growth rate of water infrastructure investment was higher than that of the national infrastructure investment. Although annual growth rate of water infrastructure accelerated, share of water infrastructure over total national infrastructure investment was only 2.8 percent, far lower than that before the 1980s.

Above analyses of each development stage indicates that the greatest development of rural water conservancy mainly occurred in the period 1950s to 1970s. Before the 1980s, water infrastructure construction always occupied an important position in national economy; although some fluctuations of share of water infrastructure investment existed, generally, an average 5.3 percent to 7.6 percent was kept. Since rural reform, although there were many "policies", "emphasizing", "strengthening", "great development", etc., most were hard to be implemented; in actuality, the government overlooked water conservancy and the proportion of water infrastructure investment over total national infrastructure investment exhibited an annual decline trend.

RELATIONSHIP BETWEEN IRRIGATION AND POVERTY

On applying provincial data to the percentage of irrigated area over total land area and poverty incidence in 1996, we can understand the relationship between irrigation and poverty. Figure 2.2 shows the negative relationship between share of irrigation area and poverty incidence. Generally, except for Xinjiang province (a full irrigation area), if provinces have a high share of irrigated area, poverty incidence in these provinces are also relatively low; this implies the importance of irrigation in poverty reduction.

Figure 2.2. Relationship between irrigated area and poverty incidence in China.



However, from the second section's analysis of development of irrigated areas, since the 1980s, development of irrigation area has showed a decline and a stagnant trend. Even with the Central Government's increased investment in irrigation since the late 1990s, the potential of contribution of irrigation area to poverty reduction is still very limited. This is same as the empirical research of Fan, Zhang and Zhang in 2001. In any case, there is no doubt that irrigation is still important for poor farmers; therefore, under conditions of limited development of irrigated areas in most regions, how to improve water management and water productivity is the key to poverty reduction.

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Appendix 2.1. Major Milestones in Reforming Chinese Agriculture

- *1950-52 Land reform:* Land owned by landlords was confiscated and redistributed to landless or small-scale farmers. By 1952, the land reform was complete.
- *1953-57 Cooperation*: After 1952, mutual aid farming groups were formed on a voluntary basis. Land was still owned by individual households. From 1955 onwards more advanced cooperatives were formed at the strong suggestion of the government. Land and other production inputs were owned by cooperatives. By 1957, 90 percent of households participated in these cooperatives.
- *1958-60 Great leap forward and communication:* Communes were formed based on advanced cooperatives. The size of communes was large and the distribution of food was based on need rather than any economic mechanism.
- *1961-65 Economic adjustments:* Adjustments and consolidation policy were implemented in 1962 after the failure of the commune system. Agricultural production was decentralized into small units (the production teams).
- *1966-76 Cultural Revolution:* Three levels of ownership – commune, brigade, and production team – were implemented with the production team as their basis. Private ownership of land and marketing of agricultural products were severely restricted outside the government procurement system.
- *1979-84 First phase reforms:* In 1979, procurement prices for 18 commodities were raised (50% increase for above-quota sales). The household production responsibility system was introduced, and by 1984 more than 96 percent of households operated under the system. The number of commodities under state monopoly procurement control was reduced from 100 to 51 in 1993, and to 38 by end-1984.
- *1985-89 Second phase reforms:* The monopoly procurement system was changed from mandatory to a voluntary contract system. Above-quota prices were reduced.
- *1990s New stage:* The urban grain rationing system was abolished in 1993. Land contract between farmers and collectives was extended for another 30 years. Procurement prices for grains were increased by 40 percent in 1994 and again by 42 percent in 1996. In 1997, the government regained a certain amount of control over the grain marketing system.

Sources: Fan, Zhang and Zhang 2001.

Appendix 2.2. Chronology of Poverty Alleviation Policies

September 29, 1984
The CPC Central Committee and State Council jointly issued a circular calling on party committees and governments at all levels to adopt practical measures to help people in impoverished areas, and eliminate poverty at the earliest possible date.

April 1986
Poverty relief work was included in the Seventh Five-Year Plan for National Economic and Social Development. The State Council established a Leading Group for Economic Development of Impoverished Areas. The State Science and Technology Commission, State Nationalities Affairs Commission, and the Ministry of Agriculture launched their respective poverty-relief programs geared to selected areas.

October 30, 1987
The State Council announced the Circular on Promoting Economic Development in Poor Areas. It demanded that the efficiency of funds for development be raised to realize the Seventh Five-Year Plan objectives for solving problems of food and clothing among the majority of population in poor areas.

May 1991
The State Council approved the Report on the Work of Poverty Alleviation and Development in the Eighth Five-Year Plan by the Leading Group for Economic Development of Impoverished Areas. It stipulated that efforts should focus on promoting farmland capital construction and raising grain output so as to enable rural households to have a stable source of income for adequate food and clothing.

September 1993
The State Council approved the National Poverty-Relief Program, which aimed to ensure adequate food and clothing for the existing 80 million poor within seven years (from 1994 to 2000). At the same time, the Leading Group for Economic Development of Impoverished Areas was renamed the State Council Leading Group Office of Poverty Alleviation and Development.

March 6, 1995
At the UN World Summit on Social Development Held in Denmark, Premier Li Peng announced that China will eliminate object poverty in rural areas by the end of this century.

September 23, 1996
General Secretary Jiang Zemin delivered an important speech at the CPC Central Committee's meeting on poverty-relief work. He urged that no effort be spared to realize the goals of the National Poverty-Relief Program as planned.

May 6, 1997
At the 25th Meeting of the NPC Standing Committee, State Councilor Chen Junsheng suggested that poverty-relief work be listed on the agenda of legislation to guarantee the continuity and stability of the work, and that a national law on poverty relief be formulated.

Sources: Fan, Zhang and Zhang 2001.

CHAPTER 3

Irrigation Management Institutions in China—An Overview

SCARCE WATER RESOURCES IN CHINA

While China has large water resources compared to other countries, its population is comparatively even larger and its water is not evenly distributed across the country or across important agricultural regions. China ranks fifth in total water resources among the countries in the world, but on a per capita basis, it is among the poorest. The nation's water resources are overwhelmingly concentrated in southern China, while northern China, the area north of the Yangtse River Basin, has a far lower per-capita water endowment (Ministry of Water Resources 1998). The lower levels of rainfall in North China are also much more seasonal than in the South, with over 70 percent of the rain falling between the months of June and September. Northern China, however, remains an important agricultural region and the site for much of China's industrial production (State Statistical Bureau 1999). Although it only has 24 percent of the nation's water resources, northern China contains over 65 percent of China's cultivated land, produces roughly half of its grain (and nearly all of China's wheat and corn), and over 45 percent of the nation's Gross Domestic Product (GDP) (Ministry of Water Resources 1998; State Statistical Bureau 1999).

Increasing industrial output, expanding agricultural production, and rising domestic incomes have all contributed to the depletion of water resources in China. From 1949 to 1998, per capita use has increased 130 percent and total water use in China has increased 430 percent (Wang 2000). The industrial sector has experienced most of the increase; the average annual growth in water consumption for industries was 8.6 percent over the period, compared to just 2.7 percent for agriculture. Hence, over the period 1949 to 1998, the share of China's water resources consumed by agricultural producers fell from 97 percent to 69 percent. Industry's share rose from 2 to 21 percent and domestic and other consumption rose from 1 to around 10 percent.

The effects of the increase in water demand have been most acute in northern China. As demand increased in the industrial and urban sectors, shortages of water resources forced officials to cut back on deliveries of water to farmers in some provinces. In many parts of northern China (for example, in northern Anhui, northern Jiangsu, Shandong, Shanxi, Gansu, Qinghai, and Xinjiang Provinces and the Provincial-level Municipalities of Beijing and Tianjin), agricultural water consumption declined from 1994 to 1998 (Ministry of Water Resources 1994-98). In other areas (e.g., Liaoning, Jinlin, Heilongjiang, Hebei, Shanxi, Henan, Inner Mongolia, and Ningxia Provinces), water demand in agriculture increased, but only modestly. In contrast, industrial water use increased further over the period, especially in the industrial centers of Beijing, Tianjin and Shenyang, and provinces such as Hebei and Shandong that have high concentrations of urban and rural industries.

The rapidly rising non-agricultural demand for water is not the only problem facing agricultural water users in North China; water deliveries to agriculture are also threatened by deteriorating surface water delivery infrastructure and by excessive withdrawals upstream. Large portions of China's physical water storage and transfer infrastructure, much of which was poorly built during the People's Communes (1950s to late 1970s) are rapidly deteriorating and investment funds have lagged and are generally towards newer projects rather than maintenance of older projects. The river systems that supply water to many surface systems also sometimes do not provide sufficient water because, upstream users withdraw more water than are supposed to under law. Because of excessive upstream withdrawals, the Yellow River has run dry before reaching the ocean for at least some period every year since 1974 (except in 2000, due to new enforcement rules).

In many areas in northern China, increased agricultural water use and the related production increases have been partly due to easily exploitable ground water that has allowed farmers to irrigate a winter wheat crop, usually corn, in addition to another crop in the later summer season, (Stone 1993). For example, in 1995, two wheat growing provinces, Hebei and Shanxi, relied on ground water for more than 50 percent of their total irrigation water consumption (Ministry of Water Resources 1995). In other important wheat growing provinces, such as Shandong and Shaanxi, the share of ground water in irrigation use is above 40 percent. Faced with increasing water demand and declining surface water supply and reliability, many farmers have begun to exploit ground water instead of surface water (Wang 2000). The coastal parts of northern China (including northern Jiangsu, Shandong, Hebei, and Liaoning) have also seen irrigated acreage from ground water exploitation expand more rapidly than in the inland areas, where there is relatively less access to ground water (Ministry of Water Resources 1998).

Ground water is also the primary source of water used in industry and for domestic consumption in many regions (Ministry of Water Resources 1995). In 1995, the share of industrial water deliveries that came from ground water sources was above 50 percent in nearly all of northern China, and was above 80 percent for some provinces, such as Hebei and Shaanxi. Most of China's northern provinces also receive a majority of their domestic water deliveries from ground water sources. For example, in Ningxia and Inner Mongolia ground water supplied more than 90 percent of the domestic water consumption.

Increasing demand, limited surface water availability and reliability, and rising reliance on ground water extraction has led to falling water tables and a number of other problems in North China. For example, in Feixiang county, a county located in the upstream part of the Fuyang River basin in Hebei Province, the shallow ground water table fell at a rate of 0.6 meters per year in the 1980s and 1.3 meters per year in the 1990s (Hebei Hydrological Bureau and Water Environmental Monitor Center 1999). Even greater rates of decline occurred in the middle and downstream parts of the basin. In addition, the deep water table is declining at an even faster rate, currently declining by about 1.7 meters per year. Due to the over exploitation of ground water, cones of depressions or areas, where the water table has dropped in an upside-down cone formation, have developed under urban areas in six Hebei Province prefectures: Handan, Shijiazhuang, Xingtai, Hengshui, Cangzhou and Baoding municipalities. Land subsidence has also occurred in some predominantly rural counties such as in Henshui, Ren and Quzhou counties (Smil 1993; Hebei Hydrological Bureau and Water Environmental Monitor Center 1999).

While the long-run impact of the falling water table in North China is not clear, current rates of extraction are not sustainable given the current rates of recharge. In the longer run, areas with cones of depression may even lose their capacity to hold large quantities of ground water. In this and other ways, the subsidence brought on by ground water depletion may permanently harm the land's capacity for ground water storage. However, if effective water-saving practices can be implemented or if new water sources can be found in the near future, the present levels of ground water depletion would not necessarily represent permanent damage, because, most of northern China's ground water can be recharged through surface water infiltration, if the withdrawals are sufficiently reduced (Nickum 1998).

Large ground water extractions and the subsequent fall in the water table could also affect the quality of water, particularly, through the intrusion of seawater. A survey carried out in the coastal provinces of northern China in the early 1990s found that over 2,000 square km of formally fresh water table had fallen below sea level (Nickum 1998). Farmers, industrialists and city water managers abandoned more than 8,000 tubewells, and irrigated area declined by 40,000 hectares. While these losses represent only a small part of the overall agricultural production in North China, they do significantly impact residents in the affected regions and some observers predict that unless ground water sources are allowed to replenish, these problems will increase at an accelerating rate.

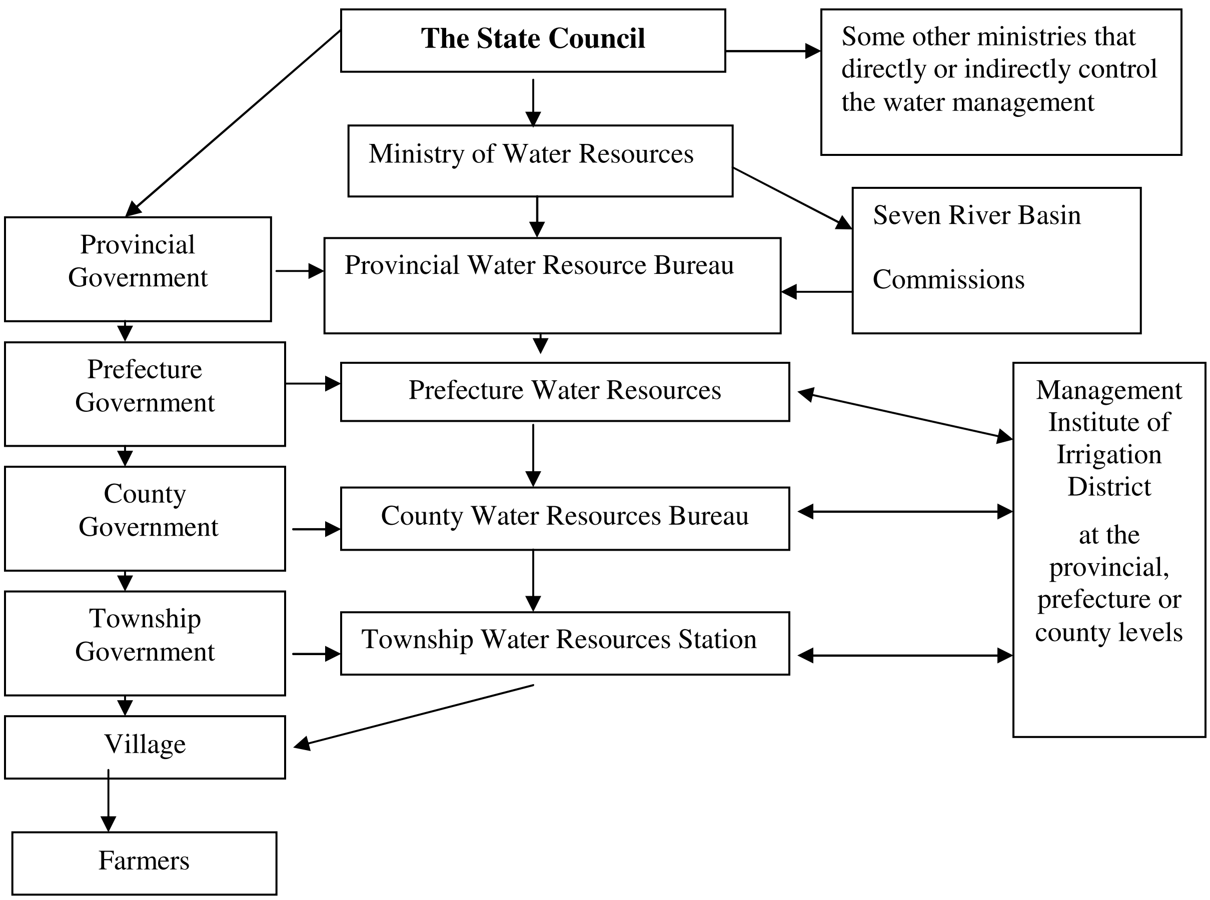
INSTITUTIONAL RESPONSES TO INCREASING WATER SHORTAGE

China is starting to see the long-term impacts of excessive water exploitation and is facing water scarcity problems that might become a serious crisis in the near future, unless, of course, policies are adopted and institutions emerge to avert such an event. Although water scarcity in northern China has been building up for decades, it has only recently begun to affect the livelihoods of people and threaten the profitability of economic activity. Unchecked, the problems could develop into catastrophic proportions. China, however, has begun to address these problems at nearly all levels, from the national down to the village and farm levels. In some cases, progress is difficult to detect, but given the length of time it took to generate these problems, it is reasonable to assume that the solutions will also be difficult to implement and progress will be slow. To understand the actions taken by the government, local leaders and individuals, in the following several sections we will examine the complex arrangements that govern how China recovers, stores, allocates and manages its water resources and institutional response.

WATER-RELATED INSTITUTIONS IN CHINA

In China, water resources are administered by a nested hierarchical administrative system. Figure 3.1 presents the structure of water management authorities in China. Article 9 of the 1988 Water Law stipulates that the water management system in China is a complex of sector-responsible and level-responsible management combined with integrated management under the control of the central government. However, Article 9 has received considerable criticism from officials and scholars in China because it results in unclear division of responsibilities across various sectors, and each level's government, and therefore, poses difficulty in realizing an integrated water management system.

Figure 3.1. Institutional arrangements for water management in China.



The Ministry of Water Resources (MWR) is the highest at the central level directly under the State Council, with Water Resource Bureaus (WRB) at the provincial, prefecture and county levels. Water Management Stations at the township are the lowest levels of state administration. Water Resource Bureaus at the provincial, prefecture and country levels are controlled jointly by the government at the same level and the MWR. Actually, water resource bureaus at sub-national level are mainly controlled by the government at the same level since governors of water resource bureaus are appointed by the government at the same level. Relationship between the MWR and sub-national water resource bureaus is technical guidance through issuing water policy, law and regulations to sub-national water resource bureaus, while the MWR can also control part functions of local water resources bureau through allocating some water infrastructure investment.

Below the national level, Irrigation Districts (IDs) were developed to administer water resources that span lower-level administrative boundaries. Any given ID always reports to the officials in the WRB that encompasses the district's entire command area. For example, if an ID includes two or more prefectures, it is under the provincial WRB, but if it lies in two or more counties within the same prefecture, it is under the control of the prefecture's WRB.

The ultimate duty of Water Resource Bureaus has always been to create and manage water allocation plans, conserve limited water supplies in deficit areas, and administer water infrastructure investment. In the early years of the People's Republic of China, the WRBs were mainly in charge of surface water development and management, working through a system of regional and local irrigation districts (IDs). The primary task of local water policy managers is to translate investment dollars into infrastructure, maintain the system once it is in place, and manage the water flows within and among IDs. More recently, WRBs in most regions of northern China spend more of their time assisting in the development of and attempting to control ground water resources, though control of groundwater resources has been more difficult. One approach has been to control the number and location of wells. In the pre- and early reform years (up through the late 1980s), the monopolization of well-drilling activity gave local authorities a fairly comprehensive control over the access to groundwater since most deep wells (and many shallow wells) were sunk by well-drilling enterprises owned and operated by the WRB.[3] In recent years, however, the rise of private well-drilling companies and competition among locally state-owned (owned by either a township or a village) well-drilling companies has reduced this avenue of control. In this new environment, local WRBs are still charged with controlling ground water extraction by using their authority to issue all well-drilling permits for water extraction and management (Wang and Huang 2000).[4] We have, however, encountered many exceptions to this process. For example, Urban Construction Bureaus are notoriously independent and in many cases urban units operate on their own without the oversight of the WRBs. The WRBs are also charged with overseeing a system of permit rights to draw groundwater in addition to well-drilling rights. This system is intended to allow them to operate a de facto groundwater allocation plan, but it has not always worked in practice.

This system of water administration is supplemented by seven river commissions, which are administered by the MWR. The Yellow River Basin Commission and Huai River Basin Commission are all old commissions created in the 1930s, while the Pearl River Basin Commission, Hai River Basin Commission, Songliao River Basin Commission and Taihu Lake Commission were all created in the 1980s. The Seven river commissions are responsible for

[3]Although, until recently, wells were mostly drilled by enterprises set up and controlled by the local WRB, the wells themselves were often managed on a day-to-day basis by the collective, enterprise, or some other agency. Today, many of the wells are drilled and operated by private entrepreneurs.

[4]The control over water permits in urban areas by local WRBs was institutionalized in 1998 by a State Council directive in 1998, although it has not been effectively implemented in all areas (Wang and Huang 2000).

coordinating water allocation between provinces by implementing the policies of the MWR. As subordinate agencies of the MWR, these commissions have no independent decision-making power while coordinating water allocation between provinces.

Besides the administrative system of the MWR, there are several other government authorities with some direct or indirect water management responsibilities such as bureaus or agencies of construction, geography and mining, environment protection, energy resource, meteorology, finance, and so on (figure 3.1). Therefore, water management in China is very complex, as it reflects the various interests of governmental agencies. Faced with increasing water shortages in most northern regions and even in some southern regions, and realizing the importance of an integrated water management has recently become an important target of the central government agency reform.

CONFLICTS IN WATER MANAGEMENT

Water management conflicts arise in several areas, including the rural and urban water uses, surface and groundwater balance, water quantity and water quality control, et al. For example, surface water and rural groundwater is administrated by the MWR, while the urban groundwater is administrated by the Ministry of Construction (MOC). Other special groundwater including heat and mining groundwater is governed by the Ministry of Geological and Mining Resources (MGMR). For water pollution, the State Environmental Protection Agency (SEPA) is responsible for inspection of pollution and fee collection. While wastewater disposal facilities are inspected by the MOC that collect wastewater disposal charges. As sewage or polluted water is delivered into rivers, water pollution control becomes the main duty of the MWR. Both the MWR and the SEPA monitor water pollution in surface and groundwater; the MGMR also takes part in groundwater monitoring. Conflict in the Management of hydropower between the MWR and the Ministry of Energy Resources (MER) is another example of management friction, since the MWR and the MER have been divided and merged several times since 1949.

CONFLICTS BETWEEN HORIZONTAL AND VERTICAL MANAGEMENT SYSTEMS

Water management conflicts also arise between vertical administrative system (from central to local governments) and horizontal local government system. Maximizing local revenue and economic growth subject to a certain level of grain self-sufficiency in a region, is the major objective of the local governments. This objective has affected the local water resource bureau's decision on water allocations among sectors, and the local government's efforts in investment and other matters related to water activities. The regional distributions of industry and agriculture are often not consistent with their water resource endowments.

CONFLICTS BETWEEN THE UPSTREAM AND DOWNSTREAM

Although the MWR always makes water allocation plans between the upstream and downstream, the MWR does not have enough absolute power to force local governments in water uses to follow the allocation plans, which always results in overuse of water in the upstream. The Yellow River dry-up is a good example of the outcome of unbalanced water allocation between the upstream and downstream, across the provinces.

EMERGING TREND IN REALIZING INTEGRATED WATER MANAGEMENT

Water Management Agency Reform

In order to strengthen water management and resolve 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 middle 1990s.

Separation and merging of MWR and MEP

Since 1949, the MWR has been reorganized several times and its functions were also adjusted accordingly. Through reorganization, the water management functions of the MWR have been strengthened and some water management conflicts among various relevant sectors have also been gradually resolved. Unified water management system is becoming a reality in China though there are still many difficulties in realizing integrated and efficient water management.

In October 1949, after the establishment of the People's Republic of China, the MWR was also established and mainly responsible for flood control and national water development. In 1958, the fifth conference of the first National People's Congress passed the decision of agency adjustment under the State Council; the MWR and the Ministry of Electric Power (MEP) was merged into the Ministry of Water Resources and Electric Power (MWREP). In 1979, the MWREP was divided into MWR and MWEP. In 1982, MWR and MWEP were again merged into MWREP. In 1988, MWREP was again divided into MWR and MWEP.

Because MWR and MEP have been divided and merged several times, the two agencies have many overlapping functions in water resources management, especially in managing hydropower. Similar to ministry level reform, sub-national water management agency and energy management agency also changed several times, with different changes of agency arrangements occurring in each province. Even in a single province, some sub-province water management agency and energy management agency are separate while some are combined.

Functions of the MWR regulated in 1988 agency reform

Based on the 1988 agency reform plan of the State Council, the newly organized MWR is the main body of water administration and comprehensive water management agency under the State

Council, responsible for national water conservancy management. The newly organized MWR has established 14 functional departments and its main responsibilities include:

- Carry out the Water Law, organize administrative regulations of water resources management.
- Take charge of integrated national water management and protection; promote comprehensive development and utilization of water resources, coordinate water conflicts between departments, autonomous regions and municipalities directly under the central government; manage national water saving work.
- Organize and draw up long-term and annual water resources development plan, coordinate other relevant departments to make national and provincial long-term water supply and demand plan; formulate water allocation plan across provinces and water projects, organize key water conservancy construction.
- Comprehensively control and develop large rivers and lakes; cooperate with other relevant departments to draw up comprehensive watershed plans of main national rivers, international and boundary rivers and supervise and implement watershed plans after their approval.
- Plan water resources by taking the whole situation into account and manage rural water conservancy, pastoral area water conservancy and town water supply.
- Manage hydropower focusing on flood, irrigation and water supply and rural hydropower.
- Coordinate with relevant departments, manage water regions of national rivers, lakes, reservoirs, sea-wall and flood storage areas and water projects.
- Take charge of national flood control and drought fighting.
- Take charge of national soil and water conservancy.
- Organize relevant departments to conduct water resources investigation and evaluation, responsible for national hydrological work management.
- Manage and supervise professional national water conservancy and development.
- Manage reservoir resettlement, hydropower, reservoir and fishery management.
- Take charge of national water science and technology, education and foreign exchange and coordination of economy and technology.
- Take charge of drawing-up and allocation of main goods and materials supply.
- Manage water resources management staff.

Summary of the 1988 water management agency reform

Although the 1988 agency reform firstly regulated the formal water resources management functions of the MWR and other departments, on analysis of the above functions of the MWR we find, that, responsibility division of water management between the MWR and other departments are not very clear and that the MWR has no unified authorities in managing water resources.

The 1994 water management agency reform

In 1994, water management was again reformed. Also, some functions of the MWR were changed. The number of functional departments of the MWR was reduced from 14 to 13 through reorganization.

At first, the 1994 agency reform empowered the MWR to take charge of urban water conservancy work including urban water supply project construction and water environmental protection. The 1988 agency reform did not provide such functional regulations of the MWR. Although the 1994 agency reform regulated that the MWR has the power to manage urban water resources, it was not clear as to how to transfer urban water resources management authorities from the MOC and SEPA to the MWR, and in fact, water management functions of the MOC and SEPA were still listed in their functional tables. Anyway, this regulation was an advantage for the MWR though it was difficult to implement the regulation.

Secondly, for hydropower management, the MWR takes charge of organizing, constructing and managing hydropower station and hydropower network belonging to the water conservancy administration system. In 1994, property right of hydropower was treated as a standard for dividing management right and responsibility of hydropower between the MWR and the Ministry of Energy Resources (MER). In 1988, the main function of the hydropower station was used as a standard for responsibility division. If the main function of the hydropower station is to produce hydropower, then the MER should manage the hydropower station, otherwise, the hydropower should be managed by the MWR since its main function is to supply water to irrigation and other sectors.

Thirdly, in the 1994 agency reform, the MWR has added its economic adjustment functions by price, tax and loan measures. This newly increased function of the MWR indicates that the Central Government has begun to realize the importance of economic measures in managing water resources and water conservancy assets.

However, although functions of the MWR have had some changes compared with the 1988 reform, functions of other relevant departments had almost no change, which perhaps is the main reason why the 1994 agency reform in water resources management did not have much obvious achievements in improving water management in China.

The 1998 agency reform in water resources management

Due to conflicts of water management among different departments, especially, among the MWR and the MOC, the SEPA and the MOE, China's government reorganized the MWR in 1998 and adjusted some conflict responsibilities among these departments. Compared with the previous agency reforms of the MWR such as in 1994 and in 1988, it has great advances in clearly defining the water management functions between various sectors, though it was still hard to implement the reform program in all provinces in a short time.

The following two functions were separated from the MWR:

- Governmental functions of hydropower construction will be undertaken by the Economic and Trade Commission
- Governmental soil and water conservancy functions of biological prevention and cure measures such as tree and grass planting will be undertaken by the State Forestry Bureau.

The following functions were incorporated into the MWR:

- Previous groundwater administrative management functions taken by the ministry of Geological and Mining Resources (MGMR) will be transferred to the MWR. For exploiting mineral water and heat water only water withdrawal permit certification was needed. Urban flood control, groundwater management and protection functions of urban program region of the MOC will be transferred to the MWR.

The following two functions were transferred between the MWR and relevant departments:

- According to relevant laws, regulations and standards of state resources and environmental protection, the MWR will draw up a water resources protection program, organize water functional region dividing, monitor water quality of river, lake and reservoir, examine and approve pollution accommodating capacity of water regions, pose suggestions of total volume of effluents. Relevant data and information should circulate to the State Environmental Protection Agency (SEPA).

- Draw up a water saving policy and program, formulate relevant standards, guide national water-saving work. The MOC is responsible for guiding urban water collection and water delivery by pipe-network, household water-saving and accept supervision from the MWR.

In the 1998 agency reform, the State Council indicated that the MWR will be responsible for integrated water management which includes water in the air, surface water and groundwater. Before 1998, it was not clearly defined what part of water will be managed by the MWR. Further, water withdrawal permit license will only be managed by the MWR; the MWR will not entrust other departments to issue it anymore. However, urban water saving is still undertaken by the MOC.

Effects and problems of the 1998 water institutions' reform:

The 1998 reform program of the State Council transferred some functions relevant to water management and previously controlled by other departments to the MWR; however, if we examine the reforms program of these departments, we will find that these functions transferred to the MWR still appeared in the responsibility regulations of these departments. For example, the MOC is definitely stipulated by the State Council to take charge of the urban groundwater management and protection and urban water-saving guidance work. Such a reform is not thorough and enough to implement for local governments; department conflicts in water management especially between the MWR and the MOC still has not been resolved. Therefore, it was not a wonder to find that the MOC indicated in August 2000 that it should take over the unified urban water management.

It seems that simply transferring overlapping functions between various departments are hard to operate, and transaction cost is also very high. A better way to realize integrated water management is to establish new management institutions such as the Urban Water Affairs Bureaus in some regions in China, since urban is almost the weakest part of the water resources management. Establishing Urban Water Affairs Bureaus has attracted more and more attention from central and local governments. In the following section we will discuss the institutional reform of constructing the Water Affairs Bureau in China.

ESTABLISHMENT OF WATER AFFAIRS BUREAU

Origin and development of the Water Affairs Bureau

Water Affairs Bureau (WAB) originated in Shenzhen. In the beginning of the establishment of the Shenzhen special region, the Water Resources and Electric Bureau of Shenzhen was canceled during agency reform. With rapid urban development, serious water shortage, flood disaster and soil and water loss problems have appeared. After promulgation of the Water Law in 1988, the Municipal Water Resource Bureau was resumed which took charge of the municipal water source establishment and flood control and drainage work. However, water supply program was managed by the Program Department, construction of water supply facilities was managed by the Urban Construction Bureau and water supply enterprise was controlled by the Urban Management Department. Four governments managed water at the same time which resulted in some difficulties: such as coordinating programs, keeping water source construction in step with water supply facilities' construction, unifying water allocation, coordinating relevant interests and dividing responsibilities. In 1991, a serious "water crisis" in Shenzhen resulted in direct economic losses of 1.2 billion yuan and in 1993 two big flood disasters resulted in 1.4 billion yuan economic losses. Drought and flood disaster led the municipal administration of Shenzhen to reform the water affairs management system and the Water Affairs Bureau was established in July 1993. As an administrative body of water resources management, the Water Affairs Bureau manages water source program, development and construction, construction and management of flood control and drainage facilities, urban water supply, planning, construction and management of water-saving program, in unison.

On 13 May 2000, the first provincial unified water management agency was established in Shanghai. The Water Affairs Bureau in Shanghai has integrated previous water- relevant functions of the Shanghai Water Resources Bureau, the Public Affair Management Bureau and the Urban Project Management Bureau. Separating management between water quantity and water quality and between rural water and urban water, flood control, waterlogging control, water demand, water supply, water saving, drainage, water protection, sewage disposal and reuse and groundwater recharge has been realized as unified management. Zhenshu Jin, the general deputy minister of the Ministry of Water Resources, gave a high evaluation of the reform of water resources management in Shanghai. Mr Jin pointed out that such water resources management reform embodied the principle of simplifying government agency, unification and efficiency, and resolved the problem of government functions overlapping with law enforcement difficulties. In August 2000, Baotou in Inner Mongolia also established the Water Affairs Bureau, the first Water Affairs Bureau along the Yellow River.

Until May 1999, 160 counties established the Water Affair Bureaus in Shananxi, Shanxi, Hebei, Henan, Anhui, Heilongjiang and Shenzhen. Hebei established 75 Water Affair Bureaus, Shanxi had 29, Heilongjiang had 8, Anhui had 7, Henan had 5 and Shenzhen had 3. Until October 2000, 494 cities and counties in 24 provinces have conducted the water affairs reform. Among these, there are 258 Water Affairs Bureaus and 236 water resources bureaus implemented water affairs' management.

Achievements and problems in urban water management reform

The MWR thought that establishing the Water Affairs Bureau can promote water resources rational allocation, improve water resources development and utilization, fully play current engineering efficiency and promote water-use efficiency and structural adjustment. Of course, no one has made an empirical research on urban water affair reform and it is too early to give a conclusion of the achievements of urban water management reform. However, it is sure, that establishing urban water affair bureaus is a valuable measure to solve separating management problems between urban and rural water management.

There exists some problems in the urban water management institution reform:

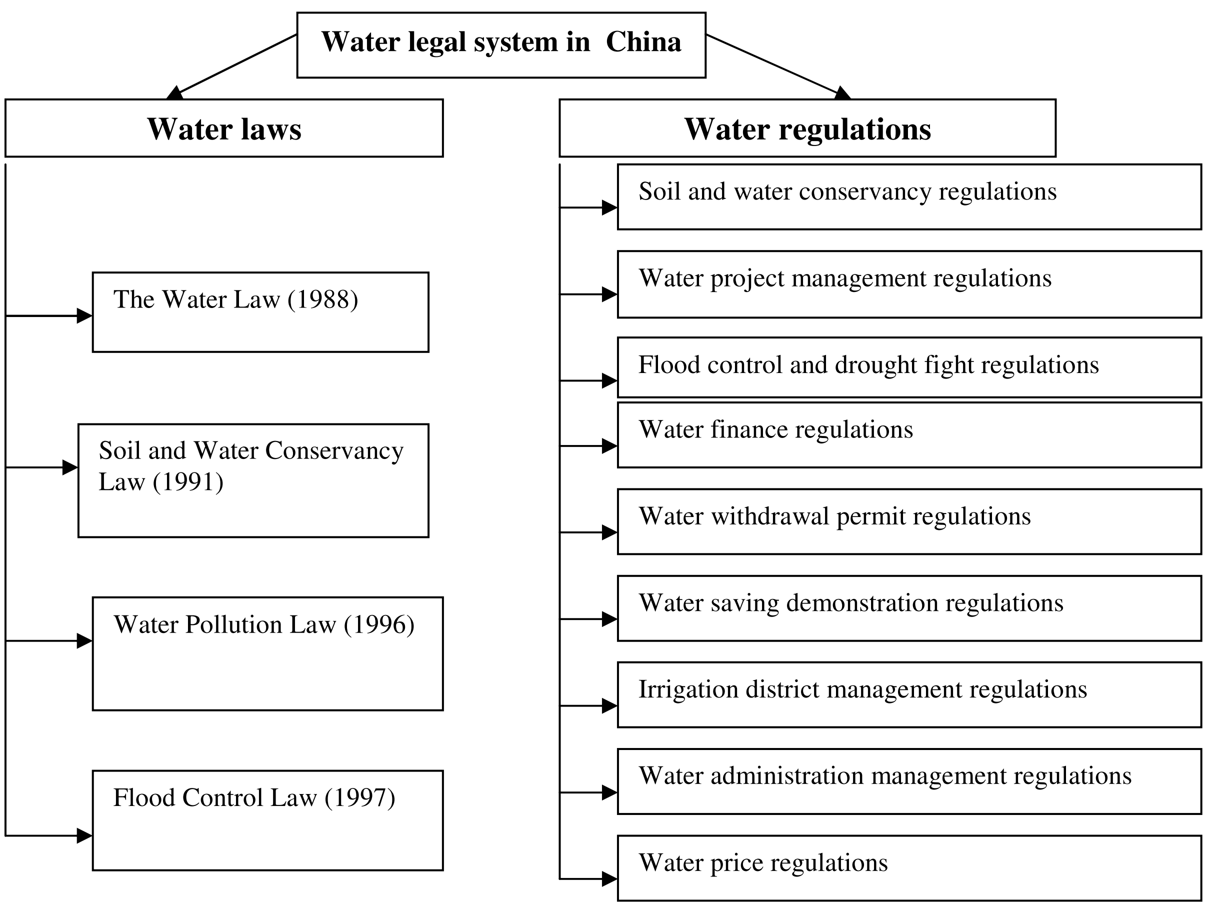
1. *Understanding problem*s: Some people think water affairs reform means the MWR is scrambling for power and profit from the MOC. Establishing Water Affairs Bureau is to put the water tap firmly under a Water Resources Bureau and does not consider water resources' effective allocation.
2. *Management of system problem*s: The current water affairs bureau does not divide governmental function from enterprising function, and how to divide them needs to be considered seriously.
3. *Investment sources:* Water conservancy investment, mainly, came from the agricultural department while urban water supply project investment, especially, urban pipe network establishment do not come under the agricultural department management, which impedes urban water supply investment source of water affairs.
4. *Slow reform in large and medium cities*: Except for Shenzhen, Shanghai, Baotou and a few other cities, reform of most Water Affairs Bureaus established in counties and water management institutions in large and medium cities are very slow, and water management conflicts are more acute in these cities than in counties.

LEGAL SYSTEMS OF WATER MANAGEMENT

National level legal system

With emerging increase in water shortage and environmental problems associated with social and economic development, China has accelerated its water legal system establishment since the 1980s. In 1988, the first comprehensive Water Law was issued, which provides the general framework and principles for water resources management in China. Other than that three water laws were formulated or revised in the 1990s. Except for the four water laws, nearly 30 water management regulations were issued, which mainly cover nine aspects of water management such as water project, water finance, water price (fee), water withdrawal permit system, water saving, irrigation district management, etc. (figure 3.2). At present, the central government is considering drawing up Watershed Management Law, Yellow River Law, and Water Saving Law. These new laws will help to strengthen integrated watershed management, focus more on water allocation and efficiency issues within and across major river basins.

Figure 3.2. Water legal system in China.



It is worthy to note that currently the legal system is mainly dominated by regulations not laws. Despite these various regulations, most of them are "temporary" and many lack implementing provisions. Further, water law and regulations are always too general to be implemented. At the same time, some very necessary laws and regulations such as water resources fee collection method and watershed management law have not been issued, though the State Council had intended to formulate them even in the 1980s. Slowness in amendment of existing legislation and issuing new necessary legislation reflects sharp conflicts among various stakeholders.

Sub-national level legal system

Based on the central government's water law and regulations, local governments should provide implementation details that reflect the local socio-economic and natural resources conditions. However, the issue of implementation details of local governments has always been very slow. By 1991, the People's Standing Committees or People's Governments in nine provinces or province-level "autonomous regions" had promulgated Water Law implementation measures or water resource management regulations. Such regulations are seen as building blocks for the formation of more local water legislation. For example, in the Ningxia Province, the implementation details of Water Law (issued in 1988 at national level) was issued in 1993, local water price regulation (issued in 1985 at national level) was issued in 1989 and local water withdrawal permit system (issued in 1993 at national level) was issued in 1999. The slow pace of formulation of provincial level implementation measures may indicate that lower levels have given a low priority to the measures stipulated in the 1988 Water Law. Another possibility is that the provinces are still carrying out experiments in water management and development and will postpone implementing legislation. Yet another explanation could be that political in- fighting over the rights to manage water and other issues at the sub-provincial levels (i.e., financing difficulties) has hindered the promulgation of implementing legislation at provincial levels. Since 1991, more provinces have passed implementation measures (e.g., Hunan and Hubei in 1993).

The problem has replicated itself at sub-provincial levels. In the Hebei Province near Beijing, the People's Congress or governments in 63 of the 85 areas, cities, and counties had not promulgated any sort of unified water resource management document by 1992. One article stated that a major cause of conflict is between governmental departments over the rights to manage water, in particular, to collect water fees and give out water withdrawal permits, especially in urban areas. Local leaders evidently complain that disputes at the center in Beijing, and in the provinces, over the control of other water resources create considerable uncertainty and make it increasingly difficult for lower levels to manage water or formulate local laws.

WATER POLICY AND MANAGEMENT

Water allocation across provinces

Seven river commissions' authorities

As subordinate agencies of the MWR, the seven river commissions are entrusted to manage water allocation across provinces. However, in actuality, the seven river-basin commissions have relatively little authority to deal with the water issues, they do not control or provide water resource investment allocations in their basins, and have relatively limited financial resources to promote improved water management and policy implementation. How to make a new type of river-basin management organization with more control ability over the allocation of water-related financial resources in the river basin, and more authority for comprehensive, integrated management of water resources in the river basin is the key to improve river-basin management. The following section will provide the water allocation evolutions of the Yellow River Basin.

Water allocation in the Yellow River Basin

Before the implementation of the Yellow River Water Allocation Program, as a typical "open-access resource" of the Yellow River, upstream and downstream water users could freely draw water. Regional water use is determined by water demand and the major constraints of water supply is water withdraw capacities. Open-access resource implies high risks of resources degradation which will lead to "tomb tragedy". Each province along the Yellow River Basin has competed for water and actively constructed every kind of water withdraw facility to satisfy the increasing water demand. From the 1950s to 1990s, water consumption of the Yellow River has increased 1.5 times. As a public resource, the Yellow River cannot bear the overdraft resulting from low water price and poor management. Cutting-off of the Yellow River has been a frequent phenomenon and has aggravated especially after 1991.

In view of increasing water use conflicts between the upstream and downstream, the Yellow River Water Allocation Program was issued in 1987 by the State Council. Based on this program, 34.96 billion cubic meters of water will be allocated to nine provinces along the Yellow River, but the actual water use differs greatly in the program. According to the published data from the Yellow River Commission, during 1992-1995, compared with the program, water use in Inner Mongolia and Shandong exceeded 13 percent and 11.3 percent, respectively; while water use in Shanxi and Shananxi was lower than the plan average by 52 percent and 75.8 percent, respectively. A report of the Geological Department of Chinese Academy of Sciences points out that due to lack of integrated water management and relevant laws and regulations, it is difficult to effectively supervise and control actual water use and no punishment has been conducted for some regions and departments who use water above the permitted quota, which result in failure to implement the Yellow River Water Allocation Program. In the dry years when water consumption peaks, every region along the Yellow River will try to be the first to draw water and water allocation is thus thrown into confusion. Not being effectively carried out the Yellow River Water Allocation Program has reflected the management system's failure of instructive water allocation measures. Instructive allocation is to allocate resources by regions based on the central government's instructions. The characteristics of decision-making mechanism are like the black box operation, central government (departments) have the final say and highly centralized power; binding mechanisms mainly are the administrative measures and commanding officers' will. Under such a management system, water users are in a passive position, and neither have participating rights nor expressing rights. In fact, instructive allocation mechanism is a typical planned economy model, in which resource allocation efficiency is very low and constraints of interests are also very poor. The direct consequence is sharper water supply and demand in river basin, deterioration in water quality and water environment, serious cutting-off of river.

Due to easy water withdrawals upstream, over-draft water and water use efficiency is very low, while water is very short in downstream. Per capita water use and per ten thousand GDP water use in four upstream provinces (Qinghai, Gansu, Ningxia and Inner Mongolia) are greatly higher than in downstream provinces (Shananxi, Shanxi, Henan and Shandong). Due to constraints of geographical condition Shanxi finds it difficult to get water and its per capita water use and per ten thousand GDP water use are less than 200 cubic meters and 400 cubic meters, respectively, while the Ninxia its more than 1,500 cubic meters and 400 cubic meters, respectively.

As an agency of the Ministry of Water Resources (MWR), the Yellow River Commission (YRC) has no actual water allocation power in the river basin, it is only responsible for downstream water management and has limited power in managing upstream and middle stream water management. Water allocations in upstream and middle stream are controlled by upstream and downstream control commission of the Yellow River. Different functions and purposes of the two departments lead to difficulties of cooperation in water allocation.

Increasing serious Yellow River cutting-off received extensive attention from the central government, the State Council and the overall societies. In December 1998, on approval by the State Council, the State Planning Commission and the MWR jointly issued the Annual Allocation and Main River Water Quantity Controlling Program of the Yellow River. The YRC was authorized to conduct unified control of the Yellow River water. Since 1 March 1999, the YRC has begun to control non-flood period water from the Liujiaxia Reservoir to Toudaoguai and from the Sanmenxia Reservoir to Lijin main river. Under the high attention and unified leadership of the MWR, and close cooperation among provinces, autonomous regions and relevant departments along the Yellow River, integrated water control has obtained marked achievements. Compared with an average 126 cutting-off days during 1995 to 1998, Lijin Station of the Yellow River had only 8 cut-off days in 1999, and in 2000 no cutting-off has happened till date.

Based on the 1999 experiences, the Yellow River Commission has put forward four elaborate work methods: elaborately forecast, elaborately control, elaborately coordinate and elaborately supervise. They mainly focus on three aspects of work:

- Coordinate, consult and control upstream and downstream reservoirs in union, and timely increase of reservoir discharge.
- Strengthen timely control, issue month and ten-days water control plan, issue control instructions in time and deal with emergencies. Till June 2000, 27 water allocation implementation suggestions and nearly 30 water control instructions have been released in time.

- Strengthen supervision. To ensure strict implementation of the water control plan, the work group of the Yellow River Commission has conducted several circuit checks for two main controlled rivers and rigidly control water use above the planned quota.

The Yellow River Water Control is the first case for large rivers in China; it involves direct interests allocation among the main river pivot and water users in related provinces and autonomous regions, and there exists many conflicts and great differences in the Control Plan. Obeying the control order completely depends on overall consciousness and coordination of the relevant departments. Although the YRC is authorized to conduct unified control of the Yellow River water by the State Council, the YRC is not the first-level government. Water law does not clearly define water administrative enforcement power and administrative supervision and punishment power of the YRC, management agency of the Yellow River Water Control has not been made clear and the relationship with local governments is still very confused. Integrated control of the Yellow River water is still faced with many difficulties. Integrated control of the Yellow River water is a new work and no readymade river control standard can be followed. Further, the Yellow River Water Quantity Control Management Method does not have detailed implementing regulations; many contents of reservoir control application regulations of hydropower station do not harmonize with the Yellow River Water Quantity Control Plan. It is urgent to establish detailed implementation of the Yellow River Water Quantity Control. In addition, control plan has hardly been implemented and no effective measures have been taken. Currently, the YRC has only conducted an integrated control for two main river reaches, i.e., from the Liujiaxia Revervoir to Toudaoguai and from the Sanmenxia Reservoir to Lijin main river; there are still large distances to integrate and control water for the overall Yellow River.

Except for the administrative measures taken by the YRC to effectively allocate the Yellow River water, some provinces have also taken some economic and institutional measures to improve water use efficiency to reduce the Yellow River water use. Ningxia government has doubled water price in April 2000 in order to improve irrigation water use efficiency. Compared with 1999, total water use drawing from the Yellow River reduced by 0.53 billion cubic meters in 2000. Furthermore, water resources agencies in Ningxia have also taken the following measures to improve water use: introducing some water-saving methods, reforming the irrigation management system, establishing water users association, opening water affairs and implementing rotation irrigation and contracting branch canals, supplying water by bill and narrowing water meter scope. Although Ningxia has increased its water price, it is still not enough to realize the real water value of the Yellow River. Low water price and induced low water use efficiency are important reasons for low water allocation efficiency of the Yellow River. Using economic and institutional measures to effectively allocate water have still not been implemented by the central and local governments.

Some other inter-province policies have also been discussed recently. These include applying taxes, and different fiscal and financial policies to the provinces along the Yellow River. However, formation and implementation of the inter-provincial policies in water use through an incentive system requires a lot of information on the efficiency of water use among the provinces along the river, and the ability of coordination horizontally (regions) and vertically (central and local governments).

WATER ALLOCATION WITHIN A PROVINCE

Generally, upper-level water resources agency such as provincial and prefecture level will make an annual water allocation plan for lower-level regions, and then submit the allocation plan to the local government at the same level to get the approval. Before making a water allocation plan, the water resources agency at the upper-level will solicit opinions on water requirement from the water management agencies at the lower levels. Opinions on water allocation from lower level water management agencies will become the foundation of the water allocation plan and will also be adjusted and coordinated by the upper level's water management agency, according to the overall water supply and demand situation. After the local government approves the water allocation plan, will be sent to the lower-level government to be implemented. Last year's water supply and demand situations and the current year's water demand are important bases for making the water allocation plan. Because water supply in the current year cannot be exactly predicted and perhaps because some water use sectors do not satisfy the water allocation plan, the water allocation plan usually will be adjusted and difficult to be implemented; water conflicts among various water use departments will be still harder to be avoided.

It seems that water resources agency at the upper level will coordinate and decide water allocation between upstream and downstream water users. However, the actual water allocation decisions between the upstream and downstream will be decided by the upstream local government; downstream water users have no power to compete water with the upstream water user. The upper-level government's role in water allocation between regions is very limited. Relationships of water resources agencies between higher level and lower level are mainly a technical relationship, not an absolute administrative relationship. This means that the water resources agency at the upper level has no absolute power to control the activity behavior of the water resources agency at the lower level.

In case of water conflict, the water resources agency at the upper level will try to coordinate; if it still cannot be solved, the local government will interfere. For some sharp water affairs conflict, the local court, sometimes even the higher court, will help interested parties to solve the water conflict.

WATER ALLOCATION AMONG SECTORS

According to Article 14 of the Water Law, water allocation should firstly ensure domestic water demand, then make unified planning with due consideration for agriculture, industry and shipping water demand. In water-short areas, urban scale, high, water-consuming industry and agricultural development should be limited. How to actually arrange water allocation priorities among sectors will be controlled by the local government.

In fact, water, especially surface water, to be easily controlled by the policy maker will first be allocated to the domestic sector, then the water demands of the industry will be ensured and then the agriculture water use will be ensured. Hydropower, shipping and environmental and other water demands are always arranged before agriculture. Generally, if agriculture cannot get enough surface water, it will turn to groundwater.

In spite of farmers' political position or water productivity, the agricultural department finds it difficult to compete for water with the industry department and other departments, and at the same, the agricultural department is always criticized for consuming a large share of the water resources. Therefore, how to reduce agricultural water use and improve agricultural water efficiency has become a hot issue of discussion in government agencies and societies faced with increasingly serious water shortage problem in China. Of course, reducing agricultural water consumption by transferring water from agricultural sector to non-agricultural sectors is a general development trend and is also necessary for promoting social welfare and economic growth.

However, how to efficiently allocate water between agricultural water users and non-agricultural water users? Is higher water use efficiency better for water utilization and water allocation efficiency? Faced with increasing water shortage, how do farmers respond to agricultural production and water use? What kind of policy can lead to social and economic sustainable development given a growing gap between water supply and water demand? Although all the above problems have great import and practical implications, very little empirical research has been done in China; this paper itself can only answer a few questions, more comprehensive research needs to be conducted in future.

For water allocation among sectors, a relationship and mechanism exists between higher level government agencies and lower level government, -- the government agency at the higher level cannot absolutely control the water allocation patterns but can give technical guidance to lower level agencies. Water allocation among sectors will be decided by the local government and service for the local government's political and social targets, which is usually short-term behavior and beneficial for non-agricultural water users.

WATER FINANCE SYSTEM

Evolution of a Water Finance System for Irrigation Projects

The total input for irrigation projects in China can be divided into two parts: input for the construction of new irrigation projects (construction input) and input for system operation (operation input). Different policies have been formulated for these two different kinds of inputs.

The construction input mainly comes from basic national construction funds. From the mid-1950s, China began to use its limited financial and material resources to construct a large-scale rational economy, among which the basic water conservancy facility is one of the important items. The construction input is mainly funded by the government, supplemented by farmers' labor input. Before the 1980s, the Central Government was in charge of constructing important national irrigation projects. Also, the construction fund and material for main canals and higher-level key projects of large-scale irrigation districts were allocated to each province annually, according to the construction scale and macroscopic planning capacity of each province. Moreover, the Special Subsidy Funds for Small Rural Water Conservancy Projects (SSFSP), water soil conservation projects, and lower-level conveyance system of large projects have been funded.

Following the macroscopic planning of the Central Government, each lower-level government carried out its varied project constructions, according to its local economic capacity. From the 1950s to the 1980s, government input was mainly utilized in the construction of key projects. The soil-digging work in the construction of reservoirs and canals was mainly finished through farmer labor input. According to studies, farmer labor input accounts for more than one-third of the total input to the existing irrigation projects. During construction, farmers performed at a very high level. From the 1960s to the 1970s, since the government could not provide enough funds, material subsidies and technical aids, a large number of medium and large projects were constructed by farmers themselves, at times even without initial planning. There are countless small projects that have been constructed by farmers. The famous Hongqi and Renming Shengli Canal irrigation projects in the Henan province were constructed in this manner.

In principle, the government will not provide any further funds for irrigation projects already constructed, except two kinds of subsidies: 1) operational subsidy for projects in conjunctive use of irrigation and drainage, mainly used as a subsidy of energy charge; and 2) some operating expenses allocated from the national finance fund, for the poor regions with limited fund sources, which indicates the protectivist policy of the government towards agriculture. For all constructed irrigation projects, the operation and maintenance (O&M) costs mainly come from the following channels: the day-to-day expenditure (including salaries, travelling and electricity charges, etc.), and maintenance costs, mainly from the water charges collected from farmers and other water users. Different regions have different measures of making up the difference between O&M costs and water charges. For example, for the soil-digging costs, the most popular measure is for the local farmers to simply contribute some labor input or to pay a relevant amount of money. In some regions with better economic conditions, a proportion of the local industrial benefit can also be arranged as a subsidy fund to sub-serve agriculture.

Farmers should also take up the responsibility of field facilities maintenance. Governments also provide some subsidies for project expanding or enhancing work by using the established SSFSP, such as for the lining work, of the small canal system. Twenty to forty percent of the material fee can be provided by using the SSFSP in the local finance fund. Since the collected water charges cannot recover the irrigation costs, there is no fund source for the rehabilitation and large-scale repair of irrigation projects at this stage.

After rural institutional reform was initiated in the later 1970s, the planned financial system in water sector has been gradually decentralized since the early 1980s. The major reform has been focus on the responsibility of water management and finance between central and local government and between the government and farmers. Since the 1980s, China has experienced a financial system transfer. The Central Government is only in charge of the construction and management of giant inter-provincial projects. The construction and management of projects within provinces and the arrangement of SSFSP were transferred from construction to adjusting and consolidating, with suitable facilities for extension. The finance and its management of small-scale rural water conservancy projects had been transferred from higher to lower-level governments. Due to different financial abilities among provinces, water conservancy investment from the public sector has been declining in many poor provinces. The existing irrigation projects have been developed in two directions: 1) to improve irrigation quality in conjunction with comprehensive agriculture development, and 2) to improve the living and ecological conditions of the poor regions.

Some specialized agriculture development projects have been founded by the government, such as the Food Grain Development and, the Comprehensive Agriculture Developing Fund, and the Special Fund for Commercial Food Production Bases. For old liberated regions, minority nationality regions and boundary regions, some Poor-Aid Funds were arranged to help in the infrastructure construction of these regions. Sometimes, instead of direct fund aid, funds for providing work as a form of relief was arranged. Funds for Rehabilitation and Completion of Water Conservancy Infrastructure are also included in the above. China is still a developing country, and due to fund limitations, it is impossible to solve all the irrigation problems at this stage, especially, when there is no fund source, for the government, still adheres to the policy of letting the farmers contribute funds and labor input every year, on a voluntary basis, to carry out rural water conservancy construction and to improve the existing status of irrigation projects.

Today, the socio-economic conditions of the rural areas of China are developing rapidly. Farmers' living conditions have undergone some major improvements. Farmers have greater incomes, and especially those who were already rich, have gained considerable investment capacity. In order to obtain a higher quality of irrigation service, they have begun to contribute their own money to rehabilitate irrigation projects. Along with the practicing and improving of the water conservancy stocks system and the investment transfer system, farmer consciousness of the construction and management of irrigation projects by themselves has heightened. Some very good results have been obtained in many regions, such as in the Laiyang City of Shandong Province, and the Jiaozhuo City of the Henan Province. This has widened the fund source channel and opened up a new way for the improvement of irrigation engineering status.

DECLINE OF WATER INFRASTRUCTURE INVESTMENT IN CHINA

Table 3.1 indicates that while government expenditure and investment has shown a general increasing trend in the pre-reform period, their shares to the total economy has shown a declining trend even since the early 1960s. The bias index (BI) of government expenditure in agriculture is much below the 100 percent level, indicating strong government expenditure biases against agriculture. While reform has accelerated the growth of agriculture since the late 1970s, table 3.1 also indicates that the new institutional arrangement has not provided the incentive for investment in agriculture. Both, shares of agriculture in total public expenditure and water infrastructure in total infrastructure investment declined sharply in the early reform period (1979-85). Among the various components of the public agricultural expenditure, the decline in the share of local governments in agriculture was the highest in the agricultural capital construction investment (i.e., irrigation), which fell from 63 percent in 1978 to 47 percent in 1985.

Table 3.1. Government investment (billion yuan, in 1990 prices) in agriculture and water project, 1965-96.

Year	Fiscal expenditure			Index of government expenditure bias	Water control investment	Infrastructure investment	
	Total	Agriculture	Agricultural share (%)			Total	Share of water project (%)
1965	98	12	12	26	2	38	5.7
1970	139	11	8	19	4	67	5.5
1975	175	21	12	32	6	88	6.4
1978	233	31	13	48	7	104	7.1
1980	236	29	12	41	5	107	4.8
1985	325	25	8	27	3	174	1.9
1990	308	31	10	37	5	170	2.9
1992	345	35	10	46	9	278	3.2
1994	388	36	9	46	11	431	2.9
1995	398	33	8	41	11	432	2.8
1996	436	36	8	41	11	471	1.7

Note: Values are in real 1990 prices. Government investment (expenditure) bias is estimated as: dividing the ratio of government expenditure in agriculture to total government expenditure by the ratio of net income of agriculture to total national income. If the index is less than 100%, it implies an anti-agriculture bias, otherwise, a pro-agricultural production bias (greater than 100%).

Declining public agricultural and irrigation expenditure attracted attention to agricultural production sustainability and future domestic food-supply problems. Investment policy reviews led to increased investment in the early 1990s (table 3.1). Both the Ninth Five-Year Plan (1996-2000) and China's Long Term Plan to 2010 advocate increased public agricultural investment, including investments in rural infrastructure and loans and credits for agricultural production. Irrigation and water control are the top priorities of future government investment.

However, due to the weaknesses of the fiscal system, the new policy to increase public investment in agriculture and irrigation has been hardly 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 or staff policies cannot be effectively carried out.

WATER PRICING POLICY

Evolution of water pricing policy

Water charge collection has a long history in China. Many famous ancient irrigation projects had the custom of water charge collection throughout history. For example, the Qingtongxia Irrigation Project in Ningxia Province and Dujiangyan Irrigation Project in Sichuan Province, in their more than 2000-year operational experience never stopped water charge collection. Since the founding of the People's Republic of China, except for water charge collection, many exorbitant taxes and levies of the old government have been abrogated. The development of water pricing policy can be divided into the following five stages:

The first stage: 1949-1964

In 1949 China was a low-productivity agriculture society and many industries needed to be established. In order to promote poor farmers to develop agriculture, water supply was characterized as public affairs and almost no water fees had been collected, until 1964. In 1964 the first National Water Conservancy Conference was held and "Trial Approaches of Water Fee Collection and Management" was proposed, which began to change the free water fee situation.

The second stage: 1965-1979

In 1965, the State Council also approved the regulation of "Approaches of Water Fee Collection, Use and Management of Water Project"; this is the first important government document on the water price system. According to this regulation, management, operation and maintenance expenditure of all water projects that have produced benefits should come from water fee collection. The water fee standard should be based on the principle of self-sufficiency and rational accumulation. Water fee level should also consider the situation of beneficial units and the economic capacity of the water users. Although the basic principle of this regulation was feasible and suited the country status at that time, it did not consider the full water supply cost which resulted in low water fee.

After issuing the "Approaches of Water Fee Collection, Use and Management of Water Project" in 1965, the Great Cultural Revolution broke out and all water projects were publicized. Limited by the socio-economic conditions during that time, the water supply was simply a requirement-supply activity directly under the administration of a government department. The market economic relationship between water supply and water charge collection has not been established. Also, considering the economic capacity of farmers and their large amount of labor input for project construction, the collected water charge standard was always low and even free for many water projects. Subsequently, irrigation projects could only sustain their basic operation at a lower level, and management units had no surplus money to repair and maintain the ageing and damaged facilities.

The third stage: 1980-1985

From late 1980s to early 1985, the Chinese Government practiced reforms and open policies. The pure centralized planning economic system of the former period has been changed, and the contract responsibility system is being practised in rural areas. The consumers of irrigation projects has changed from collectives to thousands and ten thousands of individual farmhouses. This improved the transfer of irrigation management systems and the reform of water charge calculation and levying systems.

In order to deepen the water price reform, the MWR organized four groups to investigate water supply costs for 256 large-scale projects in the eastern, middle and north-western China. In this investigation, the concept of water as commercial in nature has been proposed for the first time which established the theoretical foundation of free water supply. In 1982, the central government took steps to recheck the agricultural and industry water fee.

After sufficient investigation, a new calculation and levying regulation for water charges was issued in 1985. Some clear and concrete reforms included in this regulation are as follows:

First, it was decided that all water conservancy projects "should be paid", instead of "could be paid" as in former times, for their water supply services. Second, the objective of water charge reform has been clear, i.e., to meet the project operation and maintenance costs, which include salaries of staff, traveling fees, meeting expenditure, office expenditure, large-scale repair charges, rehabilitation and reconstruction charges, etc. A standard for water charge collection should be formulated according to the water supply costs. Different regions were asked to formulate different kinds of water charge collecting standards for different kinds of water supply services, respectively, according to their local water resource availability and economic condition. In the case of agricultural water supply, it is regulated that the water charge collecting standards for food grain water supply should be formulated according to the costs of water supply. The standard for commercial plants could be higher than for food grain. The standard for industrial water supply would be the water supply cost plus 4 - 6 percent of investment profit. In water shortage areas, all water charge standards can be promoted to a higher level. There are also clear and decided regulations for water supply to domestic, hydropower, environment promotion, public health, planting and/or breeding. Third, the regulation for water charge collection, use, and management is also included. Principally, water could be collected according to the supplied amount of water. The supplied amount of water should be measured following hydropower standards. The management units can stop water supply to any user who does not want to pay the water charges. The collected water charges are duty-free, and belong to the management units. There are also limits for the use of water charges, and some regulations have been formulated to supervise the use of water charges. Fourth, the duties and responsibilities of the Central Government and local governments at each level are identified. The Central Government is in charge of formulating the standard of water charge collection, the regulation of water charge collection, and use or management of the project directly under it. The local governments at each level will be in charge of the above duties for the projects under their supervision.

The fourth stage: 1986 -1996

After issuing the regulation of the water fee approach, many provinces began to issue the local implementation regulations that decided the water price level based on the local conditions. In 1988, the Water Law was issued. The Water Law stipulates that all water users should pay water fee to water supply units. This is a very important legal stipulation for the water pricing system.

After the efforts of the 1980s, a big improvement has been achieved in water charge reform. First, from the Central Government to lower-level governments, this policy has gained universal understanding, especially, among lower-level governments and farmers. A prejudice existed among staff of the local government departments and farmers, that, farmers should not pay any water charges, since they have already contributed some money and labor input for the construction of these projects. Moreover, there are always differences that exist between the industry and agriculture in developing countries. Farmers have already contributed a lot towards original accumulation, so that the government must use national funds to sustain the operation, maintenance and rehabilitation of irrigation projects. This kind of lack of understanding formed the main constraint at the beginning of the reform, but after many years of propaganda and discussion, the situation has been reversed. Also, the policy system has been perfected. For the past 20 years, there have been no clear and decided government regulations on water charge collection, the use and management of water charges, etc. Consequently, the water charge collection standards in different regions became varied; in some regions, water charge collection went on very well, while in some other regions there was no water charge collection. In this reform, the government departments at each level, supervised the completion of the water policy charge. Further, the water charge collection linking network between management units and farmers has also been established. In the earlier period, the management units collected water charges from collectives. After the rural economic system reform, water use expanded to thousands and ten thousands of farm houses. In this context, a large amount of work has been done in different regions, and some rich experiences and effective methods of water charge collection have been established. For example, charging by goods, collecting through food grain purchasing stations, and transferring bills through banks, etc., have reduced collecting staff and cost.

But there are also some problems which have appeared in water charge reform. The first is how to supervise water charge collection while theoretically following the requirements of commercial economic laws. For example, is it suitable for rural water supply where 80 percent of water is supplied to food grain plants? It is still not clear as to whether water charge collection should be handed over as public benefit charge collection, or whether it should be brought under the national price management system for commercial products. Especially after China began to establish a socialist commercial economic system, the problem became more acute. The second is, that after ten years of water charge reform, the actual collected water charges can only cover project operation, management, and normal maintenance, while there is no capacity for irrigation management units to complete large-scale repatriation, rehabilitation and reconstruction. As a result, the deterioration of projects is becoming more and more serious. The third is, that the economic laws and regulations in water charge collection, such as price formulation, cost examination and calculation and accounting management systems, etc., are still not perfect. Especially, assets management is not perfect, which has resulted in deficits of original value evidence, and incorrect cost calculations. The fourth is, that economic development in China is unevenly distributed; in poor regions, the collected water charge standards are very low and water charge collection is very difficult.

To counter these problems existing in water charge collection, the Ministry of Water Resources started an in-depth study of the reforms, from 1994. According to the theory of the socialist commercial economic system, these reforms will focus on the following four stages: 1) Establish a management system for the value form of assets. Now, a nationwide asset accounting and property checking work is underway to identify the ownership, investigate the value amount, establish a basic account book management system and to bring it into the normal course of the nationally-owned assets management system; 2) To formulate new price management regulations for water supply. The basic idea is that the water charge standards for food grain water supply should be brought under a uniform macro prices management system; 3) Formulate a new examination and calculation method for water supply charges, finance management regulations and accounting rules and to provide conditions for further water charge reform; 4) To formulate controlling and management regulations for nationally-owned assets and a compensating method for asset values, to ensure their sustainability and increase.

The fifth stage: 1997- till date

In 1997, the State Council issued the Water Industry Policy that regulates that "water pricing level for new water projects should be decided by the principle of satisfying operating cost and expenditure, submitting taxes, returning loans and obtaining rational profits. Water price for previous water projects should be adjusted to water supply cost level and adjusted later, based on the changes of water supply cost. Water price for previous water projects should be based on the principal of the state water price policy, cost compensation and rational benefits and consider the various utilizations". In addition, according to the limits of water project management authorities, water price will be decided and adjusted by the water pricing management authority and water administrative management authority at above-the-county level. Since then, water pricing reform has been accelerated.

Firstly, water price has been involved into the commercial price management system. Some provinces such as Shanxi, Shandongm Zhejiang and Hebei, etc., have formally listed water price in the national key commercial price management contexts. The State Development and Planning Commission clearly empowered the pricing management department to manage the water pricing. The MWR also established the economic development and pricing division of the economic department to be responsible for the water pricing management. Many sub-national water resources bureaus have also established water fee collection stations and a water fee collection network has been basically formed.

Secondly, institutional establishment has made some progress. Many provinces such as Zhejiang, Hebei, Ningxia, Henan, Fujian, Guizhou, etc., have issued the local water pricing management regulation.

Thirdly, water pricing level has been increased through several times' adjustment. The national water pricing level has been increased from 0.001 yuan/m^3 in 1980, to 0.003 yuan/m^3 in 1985 and 0.01 yuan/m^3 in 1991. In 1997, the water pricing level has increased to 0.024 yuan/m^3. Water pricing increase in Liaoning, Hebei, Beijing, Tianjin, Shandong and Ningxia provinces was relatively higher than in other provinces.

Fourthly, water management units have gradually been transformed. Water pricing reform has increased the commercial opinion of management units and motivated them to strengthen management and economic accounting.

Lastly, water fee has been changed from administrative nature to management nature. In 2000, the Ministry of Finance issued the "Circular on Abolishing Some Fees That Related to Farmers' Burden". In this circular, the water fee has been changed from administrative nature to management nature and will be not treated as a budgetary fund. This regulation redefined water price and suited the requirements of market economy. The nature change of water fee has promoted business management of water management units.

AGRICULTURAL WATER PRICING: COLLECTION AND MANAGEMENT

Agricultural water pricing method is related to the water supply method, water measurement and calculation methods. For united management of reservoir and irrigation districts, water will be measured in branch inlets; below the tertiary canals, water fee will be collected by the cultivated areas. If reservoir and irrigation districts have been managed separately, water will be measured in de-watering outlets of the reservoir; irrigation districts will manage main and branch canals; township and village will manage the canals below the tertiary level. If its directly introduced water from rivers, lakes or groundwater, water will be measured at intake (intake gate) or branch canal inlets. Under the tertiary level, water volume is generally allocated by areas. China had tried to implement volumetric water price in 1970s. However, volumetric water price in the field had hardly been implemented due to measurement difficulties. The common measures adopted by the local villages were based on crop areas and household population. But these measures had resulted in conflicts between farmers and village leaders and as such led to difficulties in the actual collection of fees from water users.

Water fee collection is generally from bottom to up, i.e., the village collective will collect water fee from farmers and then submit it to township, township will then submit it to county; the irrigation district will take the water fee from the county based on certain proportions. After 1983, 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 were often linked with government grain procurement system that allow farmers to pay all these merged fees in grain equivalent (in kind).

Since 1988, with the reform of the grain circulation system, the state was not allowed to collect water fee with grain procurement. However, this policy was not being implemented well until now, and there is still this kind of water fee collection in some regions due to relatively low administrative cost. At present, several patterns of water fee collections exist in China: 1) IDs contracted with township and township will collect the water fee; 2) ID contracted with village and village will collect the water fee, the township will act as the guarantor; 3) ID contracted with Water User Association (WUA) and the WUA will collect the water fee; 4) ID will open an account in the rural credit cooperative or agricultural bank in the township, the credit cooperative or bank will then collect the water fee.

WATER RIGHT AND WATER WITHDRAWAL PERMIT SYSTEM

General definition

According to Article 3 of the Water Law of the PRC, there are two kinds of water property rights for both surface and groundwater: 1) Collective property right: If property rights of reservoir and water pocket belong to the rural collective organization, property rights of water stored in these reservoirs and water pockets will also belong to the collective organization. 2) State property right: Except for the collective property right of water resources, other water resources including both surface and groundwater all belong to the state.

Water resources property right mainly embodies a water withdrawal permit system and water resources fee.

WATER WITHDRAWAL PERMIT SYSTEM AND WATER RESOURCES FEE

The Water Law issued in 1988 has initiated some new and important water management institutions such as water withdrawal permit system and water resources fee collection. Although the Water Law promises that management methods of water withdrawal permit system and water resources fee will be issued by the State Council, the Implementation Method of Water Withdrawal Permit System was not issued by the State Council until 1 August, 1993, and no management regulation of water resources fee has been issued by the State Council up to now.

According to the 1993 Implementation Method of Water Withdrawal Permit System, any institution or private person who draws water from river, lake and groundwater through water projects or machinery must apply for a water withdrawal permit license except for small-volume water-draw for domestic, livelihood or irrigation demands and the quota of small volume is decided by the provincial government. In several cases, water withdrawal permit can also be exempted, such as in emergency agricultural drought, ensuring security of groundwater projects and avoiding danger of public security or benefit. Water withdrawal must firstly satisfy domestic water consumption and then arrange agricultural, industrial and other water demand in overall considerations. Provincial governments can arrange water withdrawal order based on local situations under their jurisdictions.

Groundwater withdrawal cannot exceed annual planned available groundwater exploitation volume under their administrative regions, and it should accord well with the layout and requirement of the water withdrawal layer that was decided by the water resources administration of the Government above county level through coordinating geological and mining resources administration. For urban areas, urban construction administration will also make the decision.

Seven large river commissions were also entrusted to issue water withdrawal permit license in certain sections of rivers, lakes and regions assigned by the MWR. Based on the 1993 Implementation Method of Water Withdrawal Permit System, seven large river commissions also issued their implementation details of the water withdrawal permit system, such as the Yellow River Commission issued in 1994 and the Yangtze River Commission issued in 1995. River Commissions will be responsible for rivers, lakes and groundwater withdrawal permit across provinces, and generally, River Commissions can issue larger volume water withdrawal permit than provincial management agencies. The procedure of water withdrawal permit management of the seven river commissions is that local governments higher than county level will accept water withdrawal permit applications and propose to examine suggestions to the river commissions, which in turn will examine, verify and issue water withdrawal permit license to the water users.

For water withdrawal volume above requirement standard, there are some punishments. According to the regulation, if water consumption exceeds the water withdrawal standard, in coordination with relevant departments, the water resources administration will order the institution to improve or correct itself in due time. If the institution still cannot reach the standard, on approval by governments above county level, the water resources administration can reduce its water withdrawal according to the regulation. If Management Regulation of Urban Water Savings has special stipulations, then, they should be followed. If water is withdrawn without getting permit certification, the water resources administration or entrusted administration will prevent the institution from water withdrawal.

Although the purpose of the Water Withdrawal Permit System is to realize unified water management, the existing separate water management between rural and urban and between surface water and groundwater that has resulted in a separate management of the Water Withdrawal Permit System has made it very difficult to realize this purpose.

According to the Report on the Implementation Situation of Water Withdrawal Permit System submitted by the MWR in November 1995, until July 1995, 90 percent of water users have applied for water withdrawal permit license. Implementation of the water withdrawal permit system has resulted in some obvious achievements: 1) Clearly define the relationship between water resources administration and other departments; preliminarily overcome the situation of managing water by many sectors; 2) Put various sectors' water demand in an overall consideration; 3) Preliminarily absorb water withdrawal and water use into water use plan; 4) Preliminarily prevent non-order exploitation and destroy ecological environment of water resources; 5) Accelerate urban water supply source construction.

However, among 600 cities, 20 percent had not implemented the water withdrawal permit system until July 1995. The main reason for this is that some departments only consider their own interests and insist on being entrusted to issue water withdrawal permit license and conduct separate water management of urban and rural areas; they issued some documents that impeded the water resources administration from issuing the water withdrawal permit license. For example, in Hebei, one department published a notice in newspapers that "except for urban construction administration, no other department have a right to issue water withdrawal permit license and every city in Hebei will still apply the water withdrawal permit license issued by the Hebei Urban Construction Commission". Some departments in some cities issued Urban Groundwater Withdrawal Permit License to substitute the Water Withdrawal Permit Certification of China.

Although the State Council has not provided for the water resources fee collection method, some provinces (autonomous regions and municipalities directly under the Central Government) successively formulated a collection method of water resources fee and began to collect water resources fee under their jurisdictions, according to a "Notice Regarding Some Problems of Collecting Water Resources Fee" issued by the General Office of the State Council in 1995. The collection method of water resources fee has been listed the legislative plan of the State Council; the MWR and the Ministry of Construction are required to draw up a plan as soon as possible and submit it to the State Council. Before publishing the water resources fee collection method of the State Council, the water resources fee collection will abide by each provincial regulation.

Similar to the management system of the water withdrawal permit system, the water resources fee is also managed by various departments, mainly, the water resources agency and urban construction agency. Although the urban construction agency will collect the resources fee in urban areas, most resources fee collected by the urban construction agency is not used in water resources management, but rather used in urban construction. Except for the sectors' conflict, another problem in managing water resources fee is rural water resource fee collection. For rural water resources fee collection, according to a stipulation of the "Notice of the General Office of the Central Government of the Communist Party and General Office of the State Council, Regarding Examination and Disposal Suggestions of Farmers' Burden Projects' in 1993, rural water resources fee will be postponed for 5 years to implement. However, five years have already passed, and rural water resources fee has still not been collected in almost all provinces; the MWR and the State Council have not indicated clearly whether rural water resources fee should be collected from now onwards. Faced with an increasing water shortage and a sharper water competition among sectors, especially groundwater overdraft, more and more provinces want to collect the water resources fee. According to our investigation, the Hebei province will begin to try out collection of irrigation groundwater resources fee in some counties in late 2000. The problem in collecting irrigation groundwater resources fee is how to monitor and supervise groundwater use exactly, since, so many diversified and small farmers draft groundwater. Local governments thought of installing water meters in each agricultural well to solve the problem, however, how to ensure farmers will not make changes on the record of the water meter, and whether the meter cost will be too high to collect water resources fee is the issue.

SURFACE AND GROUNDWATER MARKETS

Compared to countries such as America, Mexico and Chile, who legally allow water right trade, transferring water withdrawal permit license or water use right is prohibited in China. If a water withdrawal permit license is transferred, the water resources administration or entrusted departments will revoke the water withdrawal permit license and expropriate unlawful income, according to the 1993 regulation. More and more evidence show that water right transfer is an efficient water allocation measure and water markets development through trading water rights will be an important potential strategic measure to solving increasing water shortage. Since agricultural water use is still the largest water user among various sectors, how to transfer water from agriculture to non-agricultural departments has attracted more and more attention from government officials and scholars. Many people argue that agricultural water use efficiency is so low that improved water use efficiency in agriculture can result in water transfer from agriculture to industry and domestic water users. However, farmers do not get much incentive with improve water use efficiency, especially, upstream farmers, since water price is so low and water use right cannot be traded. If water use right can be traded, farmers can obtain more benefit through trading water use right than through using more water in agricultural production; it is also possible that farmers will have a great incentive to save water to earn more money.

Although no surface water markets have existed in China, informal groundwater markets has appeared since the late 1980s with the increasing water shortage and innovation of groundwater irrigation system, mainly in North China.

DEVELOPMENT OF IRRIGATION PROJECTS

China needs to construct some giant irrigation projects. This has been decided on the basis of its large population, unevenly distributed water resources, and the complicated geographic and geomorphic conditions. Affected by the monsoon climate, the annual precipitation in China declines from 1,600 millimeters (mm) in the southeastern coastal regions to less than 200 mm in the northwestern region. It concentrates mainly in the summer season, from June to September, and is unevenly distributed. China is also frequently hit by drought, water logging and flood disasters. The geographic condition of China is very complex, the usable area of plains and slopes or basins in mountain areas accounting for 12 percent and 29 percent, respectively, of the total land area.

Most of the existing irrigation projects in China were constructed under special social conditions. Affected by long-term war, China was faced with poor industrial production conditions and an extremely weak national economic capacity at the time of the founding of the People's Republic of China. Farmers struggled for basic food sufficiency. In this context, the Chinese Government clearly responded and paid attention to the importance of water conservancy.

Based on the understanding that "agriculture is the foundation of the national economy", water conservancy is considered as the lifeblood of agriculture. It is also clear that all water conservancy problems cannot be solved at this stage, but efforts need to be undertaken to improve water conservancy development as much as possible. Based on the existing socio-economic conditions, the Chinese Government organized millions of farmers to continuously undertake the construction of basic water conservancy projects, such as constructing reservoirs and canals, digging wells and ditches, leveling lands, planting trees and building roads, to improve the living environment and production condition. A large number of irrigation districts have been built during this period, and the following stages have been experienced:

A 3-year rehabilitation period after the founding of the People's Republic of China: The main objectives during this period were to heal war wounds, and to resume agricultural production. Almost all existing irrigation districts were rehabilitated during this period, especially, all the gravity irrigation districts, which reached their best performance level before 1949. Some extensions were also obtained, such as the world-famous Dujiangyan Irrigation District, the command area of which after 3 years of rehabilitation reached 0.2 million hectares, while conditions for further development were founded.

A high-speed development period from the mid-1950s to the 1970s: With the development of material industry and technology, the construction of some large irrigation projects was started. Almost all the existing medium and large-scale irrigation projects in China were constructed during this period. With the development of the mechanical manufacturing industry and agricultural production, China began to construct pumping irrigation systems from the late 1950s. Examples are the Jiamakou pumping irrigation districts in Gansu Province, and the Jangdu Pumping Irrigation and Drainage Project in Jiangsu Province. From the early 1970s, tubewell technology has been developed to exploit underground water resources. It developed rapidly and, especially in the plains of North China, the exploitation of underground water resources has gradually developed to encompass the entire region.

A new period of economic reform since 1980: During this period, especially after practicing of the rural economic contract responsibility system, the ownership system in rural areas changed rapidly. To follow this change, the focal point of irrigation was shifted to management, focusing on basic management work and management system transfer.

Up to now, China has 5,683 irrigation districts whose command area is over 667 hectares, the total effective irrigated areas of these districts are 24,493 thousand hectares -- 45 percent of the total effective irrigated areas of China (Ministry of Water Resources 2001). Among the 5,683 irrigation districts, there are 101 large-scale irrigation districts whose command area is over 33,333 hectares and 141 middle-scale irrigation districts whose command area is between 20,000 and 33,333 hectares. The construction of such a large number of irrigation districts provided an essential environmental condition for China's agricultural and economic development during the past years. But due to insufficient construction and management experience, and poor national and individual economic capacity at that stage, construction quality was poor and the conveyance systems were not completed. Added to poor management skills and unsuitable management systems were project deterioration and inadequate rehabilitation even after several decades of operation. Today, most of the projects are performing below their potential.

PROPERTY RIGHT : EVOLUTION OF WATER CONSERVANCY PROJECTS IN CHINA

The evolution of property right characteristics of water conservancy projects in China can be analyzed in two stages:

First Stage (1949-1979): Establishment of Public Ownership

After the establishment of the People's Republic of China, the Chinese Government began to confiscate all bureaucratic capital that included water conservancy capital. Land Reform Law issued in 1950 clearly stipulated that: "Large water projects, ……. Rivers, lakes …….belong to the state and are managed by the People's Government". This means that most property rights of water conservancy projects are actually controlled by the State. At the same time, "If water projects are invested and managed by private persons, investors can continue to manage them according to regulations issued by the Government". This means that private investors can keep the management right of the water projects. During the socialist transformation period, private water projects were also transferred to the State. Rural water conservancy projects were transferred to public ownership in rural cooperative movement, periods which began in 1956.

Demonstration Regulation of Rural Senior Cooperatives explicitly defined that " private tanks and wells attached to farmers' land should be transferred to cooperative collective ownership, collective ownership will compensate owners to a certain degree based on the actual situation". Since then, socialist transformation of water conservancy projects was stopped, ownership patterns of water conservancy were preliminarily formed. In 1961, the Central Government commented and sent out "Ten Suggestions of Strengthening Water Conservancy Management" formulated by the Ministry of Agriculture (MOA) and the Ministry of Water Conservancy and Electric Power. These ten suggestions further made clear the public ownership of water conservancy projects in the management system. Article 1 in the suggestions stipulated that if the service area of water projects is in one community, one county, one special district or one province, then the water projects will be managed by that community, county, special district or province. If the service area of water projects includes 2 regions (2 communities, 2 counties, 2 special districts), then, the water projects will be managed by the higher government or the main beneficial units decided by the higher government. Article 5 stipulated that, water conservancy management agencies at each level should be obtained into state labor and wage plan, which indicated that water conservancy projects and water management institutions have entered into planning an economic system and formed a typical public ownership.

In 1983, Management Regulations of the Water Conservancy and Electric Power issued by the Ministry of Water Conservancy and Electric Power clearly stipulated that water conservancy and electric power projects invested by the state belong to state ownership and should be managed by the State; sometimes, collectives can be entrusted to manage state projects. Water conservancy and electric power projects run by the local people and subsidized by the State or invested by the communities or production groups will belong to collective ownership and managed by the collective; sometimes they can also be managed by the State according to demand. The ownership of land and accessories in the land under the management scope of the State-managed projects will belong to the whole people, use right belongs to the management units. For collective-managed projects, the ownership belongs to the collective, use right belongs to the project management units.

There exists several basic characteristics of such property rights of water conservancy projects. At first, the structure of the property right is single. Public pattern of State ownership or collective ownership is the single form. Whether large-scale or small-scale water projects, they are all under state ownership or collective ownership; water conservancy management unit or other water conservancy units are all typical institutions owned by the state or collectives. Second, property right of state water conservancy projects embodies management relationship such as owning, using, allocating or disposing right of water conservancy departments. Third, transfer of property right is strictly limited. The public nature of the water project property right cannot be changed and allocated by administrative order; if subordination of water projects or management units is changed, management relationship of water assets will also be changed, accordingly.

Second Stage (1979-till date): Changes in Public Ownership

Since 1978, with the deepening of the rural economic reform, implementation of household production responsibility has weakened the collective economy; management bodies of small-scale irrigation projects have become vacant and destroy these water projects, there's no one to manage and maintain rural water projects. To change the situation in time, the Ministry of Water conservancy and Electric Power began to try to find management methods to suit water project management with household production responsibility system. The idea was to try out every kind of responsibility system (including contract system), combine farmers' short-term interests and long-term interests, plan construction, management of rural water conservancy and agricultural production in an overall consideration, joint responsibility, right and benefit to arouse every level's work incentives. Such methods received good results at that time.

In large-scale water project management, the state paid more attention on position responsibility and strengthened management in the water project management units to collect corresponding water charge and electricity charges in order to ensure normal operation of the water projects.

To encourage masses to construct the rural water conservancy projects, in November 1988, the State Council verified ten suggestions of "Constructing Rural Water Conservancy Projects Depending on Masses" formulated by the Ministry of Water Conservancy. The key issue of the ten suggestions is that the State advocates and encourages farm household or several coordinated farm households to construct rural water conservancy projects according to the unified planning of the local government; the principle of investors as managers and beneficiaries was also emphasized. There is a need to conduct further research on the impacts of the ten suggestions, but at least it implies that the Central Government has begun to pay attention to property right innovation of rural water conservancy projects.

In the 1990s, there have been many advances in property right innovation of rural water conservancy projects. In 1992, the fourth conference of the Communist Party posed the important decision of establishing socialist market economy. Based on the arrangement of the Central Government and combined with the practical experiences of water conservancy reform, the MWR put forward a strategic arrangement of establishing five water conservancy systems in the national water conservancy conference; they include: water investment system, water asset management system, water price and water charge collection system, water legislation system and water service system. Since then, reform of the rural water conservancy has developed further and deepened.

This increased investment in rural water conservancy; each region extensively has collected funds from multi-channels and multi-levels, which greatly enlarged fund sources of rural water conservancy and water conservancy constructed by the farmers have appeared in some places.

Some provinces such as Heilongjiang, Shandong, Henan, Shaanxi, Hebei, Shanxi, Sicuan and Zhejiang have made an active attempt to explore the rural small-scale water conservancy reform. Through carrying out several methods of auction, rent, contract, or share system, ownership is clearly defined, use right is auctioned, construction right is opened up, management right is made flexible and stock asset is used fully, and incentives of project owners are aroused.

Construction of small-scale water projects by private or coordinated households, private contract or share system has changed the only water investment pattern of the State, mobilized the mass incentives of water project investment, realized the unity of construction, management and the use and unity of responsibility, right and benefit. Through property right reform of small-scale water conservancy, many cadres and masses have liberalized thought, renewed their ideas and strengthened market economic consciousness and enlarged investment channels, strengthened engineering management and accelerated water conservancy construction, preliminarily established the small-scale water conservancy management system suited to the social market economy (Chen and Yang 1998).

Until 1997, there existed about 16 million small-scale water projects, and about 2.41 million have conducted property right reform, with 0.31 million of share companies and 0.32 million of auction (Chen and Yang 1998).

However, property right reform of water conservancy has mainly happened in small-scale water projects; property right reform of large and medium water projects are still in the experimental stage. Small-scale water projects occupy an important position in agricultural production; property right evolution of small-scale water projects will improve water management system innovation and also attract the attention from central and local government. Therefore, research in property right innovation of small-scale water projects has large practical meanings.

DETERIORATION OF IRRIGATION PROJECTS

The deterioration of irrigation projects (DIP) in China appeared from the mid-1970s, and reached its peak in the early 1980s. It has become one of the two major crises in China's water conservancy (the other one is the shortage of water resources). The research program, "The Deterioration Assessment and Investigation Methods for Irrigation Projects" was proposed by the Ministry of Water resources in 1990, to get a clear view on DIP, find a suitable measure, and establish a foundation for improving irrigation management and go deeply into irrigation transfer. In this program, the method of "analyzing by levels" has been adopted to formulate a standard for DIP assessment and classification. A nationwide DIP investigation has been made in large-scale irrigation projects, which is based mainly on each provincial association. Targets of this investigation are key constructions at the heads of large-scale irrigation projects, and in canals with over 1 cubic meter per second of water diversion capacity. Results of computer analyses indicate that 53.8 percent of the total key constructions dropped into deterioration in varying extents. The deteriorated canal length accounts for 28.6 percent of the total investigated canal length. The damaging ration of lining canals accounts for 32.4 percent, while the deteriorating ration of construction along canals accounts for 40 percent.

There are many reasons for DIP as indicated below:

- *Natural ageing:* Over 50 percent of total large-scale irrigation districts having been constructed before 1960, most of them have by now reached their rehabilitation or reconstruction age. Thus, natural ageing is the main reason for DIP. According to the study, about 67 percent of DIP is caused by ageing.

- *Lower construction quality:* This is because a large number of irrigation projects is constructed within a short period, and the economic conditions and the technical skills of construction groups are limited during that time. Many project constructions are completed with whatever facilities are available. As a result, the construction quality is low and cannot meet the designed requirements. This situation causes congenitally deficient irrigation projects, reduces their effective operation time limit, and accelerates deterioration. The investigation results indicate that 12 percent of deterioration is due to this reason.
- *Unsuitable planning and design:* Due to limitation in technical capacity and construction standards during the early period, large numbers of irrigation projects were constructed without sufficient evaluation and examination. This caused a lot of planning and designing problems, such as unsuitable canal bed slopes and unsuitable aqueduct inlet and outlet allocation, etc.
- *Ineffective management, and damage caused by humans:* Many management units have no perfect set-up, and the educational background of management staff is low; subsequently, the management work is ineffective. Unsuitable operation has resulted in artificial damage upon the irrigation projects. On the other hand, as a developing country, China’s legal system is still imperfect; people have an indistinct legal consciousness; thus, frequent harm (destruction) was caused to irrigation projects by the humans.
- *Other reasons:* Includes factors such as insufficient maintenance funds which have resulted in insufficient project maintenance, change of water resources, etc. In this case, governments, water conservancy administrative departments at each level, and project management units have paid special attention to DIP. With the help of government finance at each level, a large amount of funds has been put into the reparation and rehabilitation of deterioration projects. But since there are too many problems left over by history, the fund deficits are too big, and the fund sources are limited. The problem has not been solved satisfactorily to-date.

MANAGEMENT OF SURFACE WATER IRRIGATION SYSTEM

Institutional Arrangement of Surface Water Irrigation System

The Chinese Government has always paid special attention to the establishment and perfection of irrigation management systems. The general principle is that the donors will be owners and the managers. Government departments are the main managers of projects funded mainly by the government. Collectives and farmers manage projects which are mainly self-funded. The command area of the State-managed irrigation districts accounts for 47 percent of the total national irrigation area. Some small reservoirs, ponds, and pumping irrigation projects (with less than 667 ha of command area) are mainly managed by collective, with the command area accounting for 27 percent of the total national irrigation areas. Other small-sized irrigation projects, mainly tubewells, are managed by farmers, with the command area accounting for 26 percent of the total national irrigation area. The government water conservancy departments at each level are relevantly in charge of planning, technical supervising, science researching, policy-making and fund allocating. They are also in charge of setting up special local management units for irrigation projects to formulate operation strategies, check and approve annual planning, coordinate water allocation, and project maintenance. According to the regulations formulated by the Ministry of Water Resources (MWR) in 1981, the management units should be set up by the MWR for the projects covering different provinces, and by provincial water conservancy departments for the projects covering different regions or municipalities, and so on.

Traditionally, irrigation projects are classified into two categories: canal systems and field facilities. Canal systems consist of reservoirs, water delivering or drifting constructions on the heads of main canals, and main-branch-tertiary canal systems; and are managed by professional management organizations. Field facilities are managed by mass management organizations. The professional management organizations should be set up by the government water conservancy departments at suitable levels, according to the scale of each command area. This is called "management in levels". The professional management structure is the institution that directly manages the project. It is the executive unit which concretely carries out management operation and implements the policies of the Party and the directives of the higher levels. The actual irrigation management system is complicated, since the management models and systems are varied due to regional differences in: economic conditions; availability of water resources; investment systems for the construction of irrigation projects; project scale, type, construction quality and standard; and local customs, etc. In most regions, reservoirs, canal head constructions, and main canals of large-scale irrigation districts are managed by the same management organization, while branch and tertiary canals are managed by the organizations set-up respectively by a lower level of the government water conservancy department.

There is another kind of management model where the entire canal system and even within-distribution blocks are all managed by the same management organization, set up by a suitable level of government water conservancy department. It is called the "uniform management model" in China, and is only practiced in a few provinces, such as the 9 large-scale irrigation districts in the Guanzhong region of the Shaanxi Province.

No matter what kind of irrigation model, democratic management systems exist at each level of management organization. The participants include the representatives of beneficiaries, local government officials and irrigation management units. They are called democratic management committees or democratic representative conferences. One or two meetings will be held annually in these conferences or associations to make important decisions for project operation, such as water volume distribution, large-scale reparation and rehabilitation, calculation and levy of water charges, etc.

In most cases, the village irrigation management group divided the voluntary labor requirements from its village into a quantity of labor to be provided by each household. If, for some reason, a household cannot contribute the required voluntary labor for canal maintenance, these households are requested to pay the wages for hiring other farmers to work. For special maintenance works, different organizations will take responsibility according to the maintenance work done on different levels of the canals. Generally speaking, for important maintenance work such as lining of canals or building a new structure along the main canal, the irrigation management office will make the plan and take responsibility for the organization; building materials will be provided by the office as well. However, one village or more which directly benefits from this will be asked to provide the required voluntary labor. All maintenance on sub-branch and field canals is organized and conducted by the village irrigation groups through whose villages the canal passes.

FUNCTIONS OF PROFESSIONAL AND DEMOCRATIC MANAGEMENT ORGANIZATIONS

The regulation on Irrigation District Management Method defined the following functions for professional management units of the irrigation district: 1) Implement relevant water polices and orders from the upper-level governments, decisions of the representative conference and management commission of the irrigation district (ID); 2) Establish and complete the water users' management organization of the ID; 3) Maintain the water projects and ensure its security; organize the beneficiary units to do well the field projects and land leveling work; 4) Organize the beneficiary units to clean the canal, blocking and emergency repair, etc.; 5) Conduct planning of water use, improve irrigation technology and quality, conduct drainage work well and improve soil quality; 6) Conduct irrigation experimental work, extend science and technological achievements; summarize farmers' experience and guide scientific water use; 7) Protect water resources and prevent pollution; 8) Organize the greening work of the irrigation districts; 9) Organize water fee collection, conduct diversified economy, perfect financial system and strengthen management; 10) Strengthen statistical work and establish technological files; 11) Organize the training of staff, improve their capability, and resolve the practical difficulties of the staff.

The function of the Management Commission of the Irrigation District is to check the work plan and summary of the management unit; make and adjust management regulations of the irrigation district, research the key issues of the irrigation district management. The major task for the representative conference of the irrigation district is to reflect beneficial opinions and requirement, check work report of the Management Commission of the Irrigation District, discuss the important issues that are proposed by the commission and make a decision. The decision of the commission and representative conference can be implemented after approval by the upper level administrative authorities.

From the institutional arrangement of the irrigation district, especially the democratic management it seems involves the water users' participation in irrigation management; this pattern is somewhat similar to participatory management. However, there is a basic difference between China's democratic management pattern and participatory management (Tao 2002). The differences can be summarized into three points:

First, the traditional pattern of China's irrigation district was established in the planned economic system, water was not treated as a commercial product and was almost free. Although some water users were involved in the irrigation management, the major management responsibilities of the irrigation district was still undertaken by the government. This situation not only resulted in increasing the burden of the government, but also resulted in unclear property right relationship, management responsibilities and poor management.

Second, the professional management unit of the irrigation district is stipulated as administrative in nature, directly controlled by the government and with no independent rights. In another aspect, the government has encouraged the irrigation district to be financially independent. Since the professional management agency of the irrigation district has no independent power it is hard for it to be financial independent. The conflicting responsibilities of the irrigation district have greatly influenced the operation of the irrigation district, a case of low income and high expenditure.

Third, the democratic management organization is not really voted by the water users and appointed by the governments. Most heads of democratic organizations are township or villages leaders. In fact, they are governments' representatives in the field-level. Water users or farmers only provide labor or money-based requirement of the democratic organization and seldom participate in any other management activities.

MANAGEMENT REFORM OF SURFACE WATER IRRIGATION SYSTEM

At the beginning of the rural reform in the 1980s, irrigation management systems could not fit the requirements of reform, which at once resulted directly in the decrease of irrigation area in China. In this case, the Chinese Government strengthened it with the water conservancy system. A series of policies, laws and regulations have been issued by the Central Government, such as the Water Law, the government policy for water conservancy management transfer, and water charge calculation and levying, etc. Further, water management offices were established in every township, and those found guilty of destroying water conservancy facilities were severely dealt with. Since 1990, along with the establishment of the China Commercial Economic System, irrigation management systems were transferred gradually. The government departments have begun: to account for property and check the financial status of the irrigation districts; to identify property rights between farmers, collectives and government departments; to re-divide duties and responsibilities between governments and irrigation management units; to establish contract responsibility management systems; to practice and improve a stock-sharing system and an inner hire irrigation system; to establish water company and Water User Association, etc. In sum, with continuous practice, China's irrigation management transfer has begun in-depth.

DIVERSIFIED SIDELINE ENTERPRISES

Irrigation districts often have under-utilized assets and resources that have a potential economic value. There was generally a gap between the level of resources which could be raised by the irrigation fees (because of political reluctance to require farmers to pay for the full cost of irrigation service) and the actual costs of operations and maintenance. By the 1980s, the salaries of irrigation district officials were dropping in real terms below alternative employment opportunities in rural China, and skilled staff were leaving the service due to low salaries and poor working and housing facilities in irrigation districts. In order to bridge the gap between the limited revenue and the amount needed for O&M and to boost salaries and facilities for irrigation workers, the government introduced the concept of diversified sideline enterprises into the irrigation sector. In the early 1980s, the State Council issued the regulation on Diversified Sideline Enterprises. Irrigation districts were encouraged to develop sideline enterprises to raise additional revenue. Profits from these businesses were to cross-subsidize the costs of irrigation management. By 1988, it was official policy that no central or provincial government funds could be used for regular O&M in irrigation districts.

Officially, the profit from these sideline activities is to be used for the operations and maintenance of the water unit in question, but often the profits are reinvested in the sideline operation itself or paid out to employees as bonuses. Some water units are evidently neglecting water management in their pursuit to earn profits from economic sideline activities. These inefficiencies represent an unintended outcome or necessary evil resulting from the government's policy to encourage economic entities. Beijing cannot and should not monitor every economic sideline operation undertaken by every irrigation district in China. On the other hand, not all water units have succeeded in keeping the sideline activities in operation and have subsequently been unable to use this means to finance their water activities. The main reason has been the lack of scientific, technological and managerial experience, leading to the production of items that are not competitive.

The central government has been formulating economic policies and water laws to encourage the development of economic entities and help water management units function better. In the period of the Eighth Five-Year-Plan (1981-1985), every water management unit that used its own natural resources to plant crops, raise fish, or construct its own agricultural processing plants or water conservancy projects was to be exempt from all state industrial taxes. Regulations on water conservancy entity management were promulgated in 1988. The State Tax Bureau also issued a document in 1992 which stated that "water management and water protection stations, and water production station units that provide technological expansion, irrigation and technological management for a fee shall be exempt from state taxes on their revenue."

Many water management units do not appear to be taking advantage of these tax breaks or using other conservancy economic policies to look for opportunities to develop economic entities and raise funds. Why have the government's attempts at providing incentives for better management proved unsuccessful? One possibility is that lower level water bureaus and stations lack the time, expertise and experience to become financially self-sufficient. A structural problem limiting the development of economic entities in much of the interior of China is the lack of market-oriented infrastructure such as roads and railways. Also, economic entities are possibly a self-defeating attempt at providing a solution to the underlying unprofitability of many water management operations.

WORK POST RESPONSIBILITY SYSTEM (WPRS)

Most of the irrigation districts are faced with the following problems: too large in organization, too many persons not engaged in management, low work efficiency, high management costs, poor staff living conditions, etc. Since the 1980s, a lot of work has been done by the MWR and the water conservancy administrative departments at each level, and by the management units. The work post responsibility system (WPRS) was introduced in the early 1980s since the "The Regulation for disposition of establishment and personnel in management units of water conservancy projects" issued by the MWR. It regulates the standards of establishment and personnel disposition for management units of all types of water conservancy projects. The general limits for disposition of establishment levels and management of staff numbers in different kinds of management units have been set, each position and its responsibilities in the unit have been stated clearly. According to the amount of work of each post, the number of staff members for each post can be decided, and the personnel can be allocated according to their responsibilities. Then expenditure such as salaries, office expenses and traveling fees can be controlled according to the total number of staff members disposed. This can save unwanted expenses and cut down costs.

The WPRS was an attempt to introduce a system of incentives to the water resources bureau officials to improve their work productivity. It was seen as a counterpart to the agricultural production responsibility system. Monetary bonuses and penalties were introduced in annual work performance evaluations amounting to 20 percent or more of base salaries. For collective-owned systems, a revolutionary reform system was implemented, the economic contract responsibility system (ECRS). Although originally limited to small irrigation systems, in many cases, elements of the ECRS have also been implemented -- within larger government irrigation systems. The county water resources bureau remained intact with the demise of the communes.

CONTRACT RESPONSIBILITY SYSTEM (CRS)

The principle of contracted management separating proprietary rights from management rights, was the guiding thought for contracted management. This can be elaborated as follows: Ensuring the social benefit, contracting the base number of income, and checking up the expenditure; extra earning can be used for individual expense but no subsidy will be offered to the debtors.

The method for establishing contract responsibility system includes perfecting organizations and implementing contracts at different levels. The concrete steps taken are generally as follows: First, seriously checking up the base number, setting preliminary targets and setting the contract schemes. For this purpose, it is necessary to carry out a general investigation of all-level canals and installations, to check up fixed assets and to evaluate the present management states of the irrigation district. Based on the preliminarily calculation, such items as contractor's requirement, contract forms, duration, rights and responsibilities of contractor and ways of reward and punishment are decided. The next step is to issue the bid for contract among cadres in the irrigation district, to evaluate the contractor's qualification, and to select the contractor by vote. Finally, the contractor signs the contract with the head office of the irrigation district. The second comes after the perfecting of the relevant organizations; the third is the distribution of the contract targets level by level to the divisions, stations, sections and individuals. A set of evaluation indexes such as irrigation area, project perfect, income and outlay, crop yield and production value, water use efficiency, irrigation quota, rebuilding project, safety, technical popularization and training, etc. will be established. The contractor will be examined at the end of the year. The diligent contractors will get rewards while the lazy ones will be punished.

According to empirical evidence, some contracted management can get some achievements on increasing water fee, improving water facilities and promoting working efficiency, etc. However, judging from the demand for reform, there are still many problems of contracted water management, such as hard to realize self-sufficiency in funds, ageing and un-repaired projects, field projects which have a lower completeness, contract targets which still remain to be perfected, majority of employees with a lower education level, etc.

SELF-FINANCING IRRIGATION AND DRAINAGE DISTRICT (SIDD)

Although WPRS and CRS have played an important role in improving water management and water use efficiency, reducing water management cost and ensuring high quality of irrigation service, the planned management system of irrigation districts have not changed basically and hardly suit the market economy development. New management reform patterns of irrigation districts are urgently needed to cope with some old problems and greatly improve the overall water management level. In this situation, in the middle of 1990, a new water management reform – Self-financing Irrigation and Drainage District (SIDD) was introduced with the implementation of the Yangzi River Water Project funded by the World Bank.

SIDD was firstly experimented in the Zhanghe Irrigation District of the Hubei Province and Tianshan Irrigation District of the Hunan Province. Experimentation works in the Hubei Province have been confirmed by the China Irrigation District Association and Hubei Water Resources Bureau. The Hubei Water Resources Bureau has planned to extend SIDD in all provincial irrigation projects. In the second stage of the irrigation agriculture project of the World Bank, the experimentation work of SIDD has been conducted in the irrigation districts of Hebei, Jiangsu, Henan, Shandong and Anhui.

According to the report of Dongfeng Canal Management Division of the Zhanghe Irrigation district (2002), the establishment of SIDD in 1997, has improved the facility situation and some damaged constructions have been repaired, has reduced the administrative costs due to labor use reduce (like in 1998, it reduced the administrative cost to 180 thousand yuan) and reduced farmers' water fee (in 1998, per hectare water fee reduced to 277.2 yuan) which greatly reduced farmers' burden. Under the new management system of SIDD, water supply procedures have been simplified, water supply company directly contact with WUA, water supply guarantee rate has increased from 40 percent to 80 percent, 100 percent of water can be supplied in due time. Water fee collection rate also increased 50 percent and this greatly improved the WSC's economic status. However, the reform of SIDD is still faced with the following questions: 1) Water price is still far lower than water supply cost; 2) Hard coordination relationship between the SIDD and local administrative authorities; 3) Property right of fixed capitals are still not clear; 4) Poor completion of basic facilities. The evidence from other regions' SIDD also shows some achievement, especially in reducing water fee level and increasing water supply availabilities. However, they are all facing similar problems like the Dongfeng Canal.

The experiences of SIDD development in China include (Water Saving Irrigation Project Office 2002): 1) Improving the understanding of the SIDD. SIDD emphasizes farmers' participation in irrigation management. According to the economic regulation, self-management, independent financing and self-sustaining management system will be established; such a management system is suited to the theory of market economy and strategy of sustainable development. In SIDD, farmers' incentive in water management can be motivated and can play an important role in improving water management. 2) Accumulating some experience of SIDD patterns. SIDD will establish Water Supply Company (WSC), Water User Association (WUA), establish a management system of water supply and utilization, establish a monitoring system of water users, project management, pricing and decision institution, etc. Through establishing such a management system, WSC and water users will have clear duties and responsibilities; one united management system on water project operation, water utilization and irrigation benefits will be established. 3) SIDD needs a certain engineering and socio-environment. Establishment of SIDD needs a complete system of facilities and management measures. In addition, the establishment of SIDD needs to get the support of every level of government and societies. 4) Township governments and village collectives are an important foundation for establishing SIDD. SIDD will serve the farmers directly and should let farmers fully understand SIDD. However, due to too many small farmers and few water management officials in the water authorities, this work cannot be depended only on water departments and should depend more on township governments and village collectives for their rich experience in working with farmers. 5) Pattern of SIDD should be suited to the local conditions. At present, the major pattern of SIDD is to transform the water management units at the branch or tertiary canals into WSC, establish WUA in the villages or townships. In fact, there are many patterns for SIDD and local regions should explore the suitable management patterns of SIDD.

MANAGEMENT OF GROUNDWATER IRRIGATION SYSTEM

Process of Property Right Innovation

Before rural reform, most village Groundwater Irrigation Systems (GWIS) were built in the 1950s or 1970s by state or collective investment and farmers' labor input. After construction of the GWIS, generally, collectives will be responsible for management of the GWIS. Before the 1980s, property right of the GWIS was collective property right and it suited the agricultural production patterns of the planned economic system such property right has played important roles for agricultural production growth and water resources effective utilization. However, any property right has historical constraints and its existence and development need the support of certain social, economic and institutional environments; if it violates the rule, its existence will necessarily impede productivity improvement.

Since the implementation of a household responsibility system, agricultural production patterns and management mechanism have greatly changed; agricultural production has shifted from collective production to household production, which implies that GWIS served for agricultural production will also change correspondingly.

In the past few decades of rural reform, property right of the GWIS represented by the Hebei Province in North China exhibits several obvious development trends (Wang 2000):

Each kind of property right of GWIS exists at the same time, but structure has changed obviously

For collective property right of the GWIS, the number of quasi-collectives has been basically kept constant while the number of pure collective property right has decreased nearly 3 times from the early 1980s to 1998; which results in number decrease of collective property right.

When collective economic power is relatively weak, previous GWIS of collective property right is either deteriorated or its facility is incomplete, and farmers' economic condition and management ability is not enough to organize GWIS by themselves; quasi-collective property right will appear. On the contrary, if collective still has economic power to manage GWIS, collective property right will be kept.

Outwardly, quasi-collective property right combines the advantages of both collective and farmers and both collective and farmers can play their potential, i.e., it not only utilizes previous collective water projects and some collective organization and construction abilities, it also explores the farmers' investment ability and involves farmers in the management of the GWIS. However, property constraints (unclear property right), determines that quasi-collective property right is only one transition form of property right innovation; it will necessarily be substituted by more effective property right. It may be a nice example to approve that share of quasi-collective property right decreased from about 40 percent in 1983-1990 to 26 percent in 1998.

One key disadvantage of quasi-property right is unclear property right and management responsibilities. In appearance, property right of collective has transferred to each farmer and the GWIS will be controlled by farmers, while in fact, property right relationship and management responsibilities are not clear, farmers can be free to use water projects but property right of each farmer is so small that no one would like to be responsible for GWIS management; in addition, since each farmer owns some parts of property right, they are afraid that their property rights cannot be fully implemented, they try to be the first to use water, which results in wastage of water resources, destruction of water facilities and increasing serious water conflicts.

For non-collective property right of GWIS, number of shareholding property right increased from 88 in the early 1980s to 599 in 1998, i.e., it increased 5.8 times. Development of shareholding property right has captured much attention of every level government, for instance the Hebei System Reform Commission and the Hebei Water Resources Bureau jointly issued "Trying out Approach of Developing Small Shareholding Property Right of Small Water Projects of Hebei Province". In order to promote shareholding property right of irrigation system, the Hebei Finance and Water Resources Bureau is formulating "Implementation Program of Small Shareholding Water Projects in the Hebei Province" and "Implementation Detail of Small Shareholding Water Projects in the Hebei Province". Many municipalities and counties of the Hebei Province also issued relevant documents on shareholding water projects to encourage farmers to invest in water projects. According to information obtained from officials of the Ministry of Water Resources (MWR), MWR is also formulating a national management regulation on shareholding water projects.

Private property right of GWIS mainly developed after 1990. In 1990, only 4 private property rights of GWIS existed; in 1998, the number of private property right of GWIS reached to 99, increased nearly 24 times. According to our field survey, occurrance of private property right is mainly due to profit purpose, not for satisfying agricultural production; appearance and development of private property right of GWIS also indicates improvement of farmers' investment and market consciousness; farmers have a further understanding of water resource's value.

With quick development of shareholding and private property right of GWIS, number of non-collective property right of GWIS has increased rapidly after the 1980s, which results in shifting of property right from collective to non-collective property right.

Collective property right has been gradually substituted by non-collective property right of GWIS

The most significant change in the property right of irrigation system in our study area is shifting from collective to non-collective. In the early 1980s, the collective owned groundwater irrigation system accounted for 83 percent of all groundwater irrigation, while share of non-collective property right was only 17 percent. Till 1990, non-collective property right of GWIS developed much and share of collective property right was only higher 12 percent higher than non-collective property right. After 1990, non-collective property right of GWIS has continued to develop and collective property right has continued to decline, which resulted in substitution of collective property right by non-collective property right. In 1998, share of non-collective property right reached 69 percent and became main pattern of property right; while share of collective property right decreased to 31 percent.

Within collective property right of the GWIS, quasi-collective property right has been gradually substituted by pure-collective property right

Within collective property right system of the GWIS, pure-collective owned irrigation system has gradually decreased from 52 percent in the early 1980s to 16 percent in 1997, though it increased to 18 percent in 1998, it was still lower than that in the early 1980s. Compared with the decline in share of pure-collective property right, share of quasi-collective property right has increased continuously. Even in the early 1980s, share of quasi-collective property right was as high as 48 percent, which was somewhat slower than that of pure-collective property right at the same period. In 1990, share of quasi-collective property right reached 76 percent, which became the dominating pattern of collective owned irrigation system. In 1998, the share of quasi-collective property right rose to 82 percent.

In non-collective property right of the GWIS, shareholding of property right had been a dominating position, private property right developed quickly in recent years.

The non-collective owned groundwater irrigation system was dominated by the farmers' shareholding in the initial stage of property right changes due to credit constraints of individual farmers. Even in 1998, share of shareholding property right was still 86 percent. The individual (private) owned irrigation system has been growing rapidly since the early 1990s, increased from 1 percent only in 1990 to 14 percent in 1998.

BEHAVIOR CHANGES OF FARMERS AND GOVERNMENT IN THE PROPERTY RIGHT INNOVATION

Property right innovation of the GWIS generally accompanies behavior changes of farmers and government, which induce the direction and progress of property right innovation. Analyzing the motive power and socio-economic and policy environmental conditions of property right innovation of the GWIS, we found that property right innovation is an induced institutional change under relaxing constraints of government. With commercialization improvement and market development, property right of the GWIS has gradually became market-oriented. According to an economic theory, institutional innovation accompanies technological improvement; there exists a mutual influence relationship between institutional innovation and technological improvement. Therefore, property right innovation of the GWIS inevitably accompanies renewal of water infrastructure.

Based on the behavior changes of farmers and government, motive power and characteristics of property right innovation of the GWIS are analyzed as follows: (Wang 2000):

Farmers' behavior has transferred from spontaneous to consciousness.

Property right innovation of the GWIS originated from farmers' spontaneous behavior under serious livelihood stress. When development of agricultural production was constrained mostly due to increase of water shortage and drought problems, destroying and aging water infrastructure and weakening organizational and investment capacity of village collective, in order to improve livelihood ability and improve agricultural growth, non-collective property right of the GWIS organized by farmers began to develop. Our field survey also presented that more than 90 percent of farmers believed that if there was not a serious drought problem and if collective GWIS could continue to operate and satisfy their irrigation demand, they would not have invested in the GWIS. One reason that resulted in the farmers' spontaneous behavior is the farmers' limited knowledge and consciousness; another reason is that of economic constraints.

With social development and livelihood condition improvement, some farmers have begun to organize irrigation systems consciously, which promote quick development of non-collective property right of the GWIS. Farmers have gradually realized that water resource is not only a natural resource to be used for serving agriculture; water resource is also an important economic resource. Increasing water shortage also force farmers to consider what is the most suitable property right patterns for them. Therefore, farmers' behavior has gradually changed from spontaneous behavior to conscious behavior. Establishment of market-oriented economic system and water management policy was also an important inducement for property right innovation of the GWIS.

Government behavior has transferred from silent, tacit approval to active mobilizing.

In the early 1980s, rural water conservancy was ignored by every level of government. Groundwater irrigation system was in an unclear policy position and went unchecked. Developing agriculture focused on reforming land tenure and mobilizing farmers' incentives, water resources development was not emphasized. However, with the decline of irrigated areas and accompanied agricultural production decrease, government has realized the influence of mismanagement of water resources and the importance of improving water resources management. In order to improve water resources management, the water resources management system has begun to reform and rural water conservancy reform, especially, non-collective irrigation system attracted attention from the policy makers.

For non-collective property right innovation of the irrigation system, government originally remained silent, i.e., they neither supported nor prohibited their development. Since innovation of non-collective property right of irrigation system has promoted agricultural development and improved water management, the government was reluctant to express their opinion so early and wanted to observe the influences of this innovation for some time.

Under the relatively relaxing policy environment, non-collective property right of the GWIS has developed quickly. With the improvement of political and economic environment and increase in water shortage, reforming water management system has become more urgent, which requires every level government to give the property right innovation a definite answer (in a clear manner). Every level government has realized that the achievement of property right innovation of irrigation system and a breakthrough in reforming water resources management system was what they always wanted. Therefore, the government has begun to propagate property right innovation of the GWIS and actively encourage water investment of social resources. The state's "Ninth-plan and 2010 Long-term Program" indicates that institutional system and economic growth patterns should be promoted to change. In order to promote two basic transformations in rural water conservancy and promote rural water conservancy, property right innovation should become the breakthrough and a new rural water conservancy management system should be established.

Under government attention and propagation, institutional and policy constraints and cost of property right innovation has been reduced, farmers' incentive has increased and the nature and importance of water resources have been further realized. Increasing understanding of property right innovation has also promoted water policy reform. The government has increasingly realized the potential and constraints of property right innovation of the GWIS, and also gradually found the suitable roles that government should play in promoting property right innovation. In short, the government has transferred their behavior from silent, tacit approval to active mobilizing.

Property right innovation of GWIS is a kind of induced institutional change under government, relaxing constraint.

There are two kinds of institutional change: forced institutional change and induced institutional change. Forced institutional change is supply-oriented; government promoted institutional change by legal and administrative power is one kind of specific form of forced institutional change. Induced institutional change is demand-oriented; it is not forced by the government, but is a conscious institutional change induced by obtaining profit opportunity of imbalanced institution. Some scholars believed that during reform, not only forced institutional change needed the government to compel, but also induced institutional change needed the government to relax constraint. As a normal social representative, the government must be responsible for all progress of the reform. During forced institutional change, government promotes institutional change mainly by direct measures such as legal and administrative power; while during induced institutional change, government influences institutional change mainly by indirect measures such as persuasion and benefit inducement.

Since property right innovation of the GWIS has originated from farmers' spontaneous behavior, no government force has been implemented, it is a demand-oriented institutional change; at the same time, a relatively relaxing and beneficial environment has also promoted property right innovation. Therefore, property right innovation of the GWIS is an induced institutional change under the government, relaxing constraints.

Property right of the GWIS has gradually transferred to market-oriented.

Management purpose of the GWIS, especially, non-collective property right, has transferred from one purpose of serving agriculture to two purposes of serving agriculture and obtaining profit; obtaining profit has even become the main purpose of operating the GWIS. An increasing number of farmers have realized the economic value of water resources and treat water resource as a tradable good. Establishing non-collective property right, the GWIS has become one way of increasing the income of some farmers. Our field survey shows that 62 percent of shareholding property right of the GWIS have conducted water trading; share of traded water quantity over total water production in 20 percent of these GWIS exceeds 70 percent, and share of traded water quantity in 5 percent of the GWIS reaches 100 percent. All private property right of GWIS have traded water; share of traded water quantity in 85 percent of private property right of the GWIS exceeds 70 percent.

Field survey shows that water trade in the GWIS has the following influences: groundwater market has been developed, water pricing has been transferred from administrative control to market control; water resources value has been reflected in some degree; water use efficiency has been improved; institutional and fund foundation of extending water saving technology has been ensured in some degree; water saving incentive of farmers has been mobilized and water saving consciousness has been strengthened; natural resources arrangement has been optimized and management system of the GWIS has been improved.

Property right innovation of the GWIS was accompanied by renewal of water infrastructure.

In the early 1980s, water resource was relatively sufficient and groundwater table was relatively high; most the GWIS used large open-wells (average 10 meters depth) and centrifugal pumps. At that time, the main form of the GWIS is collective property right; most large, open-wells belonged to collective, and centrifugal pumps either belonged to collective or belonged to farmers (if collective centrifugal pump was destroyed), which resulted in pure collective property right and quasi-collective property right of the GWIS. Generally, one large open-well can install several pumps; the centrifugal pump has easily movable characteristics. Therefore, one large open-well was installed with several centrifugal pumps which resulted in serious water conflicts among farmers. Although some farmers did use water they also put their pumps into the well in order to occupy water for future use, which not only destroyed well and pump and resulted in water waste, but also resulted in misallocation of water resources. Some farmers overused water resources, while some farmers had no sufficient water; that, influenced the agricultural production.

With groundwater table drop, most collective owned large, open-wells were dried and centrifugal pumps were discarded in 1986, shallow-well began to be drilled (30-40 meters depth), deep-well pump or small diving pump was used. At this time, collective owned GWIS was still the main form; pure collective and quasi-collective property right still co-existed. Since mouth area of the shallow-well is not large, it is not possible to install several wells at the same time; and deep-well type pump and small diving pump are not easy to move and fix; shallow-wells are more convenient to manage than large, open-wells. Therefore, shallow-wells can not only reduce water conflict, but also promote water management improvement and make non-collective property of the GWIS development possible. During the period, non-collective property right of the GWIS has developed in some degree.

After the 1990s, with groundwater table further dropping and water shortage becoming serious, most shallow-wells were discarded, deep-shallow wells (more than 50 meters depth) were drilled and deep-well diving pumps were used. Deep-shallow wells need large investment and strict management, which resulted in more quicker development of the non-collective property right of the GWIS (main form is shareholding property right). Even for collective owned property right of deep-shallow wells, management mechanisms also needed to be reformed.

Based on the above analysis we found that during property right innovation of the GWIS, water infrastructure will also be renewed. From this perspective, property right innovation of the GWIS has promoted extension of advanced and highly efficient water infrastructure; from another perspective, it is renewal of water infrastructure that promoted property right innovation. Various water infrastructure require various property right of the GWIS. Induced innovation theory believes that, changes of natural resource endowment and market demands will necessarily promote technological and institutional innovation. This theory has been approved many times in development history. Scarcity of land resources led to development of land-substitute technologies such as variety, fertilizer and agricultural, chemical and land tenure reform. Scarcity of labor resources and increase in opportunity cost led to extension of machinery technology and institutional change of labor hire. Scarcity of water resources led to innovation of irrigation and water-saving technologies, while technological innovation ensured institutional innovation. Therefore, property right innovation of irrigation system is an inevitable trend of development of history.

Determinants and impacts of property rights innovation

Based on the case study of the groundwater irrigation system, Wang, Huang and Scott (2000) analyzed internal relationship between property right innovation and inducement factors, impacts of property right innovation on water supply efficiency and cropping patterns. Research results show that property right innovation of the groundwater irrigation system is subject to theoretical assumptions; it is induced by increasing water resources scarcity and groundwater exploitation, worsening existence environment, weakening local community power (mainly weakening of collective), improving of human capital, water finance policy and water credit policy, and market development. Property right of the GWIS will change continuously with changes in inducement factors.

Technical efficiency is determined by property right, management mechanism, irrigation system scale and irrigation system age. The impact of various property rights on technical efficiency is different; compared with collective property right, non-collective property right can improve the technical efficiency of the groundwater irrigation system; obviously, it is also identical to theoretical discussions on technical efficiency of property right (Wang and Huang 2002). Except for property right, relevant related factors with technical efficiency include management mechanism, irrigation system scale and irrigation system age. Results show that bonus management mechanism, larger scale of irrigation system, and a longer founding year of the irrigation system will be beneficial to the technical efficiency of the irrigation system.

Further, innovation of non-collective property right of the GWIS has advanced changes of cropping patterns, which has expanded the share of sown area of high-value crops and declined the share of sown area of grain crops (Xiang and Huang 2000). In addition, rise in price ratio of grain crops over fertilizer, increase of per capita grain purchase quota and opportunity cost of agricultural labor can all result in increase in share of sown area of grain crops. The following sections will discuss policy implications of these research results.

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CHAPTER 4

Study Settings and Data

Data and information used in this study come from secondary and first-hand sources. We have extensively reviewed related literature especially past research reports, government documents and publishing materials on poverty and water institution issues at national, river basin and local levels (focus on Ningxia and Henan Provinces) in China. In addition, we also interviewed related management authorities at central, provincial, prefecture, county and irrigation system levels, such as Ministry and Bureaus of Water Resources, National and local Pro-poor Offices, Ministry and Bureaus of Agriculture, River Basin Commissions and its local offices and some others. Through these extensive interviews, the related poverty and water institutional issues have been further understood. These interviews also strengthen our cooperative relationship with central and local government in field-survey work and further research.

More importantly, we conducted surveys that covered the various stakeholders of irrigation districts in Henan and Ningxia Provinces along the Yellow River Basin (YRB) during the winter of 2001. To increase the variation among regions, we chose our provinces to be located in the upper (Ningxia) and lower reaches (Henan) of the Yellow River Basin (YRB). In selecting the irrigation districts for our study, we considered a number of criteria. From a number of Irrigation Departments(IDs) in each province, we chose the two IDs based mostly on water availability, by selecting one that is upstream in the province and one that is downstream. After the IDs were selected, we randomly chose sample villages from the census of villages in the upper, middle and lower reaches of the canals within the IDs. Enumerators also randomly chose four households within each village. After getting the basic information about each plot, the enumerators chose two plots from each household for more careful investigation. In total we surveyed 56 village leaders, 68 water managers, 213 farm households and gathered information on 426 plots.

Within our sample IDs in Ningxia and Henan Provinces, the average share of irrigated areas are as high as 90 percent, few samples on rainfed-irrigation have been randomly selected. In order to explore the pro-poor implications under irrigation and non-irrigation condition, we also complemented our study with some household survey data conducted by the Center for Chinese Agricultural Policy (CCAP) in 2000. These data came from a randomly selected, almost nationally representative sample of 60 villages in 6 provinces of rural China (henceforth, the China National Rural Survey or CNRS).[5] To reflect accurately the varying income distributions within each province, enumerators selected randomly one county from within each income quintile for the province, as measured by the gross value of industrial output. The survey team selected randomly two villages within each county and used village rosters and our own counts to randomly choose twenty households, both with and without their residency permits (*hukou*) in

[5] The provinces are Hebei, Liaoning, Shaanxi, Zhejiang, Hubei, and Sichuan. The data collection effort involved students from the Center for Chinese Agricultural Policy, Renmin University, and China Agricultural University. It was led by Loren Brandt of the University of Toronto, Scott Rozelle of the University of California, and Linxiu Zhang of the Center for Chinese Agricultural Policy, Chinese Academy of Sciences. Households were paid 20 yuan and given a gift as compensation for the time that they spent with the survey team.

their village. The survey included a total of 1,199 households. The household data from this survey are mainly used in chapter 6, analyses in all other chapters are based on the data from the four IDs of the Henan and Ningxia Provinces that we collected in 2001.

CRITERIA AND SELECTION OF RESEARCH AREAS

To increase the variation among regions, we chose our provinces to be located in the upper and middle reaches of the Yellow River Basin. Ningxia Province is located in the upper reaches of the YRB; Henan Province is in the lower reaches (table 4.1.) In addition, we tried to increase the variation among sample regions within each province. To do so, one irrigation district in each province was chosen in the upper reaches of the province's segment of the YRB. Another was chosen in the lower reaches.

Table 4.1. Characteristics and distribution of samples in the four irrigation districts of the study, 2001.

	Irrigation District			
	WID-N	QID-N	PID-H	LID-H
Total in sample districts				
Primary main canals	1	2	1	1
Secondary main canals	6	16	5	3
Branch canals	na	na	50	14
Total in the study area				
Primary main canals	1	2	1	1
Secondary level main canals	4	8	3	3
Branch canals	6	11	8	4
Tertiary canals	8	24	16	8
Samples				
Villages	8	24	16	8
Households	34	95	66	36

Note: na = not available
Data source: Authors' survey (2001)

In selecting the irrigation districts for our study, we considered a number of criteria. From a large number of districts, we chose the irrigation districts based on the level and variations of their poverty incidence, size, water availability, and the age of the infrastructure. It turns out, when examining such a wide diversity of irrigated areas, that we were able to observe a wide number of institutional arrangements, incentive systems and local operating rules. Based on these criteria, four irrigation districts in two provinces along the Yellow River Basin (YRB) were selected. Specifically, we chose the Weining Irrigation District (WID-N) and Qingtongxia Irrigation District (QID-N) in the Ningxia province.[6] In the Henan Province we chose the People's Victory Irrigation District (PID-H) and Liuyuankou Irrigation District (LID-H).[7] Within each irrigation district villages were randomly selected since all the villages in each district were classified by differences in the size and age of the village's irrigation systems and variations in infrastructure conditions.

The two districts in Ningxia differ sharply in their size. Among our four sample districts, QID-N is the largest irrigation district with a command area that covers nine counties that are evenly spaced along the main canals. In this district, we chose one county from the upper, middle and lower reaches of the district. In contrast, the other district in Ningxia was smaller. WID-N's command area covers almost two counties. Both of these counties are in the sample. In each county, two townships were randomly selected.

Likewise, the two districts in Henan differ in their size. PID-H has a total of seven counties. The distribution of these counties along the main canals is spatially complex. As a result, we randomly selected three of the system's main canals to be in our sample. These three canals cross five counties. Since the command areas of two selected main canals are much larger than the third one, we randomly selected three townships that were served by each of the two larger canals and only two townships along the smaller one. LID-H is the smallest irrigation district among the four selected IDs. A single county, Kaifeng, makes up most of its command area. We randomly selected two townships from the upper reaches of the district and two townships from the lower reaches.

After the townships were selected, we selected the sample villages and households for our primary survey work (table 4.1, rows 8 and 9). In each township, the survey team selected two villages and an average of four households per village. Sampled in this way, we conducted community, irrigation system, and household interviews in 11 counties, 56 villages and 233 households. However, due to data problems, we were forced to drop one household in the LID-H and one household in the QID-N, making the actual number of usable number of observations equal to 231.

BASIC CHARACTERISTICS OF THE RESEARCH AREAS

[6] The WID-N and the QID-N include gravity and lift irrigation regions, in order to compare with Henan's irrigation management (mainly gravity irrigation); we only selected the gravity irrigation regions to do case studies. In the gravity irrigation regions, there are scattered samples of lift irrigation.

[7] The selection of these two provinces is also due to the fact that two other major water projects are located in the provinces: IWMI's rice water saving project in LID-H of Henan and ADB's Shapatou water project in WID-N of Ningxia. The selection of our irrigation districts in the above 2 project areas helps and complements our project in many aspects.

Ningxia and Henan Provinces

Different from the Ningxia Province, besides the Yellow River, the Henan Province is also fostered by several other large rivers. The Ningxia Province is located in the North-west of China and mainly depends on the Yellow River to support its local socio-economic development. The total length of the Yellow River in the Ningxia is 397 kilometers and water area is about 30 thousand hectares (Ningxia Statistical Bureau 2000). Located in the middle of China, the Henan Province has branches of the Huai River, the Yellow River, the Hai River and the Yangzi River. The length of the Huai River in the province is the longest (88.3 thousand kilometers), the Yellow River is second (36.2 thousand kilometers), the Yangzi River is 27.2 thousand kilometers, and the Hai River is the shortest (15.3 thousand kilometers).

Despite their differences in the endowment of land and population resources, both the sample provinces are mountainous and agriculture-oriented regions. Although the total area is more than three times of Ningxia province, (160 thousand square kilometers), the Henan Province faces more severe population pressures. The population intensity in the Henan Province is 587 people per square kilometer nearly 30 times that in the Ningxia Province and more than 4 times the national average level (China Statistical Bureau 2000). Both Ningxia and Henan Provinces are mountainous regions occupying more than 70 percent of their land. As agriculture is the most important industry in these two regions, about 70 percent of the population in both Ningxia and Henan Provinces are employed in agricultural production activities.

Given the poverty focus of the study, the two provinces selected for this study are both considered as less-developed when compared to the other provinces in China (table 4.2). Average per capita annual income in rural Ningxia was only 75 percent of the national average for rural China in 2000 (1,724 yuan versus 2,253 yuan).[8] The average income of rural residents in Henan is about 260 yuan, higher than that in Ningxia, but still 12 percent lower than the national average.

The lower average income levels means that both provinces suffered from higher incidences of poverty. According to the most recently available secondary data on poverty (using the national poverty line from the State Statistical Bureau 1996), the incidences of poverty in Ningxia (18.5%) and Henan (17.6 %) were about three times the national average (6.3%). At the national level, this rate declined to 3.4 percent in 2000. Based on this national trend and the growth of rural income in Ningxia and Henan in the late 1990s, it is highly plausible that the incidence of poverty in these two provinces is about 10 percent.

Despite the fact that the Yellow River flows through it and it is located in the upstream, Ningxia Province is still a water-short region. Per capita water availability in the Ningxia Province is only about 300 cubic meters, 1/7 of the national average level. As a very dry area, average annual rainfall in the Ningxia Province varies greatly from 200mm in the north to 5mm in the south; in addition, more than 60 percent of rainfall concentrates in the period June to September and cannot be effectively used by crops (Ningxia Statistical Bureau 2000).

Located in a semi-humid area, though not a water-rich region, the water situation in the Henan Province is better than Ningxia at the overall regional level. In the Henan province,

[8] 1 US$ = 8.3 yuan

average annual rainfall is between 700-1,100 mm, 55 percent of rainfall concentrates in the summer season, i.e., from June to September (Henan Statistical Bureau 2000). Per capita water availability of 2,100 cubic meters in the Henan Province is near to the average national level 2,200 cubic meters.

Although the overall water endowment is poor, crop water-use level of irrigated land in the Henan Province is substantially higher than that in Ninxia. In 2000, the average per hectare agricultural water use reached 24,525 m^3 in Ningxia, a level about 3.4 times the national average. In contrast, Henan farmers used about 3,810 m^3, a level about six times less than that in Ningxia (table 4.2, row 3). Given such differences in water use, it is clear that existing water rights and the current allocation system are clearly critical policy issues. Moreover, under the current water use regime, upstream regions -- i.e., those in Ningxia--obviously have access to more water than the downstream ones. As a consequence, we would expect that an alternative water allocation scheme could generate large welfare gains for the whole YRB. However, such a shift (that is, providing more water downstream and less upstream) would invariably entail significant changes in the local cropping system, land use pattern, water productivity, and farmer income in different reaches of the basin. More fundamentally, such changes would also have implications for poverty—both positive and negative, depending on whether one were to have water allocations cut or raised. In addition, large differences in water access between the two study areas mean that there will likely be fundamental differences in how water is used by farmers and managed by the IDs and villages.

Table 4.2. Basic characteristics of Ningxia and Henan Provinces, 2000.

	National	Ningxia	Henan
Per capita income (yuan)	2,253	1,724	1,986
Poverty incidence (%)	3.4/6.3[a]	18.5[a]	17.6[a]
Water use (m^3/ha)	7,320	24,525	3,810
Cereal yields (kg/ha)	4,953	4,288	4,610
Share of irrigated area (%)	55[b]	48[b]	66[b]
Share of water use by agriculture (%)	69	93	70
Share of surface water (%)	81	94	47
Share of groundwater (%)	19	6	53

[a] Figures are from 1996
[b] Figures are from 1998.

Data sources: Rows 1, 4 and 5: State Statistical Bureau (2001); row 2: World Bank (2001); rows 3, 6 to 8: Ministry of Water Resources (2001).

Moreover, because of the way the study provinces differ in location and other geographical characteristics, there are different levels of overall irrigation and use of water for agriculture which could potentially affect pro-poor intervention strategies. In Ningxia, irrigated land accounts for 48 percent of the province's cultivated land, 7 percent less than the national average in 2000 (55%--table 4.2, row 5). A much higher proportion of Henan's cultivated area, however, is irrigated, (above 66%). If one looks at the nature of irrigation in the two provinces, the higher proportion of irrigated areas in Henan is mainly due to the expansion of groundwater use. In Ningxia, surface water contributed to 94 percent of the total agricultural water use in 2000; in Henan, one of China's most diversified areas in terms of conjunctive water use, farmers use both surface and groundwater (table 4.2, rows 6 to 8). Although historically, most irrigated areas were from surface sources, currently it is less than 50 percent.

SAMPLE IRRIGATION DISTRICTS

The four sample IDs, two in Ningxia and two in Henan, have a number of similarities, but also several fundamental differences. Each of the sample IDs belong to a class of "large scale" irrigation districts. The effectively irrigated area, or command area, of the IDs range from 31,000 hectares (LID-H in Henan) to 304,000 hectares (QID-N in Ningxia--table 4.3, row 2). The two irrigation districts in Henan have been in operation for 40 to 50 years. In contrast, the Ningxia IDs have a much longer history. In fact, several of the canals and their command area have been in operation for more than 2000 years (table 4.3, row 3), although during the past 50 years, enormous investment has been sunk into both fundamental renovations of the original system and expansion into adjacent areas.

Despite the importance of irrigation in China's agriculture, aging infrastructure, outdated water delivery technology and chronic funding shortages for canal maintenance have affected the irrigation facilities of the four IDs. All four are plagued by poor physical conditions and low efficiency of water delivery. The water conveyance efficiency in each ID ranges from 40 to 50 percent. Consistent with the water endowments of their host provinces, as the IDs have developed, their water use patterns have evolved. The WID-N and QID-N IDs in Ningxia almost exclusively rely on surface water; the PID-H and LID-H IDs in Henan are best characterized as conjunctive systems, using both surface and groundwater resources.

Since both IDs are located in the northern part of China, they have similar climatic characteristics that basically can be classified as rain-short and seasonally variable. Annual rainfall ranges from about 200 mm in the two IDs in Ningxia to 630 mm in the two Henan IDs (table 4.3, row 5). Moreover, because of the dominance of weather patterns created by Siberia in the north and the Himalayas far to the south, more than 70 percent of the rainfall is concentrated in the summer months.

In such a dry, seasonally variable climate and being far from the nation's booming coastal areas, irrigation has played an important role in the economies of the area served by our study's four IDs. The shares of irrigated area inside the ID boundaries ranged from 82 - 93 percent in 2000 (table 4.3, row 6). Without access to the transportation and other locational advantages of the provinces in the eastern part of the nation, agriculture is still an important sector in the local economies. Above the national average (16% - NSBC 2001), the share that agriculture contributes to GDP ranged from 27 - 46 percent in 2000.

Although there are unique features about each of the IDs, the cropping patterns of the farmers are mostly typical of China's northern and north-western irrigated areas (table 4.3, rows 9 to 11). Wheat is the dominant crop, a crop that is grown almost exclusively in the winter season (that is planted in fall and harvested in late spring). In terms of cultivated area, maize is second, and is mostly a crop that is grown in rotation with wheat (typically being planted in early June — sometimes between the rows of wheat that is almost ready to be harvested — and harvested in late September or October).

Some of the farmers in our study areas also produce a number of crops that are somewhat special in north China. For example, rice is an important crop in the upper reaches of the IDs in Ningxia (WID-N and QID-N) as well as certain areas in one of the IDs in Henan (PID-H). Cotton, a crop that can only be grown with access to irrigation, can also be found being cultivated on land in some of our study IDs. Non-grain crops also vary among the irrigation districts.

The tremendous diversification of cropping systems that characterize all regions of China, including the IDs, make it difficult to precisely assess the water productivity for the whole agricultural sector. Therefore, our analyses on water productivity concentrate on wheat, maize, and rice (table 4.3, rows 12 to 14). Based on our survey data, water productivity (that is unit of output per unit of water input) differs significantly by major crop and between upstream and downstream areas along the YRB. For example, farmers produced somewhat more than 0.5 kilograms of wheat (in two of the IDs) and rice (in three of the IDs) per cubic meter of water. In contrast, maize farmers produced 1.29 to 2.97 kilograms. However, the productivity of water of wheat farmers varied sharply among IDs. Farmers in Ningxia produced less than one kilogram per cubic meter of water (table 4.3, columns 1 and 2), while those in Henan (LID-H) produced more than 1.5 kilograms. Such large differences among crops and between regions are an indication of the potential opportunities to increase water productivity through water re-allocation within and between IDs.

We also observe large differences in the O&M cost recovery rates among the four sample IDs (table 4.3, row 16). In WID-N and QID-N, both located in Ningxia province, the average O&M cost recovery rate is 61 percent. Although far below 100 percent, the rates are even lower in Henan (25% in PID-H and 19% in LID-H). These large differences among IDs in the O&M cost recovery offer an opportunity to investigate how differences in O&M recovery affect the performance and management of irrigation systems in our study areas.

Water prices also differ across the IDs. Water officials in Ningxia charged less for water (0.012 yuan/m^3) in both the sample IDs (WID-N and QID-N) (table 4.3, row 15). Farmers in Henan, however, had to pay a higher price for their water (0.03 yuan/m^3 in LID-H and 0.04 in PID-H). These differences, while large in percentage terms (the price of water in Henan is more than three time that in Ningxia), are consistent with the relative abundance of water (since Ningxia is in the upper reaches of the YRB and Henan is in the lower reach). If the lower price of water is in fact a function of the lower cost of supplying water in Ningxia, it may also help explain why IDs in Ningxia have higher O&M cost recovery rates.

During our survey, we also discovered a great deal of heterogeneity in the way villages managed water both within and between the four sample IDs. Villages in the two IDs in Ningxia and one in Henan (PID-H) use Water User Associations (WUAs), contracting with individuals, and group and collective management to manage their water. Interestingly, the collective (village leadership) water management dominated in only one Henan ID (LID-H). A more detailed discussion of water institutions and management issues is included in the third chapter.

Table 4.3. Characteristics of the four sample irrigation districts, 2000.

	Irrigation District[a]			
	WID-N	QID-N	PID-H	LID-H
Location along YRB within province	Upper Reaches	Lower Reaches	Upper Reaches	Lower Reaches
Effective irrigated area (000 ha)	56	304	99	31
Year of initial construction	B.C.	B.C.	1952	1967
Water use efficiency (%)	40-45	40-45	40-45	40-45
Rainfall (mm)	200	195	620	639
Share of irrigated area (%)	82	90	93	86
Share of agricultural population (%)	82	72	82	71
Share of agricultural GDP (%)	32	27	31	46
Share of area (%)				
Wheat	24	29	42	39
Rice	13	16	6	1
Maize	22	24	20	10
Water productivity (kg/m^3)				
Wheat	0.58	0.8	na	1.63
Rice	0.58	0.53	na	0.62
Maize	1.29	1.4	na	2.97
Water price (yuan/m^3)	0.012	0.012	0.04	0.03
O&M cost recovery rate (%)	61	61	25	19

[a] WID-N and QID-N districts are in Ningxia Province; PID-H and LID-H are in Henan Province.

Note: na = not available
Data sources: Rows 2 to 6 and 12 to 16 from authors' survey; rows 7 to 11 from Statistical Bureaus of Ningxia (2001) and Henan (2001).

DATA DESCRIPTION

Data Collected from IDs in the YRB

In order to meet the study's objectives, we designed three separate survey instruments — one for farmers, one for canal managers and one for village leaders in the survey of IDs of the Ningxia and Henan Provinces. During our survey, three types of management institutions were identified: collective management, Water User Associations (WUAs) and contracting. In our village and canal management questionnaires we recorded the share of canals within the village that is controlled by each management type for each of the three years (1990, 1995 and 2001). In addition, enumerators also asked about how managers were compensated. When managers have rights to the earnings of the water management activities (that is, to the value of the water saved by water management reform), we say that they face strong incentives (or henceforth, merely 'with incentives'). If the incomes from their water management duties are not connected to water savings, they are said to be 'without incentives.'

The survey also collected information about the development of several measures of the effects of water management reform — water use, production and income. In order to get relatively accurate measures of water use, which in surface water systems is typically difficult to elicit, we adopted the strategy to ask all those who were involved in the irrigation scheme: farmers, water managers and village leaders. We asked about crop water use in a number of different ways: on a per irrigation basis, the number of irrigations per crop, the number of hours per irrigation, the average depth of the water, etc. With this information, we were able to combine the various measures into a single meta-measure on which we developed our final estimates of water use (appendix A).

We also systematically collected information on both income and crop production by plot and by crop for all cropping seasons during the year 2001. Income is an estimate of each household's full net income and includes all major sources of income of the household, including that from cropping, livestock, off-farm wage labor, earnings from the family's business enterprise, and other miscellaneous sources. With information on income, we were able to construct a measure of poverty status by comparing household per capita income (dividing total household income by the number of family members, which include the household head, the household head's spouse and all individuals that lived in the household for at least three months per year) with the national poverty line (625 yuan per capita per year in 2001).

The rest of our survey instrument asked for information about a number of other important variables that we believe affected either water management institutions or outcomes or both. For example, we asked village leaders and water managers if upper-level government officials took steps to encourage the extension of reform in their villages. A number of other questions were asked about the degree of water scarcity, the level of investment in the village's irrigation system, as well as a number of other village, household and plot characteristics. Descriptive statistics of the main variables are shown in appendix B.

The data for our study come from a randomly selected, almost nationally representative sample of 60 villages in 6 provinces (Hebei, Liaoning, Shaanxi, Zhejiang, Hubei, and Sichuan) of rural China (henceforth, the China National Rural Survey or CNRS). To reflect accurately varying income distributions within each province, we selected randomly one county from within each income quintile for the province, as measured by the gross value of industrial output. The survey team selected randomly two villages within each county and used village rosters and our own counts to choose randomly twenty households, both those with their residency permits (*hukou*) in the village and those without. The survey included a total of 1,199 households.

Data Collected from Six Provinces

Enumerators collected a wide range of information on the household's production activities, and included a special block that focused on collecting by plot information on crop yields and plot-specific characteristics, including irrigation status. The household survey gathered detailed information on the household's total landholding, its demographics, labor allocation to farm and non-farm activities, investment and other activities that allowed us to create measures of household per capita income and asset holdings. In our study, we draw heavily on the part of the survey that provided a census of each household's cultivated plots. On an average, each household cultivated four plots. For each plot, the respondent recounted the crop or crops that were grown during the sample year and the plot's irrigation status (was it irrigated by surface water, groundwater, both, or neither). In addition, enumerators collected a number of other plot attributes, including: land quality (a subjective measure whereby, if the farmer ranked his plot as "good" a dummy variable was set equal to 1); topography (measured by two dummy variables that were each set equal to 1 if the plot was on a plain or hill); plot size (measured in *mu*, 1/15th hectare, and translated into hectares); cropping pattern (which is measured as a dummy variable that is set equal to 1 if the crop is not grown in conjunction with other crops during the year and is set equal to zero if it is cultivated in rotation with other crops); distance of the plot from the household (measured in kilometers); and a measure of any shock (e.g., flood or drought) that hit the plot during the year (measured in one of the two ways: either as a dummy variable set equal to 1 if there was a shock of any type, or as a continuous variable based on the farmer's subjective opinion about the percentage by which yields were reduced by the shock).

CHAPTER 5

Irrigation-Poverty Nexus: Empirical Evidence from Six Provinces

The overall goal of our paper is to understand the impact that irrigation investments in China have had on incomes, in general, and income and poverty alleviation in poor areas, in particular. To meet this overall goal, we have three specific objectives. First, we describe the relationship between irrigation status, on one hand, and crop choice, yields and household crop revenue on the other. Second, we seek to measure the magnitude and nature of the effect that irrigation has on yields and crop revenue and if we find a positive effect to try to understand why previous studies often failed to do so. Finally, we seek to understand the impact that irrigation has on incomes in poor areas.

The chapter is organized as follows. The first part is to illustrate the proportion of cultivated area that is irrigated and the unconditional differences between irrigated and non-irrigated yields and per hectare crop revenues. To our knowledge, this is the first set of by-crop estimates of sown area and yields for irrigated and non-irrigated areas in China, a statistic that, while commonly available in most other countries, till-date has not been available in China. The second and third part presents the results of our multivariate analyses; we first seek to explain the impact of irrigation on yields and revenues, holding all other factors constant, and then examine the relationship between irrigation and crop income in China's poor areas. The final section is the summary.

IRRIGATION, CROP CHOICE, AND AGRICULTURAL PERFORMANCE

Compared to other countries in the world, the proportion of China's cultivated area that is irrigated is high (table 5.1). Data from our survey shows that 52 percent of cultivated land is irrigated (table 5.1, row 1). Of the area that is irrigated, farmers irrigate 61 percent with surface water and the rest with groundwater. Although this figure is higher than the estimates published by CNSB (2001) in its annual year book (41%), both our estimates and those of the CNSB are higher than that of most other countries in the world (for example, 33% of India's cultivated area is irrigated; 4.8% of Brazil; and 12% of the US)[9].

While a majority of China's cultivated area is irrigated, the proportion of area that is irrigated varies sharply by crop. For example, China's major food grains are mostly irrigated (table 5.1, rows 2 and 3). Ninety-five percent of rice and 61 percent of wheat are irrigated, levels,

[9] Our figure may be higher than that used by official statisticians for two reasons. First, in our sample, we do not choose those villages that are more than 4 hours away from township so we are missing a set of sample households that would be from an area in which the average proportion of cultivated area that was irrigated was lower than average. This would make our number biased upward. In addition, although almost a representative sample of China, our randomly selected sample did not choose some big provinces that happen to be less irrigated than the average national level. For example, only 17% of cultivated land in Heilongjiang province is irrigated, only 27% in Inner Mongolia and 19% in Gansu. Figures for other countries are from table 8 in *Attacking Poverty* (World Bank 2001).

which in both cases are above the national average. In contrast, a majority of area for most food grains and lower-valued staple crops is not irrigated (table 5.1, rows 4, 13, and 14). Despite the growing importance of maize in China's agricultural economy, only 45 percent of China's maize farmers irrigate their crop and even a lower proportion is irrigated by farmers of coarse grain and tuber (white and sweet potatoes). Although cash crops also vary among themselves, most farmers of the important cash crops in our sample irrigate their crops (e.g., 94% of cotton area and 69% of peanut area).

Table 5.1. Proportion of sown area by irrigation type (%).

	(1) Total (2)+(5)	(2) Irrigated area	(3) Surface water area	(4) Groundwater area	(5) Non-irrigated Area
China	100	52	61	37	48
Major Grains - aggregate					
Rice	100	95	95	3	5
Wheat	100	61	34	63	39
Maize	100	45	31	65	55
Major grains - by season					
Single season rice	100	94	94	4	6
Early season rice	100	99	99	0	1
Late season rice	100	99	99	0	1
Single season wheat	100	10	37	63	90
Wheat-rice rotation	100	98	96	2	2
Wheat-maize rotation	100	77	24	73	23
Wheat-other crop rotation	100	63	23	76	37
Single season	100	15	23	71	85
Maize-other crop rotation	100	49	72	27	51
Coarse grains[b]	100	28	26	71	72
Tubers[c]	100	40	88	10	60
crops					
Cotton	100	94	13	87	6
Peanut	100	69	8	92	31

[a] Proportion of irrigated areas include areas irrigated by surface water, by groundwater and by both (conjunctively). Proportion of areas irrigated conjunctively is not reported here because it is less than 3%. Thus column (3) and column (4) does not sum up to 100%. [b] Coarse grains includes sorghum, millet, pearl millet, buckwheat and others. [c] Tubers includes white potatoes and sweet potatoes.

Data source: Authors' survey

Table 5.2. Crop yield by irrigation type (Unit: kg/ha).

	(1) Total yield	(2) Irrigated yield [a]	(3) Surface water yield	(4) Ground water yield	(5) Non-irrigated yield	(6) Percentage increase [b]
Major grains – aggregate						
Rice	5,947	5,942	5,919	6,663	6,002	-1.0
Wheat	3,305	3,853	3,302	4,518	2,255	70.9***
Maize	4,041	4,378	4,276	4,522	3,762	16.4***
Major grains - by season [c]						
Single season rice	6,195	6,207	6,202	6,367	6,087	2.0
Rice-rice rotation	9,934	9,949	9,943	11,250	9,000	10.5
Early season rice	4,516	4,516	4,513	5,250	4,500	0.4
Late season rice	5,418	5,433	5,431	6,000	4,500	20.7***
Single season wheat	1,931	3,624	4,025	3,223	1,698	113.4***
Wheat-rice rotation	9,266	9,284	9,251	11,357	7,513	23.6
Wheat	2,939	2,949	2,972	3,000	1,763	67.3***
Rice	6,327	6,334	6,279	8,357	5,750	10.2***
Wheat-maize rotation	8,263	9,174	8,309	9,617	6,271	46.3***
Wheat	3,877	4,439	3,796	4,746	2,642	68.0***
Maize	4,386	4,735	4,514	4,872	3,628	30.5***
Wheat-other crop rotation	3,331	3,926	3,375	4,212	2,411	62.8***
Single season maize [d]	2,876	3,720	3,056	4,309	2,378	56.4***
Maize-other crop rotation	3,941	3,984	4,181	2,883	3,893	2.3
Coarse grains	1,457	1,996	1,836	2,115	1,119	78.3***
Tubers [e]	4,631	3,918	4,072	2,942	5,141	-23.8***
Cash crops						
Cotton	2,357	2,561	1,190	2,790	924	177.3***
Peanut	2,538	2,758	2,731	2,770	2,143	28.7***

*** means significant at 99% level.
[a] We did not include yield of the plots irrigated by surface water and groundwater conjunctively because there are few observations of them.
[b] Percentage increase means irrigated yield compared to non irrigated yield.
[c] In this category, we divide rice into single season rice, double season rice (early season rice, late season rice). We divide wheat into single season wheat, wheat-rice rotation, wheat-maize rotation and wheat rotated with other crops than major grain. We divide maize into single season maize and wheat-maize rotation.
[d] We dropped Liao Ning province here because 80% are non-irrigated plots. 46% of the non-irrigated plots and 60% of the irrigated plots suffered from draught (loss of produce more than 50%).
[e] Tuber includes sweet potato and potato.
Data Source: Authors' survey

Examining unconditional differences between irrigated and non-irrigated yields, it is clear that for almost all crops, yields of irrigated plots are higher than those of non-irrigated ones, though there are differences among crops (table 5.2). Positive differences and large statistics (for tests of differences between means) indicate that for almost all crops (except for rice and tubers) the average yields of irrigated plots exceed significantly those of non-irrigated ones (column 6)[10]. For example, wheat yields of irrigated plots are 70.9 percent higher than those of non-irrigated plots (table 5.2, row 2). Irrigated maize yields are 16.4 percent higher and irrigated cotton yields are nearly 200 percent higher (table 5.2, rows 3 and 19).

The annual output of a particular plot of land also varies sharply due to irrigation's ability to increase the intensity of cultivation. When two crops are planted in rotation with one another (table 5.2, rows 5 to 7; rows 9 to 15 and row 17), the annual output per plot rises steeply when compared to the yields of a single season crop (table 5.2, rows 4, 8, and 16). For example, the annual yields of rice-rice (9,934), wheat-rice (9,266), and wheat-maize (8,263) rotations far exceed those of single season rice (6,195), single season wheat (1,931) and single season maize (2,876). And, although in some cases farmers can still produce two crops per year without irrigation, with the exception of rice, most single season crops are not irrigated (more than 80%) and most of those plots that produce two or more crops (more than 60%) are irrigated (appendix C).

Even larger differences appear when examining differences between the revenues (price times yields) earned by farmers on their irrigated and non-irrigated plots (table 5.3)[11]. Overall revenue from irrigated plots is 79 percent higher than that of non-irrigated plots (table 5.3, row 1). While we can not pinpoint the source of these changes, three factors account for the higher crop revenues of a plot when irrigation is introduced: higher yields (of same crop), increasing intensity (producing more than one crop per season) and shifts to higher valued crops that are possible after irrigation.

Our results also provide evidence that, to the extent that new irrigation becomes available, it will raise incomes in poor areas. Dividing villages by wealth level, farmers in rich and poor areas earn higher revenue from their irrigated crops (table 5.3, rows 2 to 3). In rich areas, farmer revenue per hectare from irrigated plots is 89 percent higher than that from non-

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[10] There are only two crops that have lower yield in irrigated plots, rice and tuber. If we further divide rice into single-season rice, rice-rice rotation (early season rice and late season rice) and wheat-rice rotation, we found for each of this sub-division, yield of irrigated plots is significantly higher than that of non-irrigated. The averaged yield of irrigated plots turns out lower because yield of single-season rice is higher than other types of rice (rice-rice rotation and wheat-rice rotation) and so non-irrigated single-season rice is higher than irrigated yield of other rice. Moreover, 64% of rice is single-season so it weights more in the average. If we use the weighted average, irrigated yield is higher than non-irrigated yield. For tuber, we found out that only in south province(Zhejiang, Sichuan and Hubei) non-irrigated yield is higher than irrigated. As is known, in those provinces, tubers' growing time coincides with rain season and in our survey this effect is not included in irrigation although those plots are actually irrigated.

[11] In table 5.3 in our regressions that explain cropping revenue we do not account for rising costs on irrigated plots due to data limitations (we did not collect inputs by plot). Since our regression analysis is based on supply analysis, this does not restrict our ability to examine efficiency gains from irrigation (since supply response is a function of prices and fixed factors). However, on the basis of another data set that we collected in 1995 in 2 north-eastern provinces, Liaoning and Hebei, we can see that although costs rise when irrigation is introduced, the rise is restricted only to a subset of inputs and the total increase in the value of inputs is less than 61% and costs account only for about a half a plot's revenue.

Table 5.3. Gross cropping revenue by irrigation type and China's regions.

	(1) Annual income per capita (yuan/person)	(2) Percentage of cropping income in total income (%)	(3) Cropping revenue (yuan/ha)	(4) Cropping revenue for irrigated plots (yuan/ha)	(5) Cropping revenue for non irrigated plots (yuan/ha)	(6) Percentage increases of cropping revenue [a] (%)
China	2,107	23	3,940	4,585	2,568	79 [b]
By wealth level [c]						
Rich area	3,652	10	4,060	4,603	2,439	89
Poor area	907	41	3,318	4,385	2,268	93

[a] Percentage increase is calculated as (column 4 – column 5)/column 5.
[b] The national level is lower than both in rich and poor areas because we do not include the middle-income area here, which has a 65% increase in cropping revenue when plots are irrigated.
[c] Rich area includes households whose incomes rank in the first 20 percentile in every province and all the households from Zhejiang province. Poor area means households whose incomes rank in the last 20 percentile in every province.
Data source: Authors' survey except for figures in columns (1) and (2), which are from China National Statistical Bureau (2001).

irrigated plots. In poor areas, revenue in poor areas rises even more in relative terms. Revenue from irrigated plots in poor areas exceeds those from non-irrigated ones by 93 percent.

While the data shows that irrigation is effective in both rich and poor areas, differences in the nature of rich and poor economies suggest that irrigation may have the largest impact on rural welfare in poor areas. Since people are poorer, and since we typically assume that utility functions
are concave, if rich and poor areas enjoy equal income gains, the gains in the poorer areas will turn into larger increases in welfare. As seen above, cropping revenues in the poorest areas (93%) increase slightly more than those in richer areas (89%). Moreover, in our sample, the data shows that cropping revenues make up the largest part of total income of those in poor areas but not those in rich areas (table 5.3, column 3). In rich areas only 10 percent of total income comes from cropping activities; in the poorest area, cropping activities contribute more than 40 percent. If we multiply the percentage increase of cropping revenue by proportion of cropping revenue in total income, irrigation increases total income in rich areas only by 9 percent, while increasing it in poor areas by 38 percent. Since one characteristic of China's poverty is that the gap between the income of the poor and the poverty line is not overly wide (World Bank 2000), raising the income of the poor by more than one-third would almost certainly have the effect of pulling a vast majority of those in newly irrigated areas out of poverty.

MULTIVARIATE EMPIRICAL MODEL

All the findings from our descriptive analysis support one fact: irrigation has substantial benefits for farmers. Yields of irrigated plots are significantly higher than those of non-irrigated plots for almost all the crops we studied. Cropping revenue of irrigated plots also is higher than that of non-irrigated plots in rich and poor areas.

Such striking differences, however, are curious given the inability of previous studies to find significant effects of irrigation on agricultural performance. The differences may be due to several factors, some of which are due to problems with possible interpretations of our descriptive statistics (in the above section) and other problems may be due to weaknesses in the previous studies. First, our findings so far do not prove anything beyond correlation since we have only been comparing unconditional means of irrigated and non-irrigated plots. In fact, the observed differences may be partly (or could even be fully) due to other factors (such as land quality or management ability) that are correlated with irrigation. Second, due to lack of data, most studies in the past have only used rough proxies for irrigation, such as government expenditure on irrigation. These proxies, however, may not be an accurate measure of irrigation because there is no guarantee that the allocation of funds to water control is ever turned into an effective irrigation system. Third, most analyses have been highly aggregated, both across states or provinces and across crops. This approach could cause omitted variable bias, a problem that would make the estimated relationship between irrigation and agricultural performance unreliable. For example, it is possible that we will underestimate the impact of irrigation in rich areas (such as, Zhejiang province, a rich east coast province near Shanghai). Although the proportion of land that is irrigated might be higher in Zhejiang than that in poorer provinces, households in richer areas have more opportunity to work off-farm and, *ceteris paribus*, they will almost certainly allocate less family labor to farming activities than households in poorer provinces that do not have as much a convenient access to off-farm opportunities. In other words, an omitted variable – in this case, for example, it could be the inability to control the household's employment opportunities -- could lead to an underestimation of the impact of irrigation on yield. In fact, after accounting for these factors, it is possible that the results about the direction of irrigation's impact on yields could be reversed.

In our analysis, we are going to take a different approach to explore the relationship between irrigation and agricultural performances that will attempt to address the three shortcomings. First, our strategy is to look directly at the relationship between irrigation and crop yield (and at the relationship between irrigation and cropping revenues) at the plot level, thereby avoiding the need to use a proxy for irrigation. In addition, by using a rich set of plot-level data, we can hold constant many of the plot-specific factors that could be affecting yields and which could be potentially correlated with a plot's irrigation status. Finally, in our study, we have collected information on all of a household's major plots. Such data allow us to control all of the non-plot varying factors that could be affecting yields by using household fixed- effect approaches.

To explain the impact of irrigation on yields, holding other factors constant, we use a fixed effect model to explain the supply response of farmers that are producing a specific crop,

$$y_{ih} = \alpha + \gamma D_{ihj} + X_{ih}\beta + \mu_h + \varepsilon_{ih} \qquad \text{(equation 5.1)}$$

where y_{ih} denotes the yield (of a specific crop) or the revenue of the i^{th} plot of the h^{th} household. The term, X_{ih}, denotes plot-specific characteristics, including the plot's land quality, its topography, the size of the plot, the distance of the plot from the farmer's household, and the plot-specific shock suffered during 2000, and the parameter, β, represents a vector of parameters that corresponds to the effects that these plot-specific variables have on yields. Holding X_{ih}

constant, the parameter γ can be interpreted as our parameter of interest, measuring the effect of irrigation status on yields. The irrigation status variable, D_{ihj}, is written with a separate subscript, j, because in some of our specifications we want to allow for a disaggregation of irrigation between surface (j=1) and groundwater (j=2). When the variable is written without a subscript, irrigation is a variable that represents irrigation regardless of the type of irrigation. Equation (5.1) also includes a term, μ_h, which represents all non-plot varying household and village fixed effects including management or the opportunity cost of the household.[12]

Estimating equation (5.1) has both strengths and weaknesses. The trade-offs are seen most clearly by rewriting it as a fixed-effects model,

$$y_{ih} - \overline{y}_i = \alpha + \gamma\left(D_{ihj} - \overline{D}_i\right) + \beta\left(X_{ih} - \overline{X}_i\right) + \left(\mu_h - \overline{\mu}\right) + \left(\varepsilon_{ih} - \overline{\varepsilon}_i\right) \quad \text{(equation 5.2)}$$

where $\overline{y}_i$, $\overline{X}_i$, $\overline{\mu}$ and $\overline{\varepsilon}_i$ denote the average household level.

Since $\mu_h - \overline{\mu}$ =0, Equation (5.2) can be simplified to

$$y_{ih} - \overline{y}_i = \alpha + \gamma\left(D_{ihj} - \overline{D}_i\right) + \beta\left(X_{ih} - \overline{X}_i\right) + \left(\varepsilon_{ih} - \overline{\varepsilon}_i\right), \quad \text{(equation 5.3)}$$

where all household and village factors (e.g., management ability, opportunity cost of the household members, etc.) are accounted for.

Although prices are not included in equation (5.1), it should be noted that we are estimating a supply function and our regression is examining the economic efficiency that farmers gain when their plots are irrigated. The price variables, which are part of the μ_h term in equation (5.1), vary only by village and, hence, their effect also is captured by the household dummy variables. Because of the use of a supply-function framework, we do not include measures of other variable inputs[13].

To use equation (5.3) to understand the effect of irrigation on agricultural performance, we adopt a four-step strategy. First, we examine the effect of irrigation on yields of individual crops. While interesting by itself, such a regression does not capture all of the dimensions of the irrigation effects, neither the impact of increased intensity, nor the impact from crop switching. To do so, we estimate two additional models, one explaining aggregate grain yields (aggregating over all grains, including rice, wheat, maize and coarse grains) and one explaining agricultural

[12] In some specifications (appendix C) we use more of the inter-village variability of yields to understand the effect of irrigation by estimating

$$y_{ih} = \alpha + \gamma D_{ihj} + X_{ih}\beta + \mu_h + \mu_v' + \varepsilon_{ih}$$

where μ_h and μ_v' denote household and village fixed effect, respectively. We include 4 household variables (land size, wealth, household size, and average education level of household head) to control differences among households and include a set of village dummies to control all village fixed-effects. Although more variability is available for the regression estimates, there is a danger that unobserved household-level factors (e.g., management or the opportunity cost of the household) are biasing the estimates of the irrigation variable.

[13] In some specifications (appendix D) in which we use more of the inter-village variability of yields to understand the effect of irrigation by estimating

$$y_{ih} = \alpha + \gamma D_{ihj} + X_{ih}\beta + \mu_h + \mu_v' + \varepsilon_{ih}$$

where μ_h and μ_v' denote household and village fixed-effect, respectively. We include 4 household variables (land size, wealth, household size, and average education level of household head) to control differences among households and include a set of village dummies to control all village fixed-effects. Although more variability is available for the regression estimates, there is a danger that unobserved household-level factors (e.g., management or the opportunity cost of the household) are biasing the estimates of the irrigation variable.

revenues. If irrigation allows farmers to cultivate two crops per year and/or if it allows shifting into cash crops that generate higher revenues per hectare, the aggregate grain and agricultural revenue equations will capture the higher output from irrigation. Third, we decompose the effect of irrigation on agricultural output by regressing revenues per hectare on a series of interaction terms between irrigation and each major crop in our sample. In this way, the observed differences in revenues per hectare between irrigated and non-irrigated plots can be accounted for. Finally, we explain yields separately for better- off and poorer areas in order to gauge the difference in irrigation effects in different parts of the economy. In all our analyses, we take the log form of yield or revenue so that the coefficient will represent the percentage change in yield or revenue.

MULTIVARIATE REGRESSION RESULTS

In most respects, our analyses perform well. More than half of the regressions have R-square goodness of fit statistics that exceed 0.4, levels that can be counted as high for cross-section yield regressions (tables 5.4 to 5.6). Most of the coefficients in the models have the expected signs and in some cases are highly significant. For example, we find that the coefficient on the land quality variable positively affects yields in most equations and the coefficient on the variable measuring the plot-specific shock, as expected, reduces yields (e.g., table 5.4, rows 4 and 9).

Table 5.4. The impact of irrigation on crop yield with household fixed effect**.**

	Dependent Variables: Crop Yield [b]						
	1		2		3	4	5
	Wheat		Maize		Cotton	Coarse Grain	Tuber
	Equation 1	Equation 2	Equation 1	Equation 2			
Irrigation Status							
Irrigated (by surface water or ground water)	0.177 (2.81)***		0.294 (4.17)***		0.284 (5.28)***	-0.147 -0.59	-0.097 -0.24
Irrigated by surface water		0.171 (2.62)***		0.039 -0.38			
Irrigated by ground water		0.203 (2.20)**		0.418 (5.18)***			
Land Characteristics							
Good soil quality	0.174 (5.41)***	0.173 (5.34)***	0.13 (3.50)***	0.119 (3.21)***	0.008 -0.24	0.028 -0.26	0.996 (2.74)***
Topography - Plain	0.07 -0.65	0.068 -0.63	0.302 -1.38	0.236 -1.09	-0.001 -0.02		-1.614 -1.34
Topography - Hill	0.132 (2.53)**	0.129 (2.44)**	0.181 -0.9	0.112 -0.56	0.083 -0.92	0.013 -0.04	-0.543 -0.53
Plot size	0.041 -0.39	0.041 -0.39	0.204 -1.42	0.197 -1.38	0.01 -0.65	0.281 -0.97	-3.195 (2.03)**
Distance from home	0.003	0.003	-0.005	-0.001	0.008	0.061	-0.193

	-0.21	-0.25	-0.16	-0.02	-0.24	-0.83	-0.66
Shock: Severity of disaster [c]	-0.009	-0.009	-0.016	-0.015	-0.001	-0.03	0.005
	(6.22)***	(6.22)***	(12.78)***	(11.41)***	-1.65	(6.38)***	-0.66
Single Season Crop [d]	-0.04	-0.04	-0.106	-0.082	0.054	0.542	-0.37
	-0.87	-0.86	(2.06)**	-1.6	(2.43)**	(2.96)***	-1.5
Number of plots	1027	1027	1116	1116	141	277	510
Number of households	507	507	573	573	69	209	354
R-square	0.15	0.15	0.47	0.48	0.39	0.48	0.11

[a] Absolute value of t statistics in parentheses. * significant at 10% ** significant at 5% *** significant at 1%

[b] Dependent variable in log form. Estimate using fixed effect model at household level.

[c] Severity of disaster means percentage reduction of production.

[d] A dummy variable that is 1 if the crop is not grown in conjunction with other crops during the year and is 0 if it is cultivated in rotation with other crops.

Most importantly, the findings of our study support the hypothesis that irrigation raises yields for most crops and show that the descriptive results hold up to multivariate analysis (table 5.4). For example, irrigation increases the yields of wheat by 17.7 percent, those of maize by 29.4 percent, and those of cotton by 28.4 percent (table 5.4, row 1). Although the coefficients on the irrigation variables in the coarse grains and tuber equations are not significant, these findings are expected (table 5.4, column 4 and 5, row 1). The results of the tubers equations are consistent with the descriptive results. In the case of coarse grains, because there are so few households (only 9) that grow one plot of irrigated coarse grains and one plot of non-irrigated coarse grains, the findings reflect outcomes on less than 1 percent of the sample (and these are only in 3 villages). The effects of surface and groundwater are nearly the same for the case of wheat, the only crop that is grown widely in areas in which both surface (the Yangtze Valley) and groundwater (the North China Plain) are common.

The multivariate analysis results of crop-specific yields do differ from the descriptive results when examining the magnitude of the differences. With the exception of maize, the magnitude of impact of irrigation is lower in the regression results than in the descriptive statistics. Most likely this is because in the regression the irrigation impacts are being conditioned on the level of other variables, such as soil quality, that is accounting part of the irrigation effect (since most irrigated land is "good").

Perhaps most significantly from a methodological point of view, when the regression is run with and without household fixed-effects, the coefficients vary dramatically. In fact, in almost all of the equations without fixed effects, the coefficients are zero, a sure sign that omitted variables may be a problem. One interpretation is that without fixed effects, the family's opportunity cost of labor is not accounted for. If rural residents in irrigated areas, which tend to be in richer areas, have a higher opportunity cost, and hence tend to spend less effort on cropping activities, the insignificant coefficient in the equations that do not use fixed effects are more likely of being biased downward to a point where there is no apparent effect of irrigation (when, in fact, once all household-specific effects are accounted for they are positive and significant).

Table 5.5. Decomposed impact of irrigation on household cropping revenue.

	Dependent variable: Total cropping revenue [b]					
	Household	Village	Household	Village [c]	Household	Village
Irrigation dummy	0.761 (15.98)***	0.429 (13.83)***				
Interaction dummies						
Major grains						
Rice*irrigation			1.156 (24.41)***	0.947 (27.34)***		
Wheat*irrigation			0.573 (10.34)***	0.421 (10.62)***		
Maize*irrigation			0.619 (10.85)***	0.415 (10.23)***		
Single season rice*irrigation					1.004 (18.36)***	0.807 (19.94)***
Single season wheat*irrigation					0.206 (1.83)*	-0.044 -0.53
Single season maize*irrigation					0.912 (4.00)***	0.462 (2.78)***
Rice rice*irrigation					1.473 (15.46)***	1.226 (18.31)***
Wheat-rice rotation*irrigation					0.106 -1.58	0.117 (2.15)**
Wheat-maize rotation*irrigation					0.989 (12.32)***	0.818 (13.43)***
Wheat-other crop rotation*irrigation					0.863 (9.02)***	0.75 (9.71)***
Maize-other crop rotation*irrigation					0.832 (9.18)***	0.558 (7.80)***
Coarse grains*irrigation			0.317 (3.78)***	0.109 -1.55	0.532 (5.67)***	0.298 (3.97)***
Cash crops - cotton*irrigation			1.365 (15.14)***	1.104 (14.22)***	1.541 (14.79)***	1.241 (14.34)***
Cash crops - peanut*irrigation			0.887 (9.45)***	0.693 (8.19)***	1.135 (10.78)***	0.924 (10.10)***
Tubers*irrigation			-1.226 (17.74)***	-1.464 (27.77)***	-1.12 (14.82)***	-1.382 (24.72)***
Land characteristics						
Good quality	0.286 (7.09)***	0.219 (7.83)***	0.217 (6.00)***	0.178 (7.07)***	0.212 (5.29)***	0.173 (6.25)***
Topography - Plain	0.098 -0.94	-0.004 -0.07	0.065 -0.69	0.013 -0.24	-0.046 -0.44	-0.029 -0.49
Topography - Hill	-0.009 -0.11	-0.104 (2.02)**	-0.027 -0.36	-0.072 -1.52	-0.145 (1.68)*	-0.113 (2.11)**
Plot size	0.095 -1.02		0.011 -0.12		-0.033 -0.33	
Distance from home	0.02	0.022	0.009	0.021	0.028	0.029

	-1.12	-1.58	-0.43	-1.37	-1.13	(1.70)*
Shock: Severity of disaster [d]	-0.009	-0.009	-0.009	-0.009	-0.01	-0.009
	(9.50)***	(11.93)***	(10.35)***	(13.97)***	(9.69)***	(12.70)***
Single season crop [e]	0.755	0.716	0.231	0.275	0.4	0.465
	(26.96)***	(28.48)***	(6.39)***	(9.60)***	(8.55)***	(12.29)***
Number of plots	5352	5347	4858	4853	4166	4161
Number of household/village	1061	60	1058	60	1052	60
R-square	0.23	0.2	0.45	0.43	0.48	0.46

[a] Absolute value of t statistics in parentheses. * significant at 10% ** significant at 5% *** significant at 1%

[b] Dependent variable in log form. Estimate use fixed effect model at household level and village level.

[c] In Village Fixed Effect model, we use 4 household characteristic variables, which are not reported here: Household size, Average Education Level, Total Wealth and Total Household Land.

[d] Severity of disaster means percentage reduction of production.

[e] A dummy variable that is 1 if the crop is not grown in conjunction with other crops during the year and is 0 if it is cultivated in rotation with other crops.

The impact of irrigation becomes even stronger when we look at the impact of irrigation on plot cropping revenue (table 5.5). Overall, irrigation will increase revenue by 76.1 percent, a figure that is only slightly less than the unconditional difference observed in the descriptive statistics (table 5.5, column 1). In other words, according to these results, most of the differences between revenues on irrigated and non-irrigated plots are due to the addition of water and not other plot characteristics. The magnitude of the coefficient drops (to 42.9%) when household dummy variables are replaced with four household variables and a set of village dummies, moving in the same direction as was observed in the yield equations when no fixed effects were used at all. Apparently, the use of village dummies and four household-level variables absorbs some, but not all, of the unobserved heterogeneity in the yield response behavioral equations in this analysis.

Decomposing revenue differences by crop illustrates differences among crops in the earnings potential that arise with irrigation (table 5.5, column 3). When a plot is irrigated, rising yields and the ability to shift into new crops, such as rice and cash crops, facilitates the largest rise in revenue (88.7% higher for peanuts; 115.6% for rice; 136.5% for cotton). Although somewhat lower, when plots are irrigated rising yields also help increase revenues on wheat (57.3%), maize (61.9 %), and coarse grains (31.7%). Of all the major crops in the sample, tubers are the only ones that do not enjoy increased revenue. The results here are robust, though the size of the coefficients somewhat smaller, when village fixed-effects are used in place of household effects (table 5.5, column 4).

Additionally, when the major grain crops, rice, wheat and maize, are disaggregated by rotation, the impact of increasing intensity can be seen (table 5.5, column 5). For example, irrigated rice increases yields by 147.3 percent, higher than single season rice (100.4%). When irrigation facilitates the shift to a wheat-maize rotation, revenues generated on a plot rise by 98.7 percent, higher than either the rise that accompanies single season wheat (20.6%) or single season maize (91.2%).[14]

[14] Significantly, the wheat-rice rotation does not show any statistical difference between irrigated and non-irrigated areas. Most likely this is because only in the case of 4 households does a single household have both irrigated and non-irrigated plots (the requirement that needs to be met for the observations to be used).

When dividing the sample into better-off and poorer areas, we find similar results (table 5.6). In both rich and poor areas, irrigation has a significantly positive effect on cropping revenue, increasing by 132.8 percent in rich areas and 43.9 percent in poorer areas (table 5.6, columns 1 and 2). While the higher marginal effects of irrigation on cropping revenue in rich areas may explain why most of the past investment in irrigation has gone into more favorable areas, it does not mean that the poor do not benefit. In fact, in terms of income effects, the poor may benefit more. From table 5.6 it can be seen that the share of cropping revenue in total income is four times as high in poor areas (41%) as in rich areas (10%). Taking this into account, irrigation benefits farmers in poorest areas one and a half times more than it does farmers in rich areas (18% in poor areas versus 13% in rich areas).

Table 5.6. Regression analysis of irrigation impact on cropping revenue in rich and poor areas in China.

	Dependent variables: Plot cropping revenue with fixed effects			
	Rich area		Poor Area	
	Equation 1	Equation 2	Equation 1	Equation 2
Irrigation status				
Irrigated (by surface water or groundwater)	1.328 (14.11)***		0.439 (3.50)***	
Irrigated by surface water		1.47 (14.30)***		0.296 (2.02)**
Irrigated by groundwater		0.717 (3.54)***		0.793 (3.55)***
Land characteristics				
Good soil quality	0.147 (1.90)*	0.167 (2.17)**	0.143 -1.5	0.139 -1.47
Topography - Plain	0.155 -0.88	0.131 -0.75	-0.327 -0.85	-0.309 -0.8
Topography - Hill	-0.006 -0.03	0.1 -0.53	-0.28 -1.52	-0.277 -1.51
Plot size	0.048 -0.25	0.066 -0.34	-0.22 -1.43	-0.236 -1.54
Distance from home	0.134 (2.96)***	0.111 (2.44)**	-0.302 (3.39)***	-0.284 (3.18)***
Shock: Severity of disaster [c]	-0.01 (4.46)***	-0.011 (4.70)***	-0.011 (5.99)***	-0.011 (5.52)***
Single season crop [d]	0.624 (11.54)***	0.599 (11.05)***	1.086 (13.91)***	1.105 (14.06)***
Number of plots	1542	1542	959	959
Number of households	330	330	187	187
R-square	0.25	0.26	0.28	0.29

[a] Absolute value of t statistics in parentheses. * significant at 10% ** significant at 5% *** significant at 1%

[b] Dependent variable in log form. Estimate use fixed effect model at household level.
[c] Severity of disaster means percentage reduction of production.
[d] A dummy variable that is 1 if the crop is not grown in conjunction with other crops during the year and is 0 if it is cultivated in rotation with other crops.

SUMMARY

In this case study, we explore the relationship between irrigation status and yields, crop choices and household cropping revenue. Our study provides evidence of irrigation's strong impact on yield and cropping revenue, both descriptively and in the multivariate analysis. Unlike some of the literature that used aggregate data, we find that irrigation increases yields and cropping revenue when we look at either different crops or examine grain or crops as a whole. Moreover, we find that although the marginal impact of irrigation on revenue appears to be higher in richer areas, since the poor relies more on cropping revenue, our findings suggest that farmers in poor areas increase their incomes relatively more than farmers in richer areas.

The strong findings in our study of the effect of irrigation on agricultural performance relative to previous studies almost surely are in part a function of our data and methods. By using plot-level data, we can account for many of the attributes in the natural environment that also affect yields as well as irrigation. By having more than one plot observation per household, we show that when we use household fixed-effects (versus only controlling for some household effects and village effects or nothing) the effect of irrigation almost always rises. In fact, when we go from controlling of no supra-plot effects to the full model, the impact of irrigation goes from insignificant (zero) to highly significant and positive. Hence, it could be that omitted variable bias may be one reason why previous studies failed to find the strong effect of irrigation on agricultural performance.

If irrigation has such a great effect on agricultural performance it is no wonder why so much of the budget of many countries has gone towards irrigation in the past. Moreover, although the costs of the project must be considered, the disinterest that seems to be pervading the international community in irrigation needs to be questioned. Our findings of the effect of irrigation on the income of those in poor areas mean that poverty alleviation programs, in particular, may need to consider increasing or at least not diminish the role of irrigation in their portfolio of activities.

CHAPTER 6

Do Small Farmers Benefit more than Large Farmers from Irrigation ?

In this section, we will further explore the relationship between irrigation and poverty within IDs. At first, we need to understand whether small farmers benefit less than larger farmers from irrigation; secondly, we need to identify if there are differences in water access between poor and non-poor farmers. Thirdly and fourthly, impacts of access to water and water reliability for pro-poor will be identified. The final part is the summary.

FARM SIZE AND BENEFIT FROM IRRIGATION

In order to test the hypothesis of whether small and poor farmers receive fewer benefits from irrigation than large and non-poor farmers, we classified our sample households into three farm-size categories. Each group contains equal number of observations (or contains one-third of the sample households). In the two Ningxia IDs, WID-N and QID-N, the average per capita land sizes for small, moderate and large farms are 0.35, 0.67 and 1.22 hectares (table 6.1, row 3). The farm sizes in Henan, both PID-H and LID-H, are even smaller. For example, the average size of a "large" farm is only 0.72 hectares, which, according to international standards, would be considered to be a small farm (table 6.1, row 11).

As according to our data, small and large farmers have relatively equal access to water. In both Ningxia and Henan, there is not much difference. In fact, in some cases, small farmers have higher per hectare water use than the large farmers (table 6.1, row 6 and row 14). This result, while perhaps somewhat surprising, is not consistent with findings elsewhere such as the South-east Asian countries.

Although this is a somewhat surprising result, caution must be used in interpreting it and not inferring that the absence of a relationship between farm size and water access is the same as the neutrality of water access and poverty. After regrouping farms, we test whether the small farmers are also the poor farmers. If the small farmers are also the poorest farmers, the results of testing one hypothesis could be applied to the other. However, table 6.1 shows that, on average, the small farmers in our samples have the highest income. In both of the Ningxia IDs, for example, the average per capita annual income of households that live on small farms (2,978 yuan) is 11 percent higher than the average income of those on large farms (2,682 yuan) (table 6.1, row 4). In the Henan IDs, the income gap between small and large farms is even larger (28%) (table 6.1, row 12). Hence, to examine the relationship between poverty and water access, a separate analysis must be carried out.

Table 6.1. Farm size and benefits from irrigation in the sample households of Ningxia and Henan Provinces, 2001.

Household categories	Small farms (33%)	Medium-sized farms (34%)	Large farms (33%)
Ningxia			
The poor I (%)[a]	7	7	7
The poor II (%)[a]	14	7	9
Farm size (ha)	0.35	0.67	1.22
Per capita income (yuan)	2,978	2,680	2,682
Per household water use (m^3)	6,977	11,104	17,517
Per hectare water use (m^3)	20,834	16,356	14,657
Per capita water use (m^3)	1,691	2,912	4,387
Non-agri income share (%)	58	36	19
Henan			
The poor I (%)[a]	3	12	9
The poor II (%)[a]	15	24	18
Farm size (ha)	0.29	0.47	0.72
Per capita income (yuan)	2,125	1,968	1,658
Per household water use (m^3)	2,641	4,110	8,285
Per hectare water use (m^3)	9,067	8,864	11,104
Per capita water use (m^3)	752	993	1,765
Non-agri income share (%)	46	43	16

[a]Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes below the World Bank's standard (878 yuan).
Date source: Authors' survey.

While this might be surprising to those unfamiliar with China, the positive relationship between farm size and poverty is common in China's rural economy. Every household in China has its own land contracted from their villages. The households with more constraints in land resources have induced farmers to explore alternative uses of their other family resources such as labor in non-farming activities. Table 6.1 shows that small farms allocate a large portion of their family labors in off-farming activities and earn more than half of their income from non-agricultural sectors (53%), while large farms receive only 16 percent of their income from non-agricultural sectors as these large farms allocate their family labor more in agriculture.

This is not to say that small farms have large incomes or lower incidence of poverty. After control for the impacts of all other factors that affect farmer's income earning and poverty, we should expect that the larger the farms the more is their income and the lower is the incidence of poverty. But the point we are making here is: it is dangerous to use farm size as an indicator of poverty in China. This typical nature of farm size and poverty in irrigated areas in China implies that testing the benefit of irrigation to the poor and non-poor and to different sizes of farms should be separated. And testing poverty based on farm size is irrelevant and could result in a misleading conclusion. Indeed, as discussed in the previous chapter, one of the major principles in allocating water to agriculture is based on land. Table 6.1 confirms to this principle. The average size of a large farm is about 3 times a small farm; on the other hand, the average water use in a large farm is also about 3 times a small farm for the whole sample.

Econometric analysis results are consistent with our statistical description. In the determinants of water use model, the coefficient of arable land per hectare in most specifications are not significant (table 10.5, row 16). It implies that there is not significant relationship between farm size and water use. Control the influence of other factors and larger farmers earn more income than smaller farmers. The coefficient of arable land per hectare in all specifications of the income determinant models are positive and statistically significant at 1 percent (table 10.17 and table 10.18, row 10). However, the significant relationship between farm size and poverty have not been demonstrated from our multivariate analysis (table 10.19 to 10.22).

WATER ACCESS TO THE POOR AND NON-POOR

To directly examine the relationship between poverty and water access, we actually find that the poorest farmers in both provinces have the greatest access to water when measured in terms of either per capita (table 6.2, rows 2 and 5) or per household use (table 6.2, rows 3 and 6). This finding also holds good for all four irrigation districts (results not shown). Although the differences among income groups using the per capita water use measures in Ningxia are less sharp, in the Henan province, the poorest farmers receive 1,348 m^3 water per person for use in crop production. In contrast, the better-off farmers in Henan receive only 1,159 m^3 water per person.

While the exact mechanism for the superior access of poor households cannot be shown using descriptive statistics, it is likely that those who are better-off in the sample are those households that have more of their members in the off-farm sector. When this is so, it could be that those in better-off households have less time or interest in spending their time lobbying ID officials and local water managers to increase the flow of water to their villages. In contrast, the poorer households (who also have more land and rely more on farming), may find it worth their while to spend their energy in working with local water managers to find ways to provide them with more water access. Alternatively, it could also be that leaders who are concerned about the welfare of the poor in their duties as water managers (in Henan) or contractees (in Ningxia) encourage the allocations of water to be directed towards the larger, poorer farmers.

From the above analysis we know that the poor farmers are even superior in accessing water than the non-poor farmers. In order to further understand the relationship between water access and poverty, we will examine the correlation beween water access and production, income, employment and food security. In the first step, we classify crop water use per hectare into three groups by the sample numbers. The lowest 20 percent of samples implies that farmers in this group apply the lowest amount of water in their arable land; farmers in the highest group (20% of samples) use the most amount of water and farmers falling in the middle group(40% of samples) use water which are between the lowest and highest groups.

Our sample data shows that water use differences among the three groups are generally large. Farmers in the lowest group use less water than in the middle group by 2 times, and the difference is even higher (5 times) when compared with the highest group (table 6.3 column 1).

The differences of water use among groups are lowest in the WID-N that may indicate its advantage in the river basin location.

Table 6.2. Water access for the poor and non-poor in sample households of Ningxia and Henan Provinces, 2001.

	Poor I [a]	Poor II [a]	Non-poor
Ningxia			
Proportion of households (%)	7.0	3.1	89.9
Per capita water use (m^3)	3,052	1,601	3,041
Per household water use (m^3)	12,006	8,861	11,959
Henan			
Proportion of households (%)	7.8	10.8	81.4
Per capita water use (m^3)	1,348	1,126	1,159
Per household water use (m^3)	7,091	5,487	4,749

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes that fall between China's official poverty standard and the World Bank's standard (878 yuan).

Data source: Authors' survey

Examining the sample data indicates that farmers in a better status with access to water intend to plant more rice, while wheat and maize will not be influenced much. Compared with other crops like wheat and maize, rice consumes more water and this is also reflected in our collected information. Either examining the data in overall or in individual IDs, farmers in the highest water use groups allocate more land to rice than those farmers in the other two groups. For example, the share of rice area in the third group of farmers is 33 percent, which is higher by more than 250 percent in the first group and by more than 70 percent in the second group (table 6.3, column 6). Different from rice, we can find a consistent relationship between water access and wheat or maize (table 6.3, columns 4 and 5) .

Table 6.3. Access to water, production and income in the sample households of Ningxia and Henan Province, 2001.

Water use group	Per hectare water use (m3)	Per capita water use (m3)	Multiple crop index	Crop area (%)			Crop yield (kg/ha)			Per capita income (yuan)		
				Wheat	Maize	Paddy	Wheat	Maize	Paddy	Total	Agriculture	Cropping
Whole sample												
Lowest (20%)	4,274	619	1.8	46	18	9	4,919	6,114	6,432	2,289	1,194	1,196
Middle (60%)	12,508	2,070	1.8	42	26	19	4,666	5,925	6,663	2,317	1,347	1,170
Highest (20%)	27,795	3,952	1.7	32	25	33	4,610	5,392	7,027	2,436	1,314	1,128
Ningxia Province												
WID-N												
Lowest (20%)	13,127	1,801	1.4	21	19	9	4,532	5,505	7,200	2,409	767	739
Middle (60%)	25,365	3,953	1.6	28	28	26	4,394	5,421	7,477	2,878	1,688	1,403
Highest (20%)	37,322	3,852	1.5	21	20	49	4,676	5,245	7,063	1,670	1,004	640
QID-N												
Lowest (20%)	5,000	1,562	1.4	37	28	18	4,187	5,302	5,861	3,376	1,792	1,799
Middle (60%)	13,896	2,577	1.7	38	36	16	4,350	5,701	6,765	2,632	1,498	1,149
Highest (20%)	25,093	4,440	1.6	33	32	29	4,692	5,597	7,180	2,551	1,544	1,333
Henan Province												
PID-H												
Lowest (20%)	3,982	436	1.9	47	20	0	5,214	6,675	n.a.	1,849	891	952
Middle (60%)	8,940	1,128	2.0	49	23	20	5,683	7,292	6,340	2,188	1,188	1,083
Highest (20%)	22,871	2,714	1.9	49	2	48	4,470	4,450	6,048	1,389	760	819
LID-H												
Lowest (20%)	3,412	396	1.9	57	6	4	5,080	6,641	7,500	1,801	1,255	1,263
Middle (60%)	7,260	795	2.0	48	15	10	4,994	4,886	7,100	1,873	1,075	1,147
Highest (20%)	14,171	1,727	2.0	50	0	29	2,604	n.a.	6,550	1,024	900	913

Data source: Authors' survey

Despite great water use differences existing in the three groups, farmers do not seem to increase the land use intensification even when they are faced with better water access situation. Sample data shows that multiple crop-index is almost the same among the three groups. For example, farmers in the lowest and middle water use groups have a similar multiple crop index of 1.8, the number for the highest group is 1.7 (table 6.3 column 3). Examining the multiple-crop index separately in the 4 sample IDs also provides this result. Reasons for this maybe due to the fact that land use is not only determined by water issues, but also determined by many other factors, such as soil type, land quality, temperature, labor resources and others.

Examining our sample data cannot provide us with any conclusion on the relationship between water and crop yield. According to our hypotheses, access to good irrigation will lead to higher agricultural productivity. However, this hypothesis is not supported by our sample data. For example, on an average, rice yield in the higher water use group seems to be higher than in the other two groups, but when we examine the data in the 4 four sample IDs, such evidence can only be supported by one of the IDs (QID-N) in the Ningxia Province (table 6.3, column 9). For wheat and maize, we are also not sure if their yields are positively or negatively related with water access issue (table 6.3, columns 7 and 8). In fact, crop yield differences among groups is not significant. For example, despite crop water use in the first group being nearly three times and more than 6 times that in the second and third group, rice yield in the first group is only lower by 4 percent and 9 percent, respectively, than that in the second group and third group.

Further, analyzing our sample data shows that we also cannot find consistent relationship between water access and farmers' income. Since a strong relationship between water access and crop yield has not been revealed by our sample data, there is no doubt that access to water will also not influence farmers' income. When we compare farmers' income based on all the samples, it seems that farmers facing better water situation will earn higher income (total, agricultural and cropping income) though it is marginal (table 6.3, columns 10 to 12). However, when separately examining the income data in the 4 IDs, even a marginal, positive relationship between water and income cannot be presented.

It is interesting to find that farmers who cannot have access to good irrigation, intend to explore more opportunities in marketing crops and working in non-agricultural industries. Sample data shows that farmers in a disadvantageous position in irrigation will have a higher share of commodity crop than other farmers. For example, average commodity rate of wheat, maize and rice in the lowest group are lower than in the highest groups; farmers in the middle-level of water use group also have higher crop (wheat, maize and rice) commodity rate than in the highest group (table 6.4, columns 1 to 3). When separately examining the data in the 4 sample IDs, evidence from most cases also support the above analysis. Further analyzing the data shows that in most cases, farmers with poor water access situation will allocate more labor in non-agricultural work (table 6.4, column 4).

Table 6.4. Access to water and employment, vulnerability and food security in the sample households of Ningxia and Henan Provinces, 2001.

Water use group	Commodity crop (%)			Non-agricultural labor (%)	Per capita grain (Kg)	Yield reduction due to disasters (%)
	Wheat	Maize	Paddy			
Whole sample						
Lowest (20%)	31	21	40	38	1,062	18
Middle (60%)	30	26	24	31	1,322	21
Highest (20%)	14	11	18	44	1,201	16
Ningxia Province						
WID-N						
Lowest (20%)	19	15	0	44	541	13
Middle (60%)	9	5	26	45	1,238	17
Highest (20%)	0	11	39	36	752	11
QID-N						
Lowest (20%)	30	36	44	41	2,009	17
Middle (60%)	29	32	24	30	1,413	19
Highest (20%)	23	18	10	33	1,487	18
Henan Province						
PID-H						
Lowest (20%)	35	13	n.a.	33	784	28
Middle (60%)	36	14	23	36	1,300	26
Highest (20%)	26	11	22	33	1,227	18
LID-H						
Lowest (20%)	21	8	26	38	770	22
Middle (60%)	31	23	23	37	841	18
Highest (20%)	38	n.a.	20	16	721	27

Data source: Authors' survey.

When combining these two evidences together we may arrive at the following conclusion. In the IDs, though at present, differences in water use betweens farmers have not generated a significant influence on their production and income, farmers receiving less water are always more worried about their potential shock from water use variation, especially potential water shortage in the future. Therefore, except for agricultural production, exploring other earning opportunities such as non-agricultural jobs and marketing crops can be treated as one way for them to enhance their ability to overcome the potential shock.

Examining our sample data also shows that food security levels and vulnerability of farmers under various water access degrees have no obvious differences. Per capita grain is always regarded as one of the important indicators to present farmers' food security level. Although the overall sample shows that farmers who are in better water access situation (middle and highest group) will have marginally higher per grain, this evidence cannot be supported by most of the IDs (table 6.4, column 5). The result is also consistent with the above analysis that agricultural production will not be obviously influenced by water access. Based on the above analysis, it is also not surprising to find that farmers' ability in overcoming natural disasters is almost the same despite their water use level being different. Either analyzing data by whole samples or by respective IDs, share of yield reduction due to disaster shock has not presented the consistent relationship with water access degree.

More importantly, econometric results support our statistic description. Based on the specified models in the chapter four, chapter five concludes that upper IDs deliver more water than lower IDs; it implies that farmers in the upper IDs have better access to water than those in the lower IDs. If we treat the dummy variable of IDs as the various water access, then we also know from chapter five that the variable IDs have no significant impact on production, income and poverty. Therefore, we can conclude that within our research areas, access to water has no significant relationship with poverty.

WATER RELIABILITY AND BENEFIT TO THE POOR

Different from the above section reflecting on water access from the quantity aspect, i.e., how much water that can be accessed by farmers, this section will focus on the impact of water access quality, i.e., if farmers can get water when they need. Water reliability is regarded as an indicator of water access quality; it is measured by how many times during the past calendar year did farmers need water but was not available on time. Similar to water use analysis, we also classify water reliability into three groups, the lowest reliability (20% of samples), the middle reliability (60% of samples) and the highest reliability (20% of samples) (table 6.5). However different the large variations existing in the three water use groups, the obvious difference of water reliability can only be found between the lowest group and the other two groups; average water reliability in the middle and highest is almost the same and near or equal to 100 percent (table 6.5, column 1). It implies that except for one-quarter of farmers, all other farmers always have a reliable water supply in the sample areas.

Table 6.5. Surface water reliability, production and income in the household samples of Ningxia and Henan Provinces, 2001.

Surface water reliability group	Surface water reliability (%)	Multiple crop index	Crop area (%)			Crop yield (kg/ha)			Per capita income (yuan)		
			Wheat	Maize	Paddy	Wheat	Maize	Paddy	Total	Agriculture	Cropping
Whole sample											
Lowest (20%)	62	1.7	38	30	22	4,418	5,239	6,505	2,151	1,240	1,194
Middle (60%)	99	1.8	39	22	23	4,718	5,954	6,946	2,204	1,200	1,095
Highest (20%)	100	1.6	39	31	14	4,383	5,465	6,133	3,223	1,889	1,466
Ningxia Province											
WID-N											
Lowest (20%)	74	1.7	32	32	29	3,951	5,543	7,065	2,614	1,416	1,350
Middle (60%)	99	1.5	22	22	27	4,588	5,306	7,669	2,444	1,296	943
Highest (20%)	100	1.7	26	24	26	4,719	5,471	6,796	2,706	1,473	1,342
QID-N											
Lowest (20%)	65	1.5	38	35	22	3,938	4,937	6,512	2,111	1,311	1,184
Middle (60%)	99	1.6	35	36	21	4,498	5,688	6,866	2,659	1,614	1,403
Highest (20%)	100	1.5	42	26	13	4,513	6,113	6,689	3,736	1,677	1,184
Henan Province											
PID-H											
Lowest (20%)	38	1.9	47	27	9	5,827	6,604	5,333	1,318	603	631
Middle (60%)	99	2.0	49	11	34	5,037	6,572	6,198	1,777	922	964
Highest (20%)	100	1.9	48	16	10	5,417	6,728	4,653	1,980	1,361	1,435
LID-H											
Lowest (20%)	80	2.1	48	11	0	4,315	3,506	n.a.	1,899	1,128	1,142
Middle (60%)	100	1.9	48	3	22	3,618	5,156	6,658	1,598	1,020	1,074
Highest (20%)	100	1.8	60	23	0	6,699	6,385	n.a.	1,919	1,098	1,167

Data source: Authors' survey.

Increasing water reliability seems to have no obvious effect on land intensification. Sample data show that multiple crop-index is almost the same under various conditions of water reliability, they are about 1.6 - 1.7 (table 6.5, column 2). It means that land use intensification is not mainly constrained by water reliability; other factors are the major concern of farmers for increasing land use intensification.

Although it is marginal, most evidence indicate that share of wheat area will be increased with water reliability improvement. For example, faced with 62 percent of water reliability, farmers will allocate 38 percent of area to wheat; this number will increase by 1 percent when reliability increases to nearly 100 percent (table 6.5, column 3). Except for wheat, the other two crops, maize and rice have not presented such a relationship between water reliability and relative sown area (table 6.5, columns 4 and 5). The results here probably implies that compared with other crops like maize or rice, wheat is more sensitive to water reliability.

Examining sample data demonstrates that water reliability has a positive relationship between crop yield and farmers' income. Most cases reveal that when farmers have almost no problem in accessing water in time, i.e., water reliability is near to 100 percent, farmers' crop will generate higher yield (table 6.5, columns 6 to 8). For example, in one of the IDs (QID-N) of Ningxia province, yields of wheat, maize and rice in the second and third group are all higher than that in the first group. Similar to the correlation between water reliability and crop yield, investigations indicate that farmers will earn more money if water is more timingly and reliably supplied to them (table 6.5, columns 9 to 11). Most cases show that farmers' income, either in terms of total, agricultural or cropping income, will be higher when water reliability has been improved, especially when we compare farmers' income in the first and third groups (such as in QID-N, PID-H and LID-H).

Differing from analysis grouping by water use, cropping marketing and farmers' employment will not be obviously influenced by level of water reliability. Examining our sample data has not revealed any consistent relationship between water reliability and share of commodity crop or water reliability and proportion of non-agricultural labor (table 6.6, columns 1 to 3). Even if water reliability has been improved from about 60 percent to near 100 percent, most evidence neither tell us if share of commodity crop will rise or fall, it is also similar to labor allocation in the non-agricultural production.

Similar to the relationship with water use, farmers' food security and vulnerability are not correlated with water reliability. Our field survey shows that in some cases like in PID-H, per capita grain will increase with improvement of water reliability; while in some other cases like in QID, per capita grain will decrease even if water reliability has been improved. The result is the same when the relationship between water reliability and yield reduce due to disaster. Therefore evidence from our sample demonstrates that water reliability is not one of the important factors to influence food security and farmers' ability to resist production shock.

Actually, we also conducted multivariate analysis on the impacts of water reliability on the pro-poor and the results are consistent with statistical analysis, i.e., water reliability has no sinificant influence on the pro-poor. When we put the variable of water reliability into the specified models (production, income and poverty) in the fourth section or substitute the water scarcity variable by water reliability in these models, the coefficient of water reliability is not significant. It may be that the differences of water reliability among IDs are not large enough.

Table 6.6. Surface water reliability, employment, vulnerability and food security in the sample households of Ningxia and Henan Provinces, 2001.

Surface water reliability group	Commodity crop (%)			Non-agricultural labors (%)	Per capita grain (Kg)	Yield reduction due to disasters (%)
	Wheat	Maize	Paddy			
Whole sample						
Lowest (20%)	21	17	25	36	1,486	21
Middle (60%)	26	20	19	34	1,131	19
Highest (20%)	31	37	42	33	1,519	20
Ningxia Province						
WID-N						
Lowest (20%)	12	5	46	38	1,443	25
Middle (60%)	12	13	29	42	821	12
Highest (20%)	0	0	11	50	1,041	11
QID-N						
Lowest (20%)	22	18	19	31	1,683	18
Middle (60%)	32	34	21	29	1,609	19
Highest (20%)	21	30	42	46	1,223	17
Henan Province						
PID-H						
Lowest (20%)	24	13	39	30	741	32
Middle (60%)	31	32	28	36	1,243	24
Highest (20%)	35	0	0	15	1,193	20
LID-H						
Lowest (20%)	41	25	n.a.	20	758	n.a.
Middle (60%)	27	50	8	28	745	26
Highest (20%)	44	0	n.a.	43	1,039	11

Data source: Authors' survey.

IRRIGATION INVESTMENT AND BENFIT TO THE POOR

We collected irrigation investment information at village-level since most surface water facilities are invested by local government, and farmers mainly contribute labor. During the survey, we asked about the irrigation facilities' investment in the sample villages, i.e., stock of irrigation investment; this variable can also reflect the irrigation conditions of the sample areas. In order to understand the contribution of irrigation investment in increasing farmers' income and pulling farmers out of poverty status, irrigation investment has also been classified into three groups by the number of samples analysed (table 6.7). Grouping irrigation investment presents large variations across the samples (table 6.7, column 1). For villages in the lowest group investment irrigation per hectare is 384 yuan, while in the highest group, irrigation investment per hectare is as high as 8,074 yuan, more than 21 times that in the first group.

Table 6.7. Irrigation investment and farmers' income in the sample households of Ningxia and Henan Provinces, 2001.

Irrigation investment group	Irrigation investment per hectare (yuan)	Per capita income (yuan)			Poverty incidence (%)		Poverty gap (%)	
		Total	Agriculture	Cropping	Poor I	Poor II	Poor I	Poor II
Whole sample								
Lowest group (20%)	384	2,078	1,382	1,208	9	11	41	66
Middle group (60%)	1,936	2,191	1,213	1,109	9	17	15	49
Highest group (20%)	8,074	3,060	1,550	1,312	2	4	7	18
Ningxia								
WID-N								
Lowest group (20%)	0	2,372	987	778	-	-	-	-
Middle group (60%)	2,024	2,499	1,384	1,033	5	14	10	32
Highest group (20%)	8,728	2,705	1,471	1,484	13	13	39	71
QID-N								
Lowest group (20%)	478	2,444	1,602	1,321	4	8	13	29
Middle group (60%)	1,796	2,468	1,509	1,317	11	11	25	54
Highest group (20%)	12,279	4,269	1,697	1,304	0	6	0	15
Henan								
PID-H								
Lowest group (20%)	326	1,408	1,124	1,130	19	19	96	144
Middle group (60%)	1,992	2,036	804	869	9	18	14	48
Highest group (20%)	4,734	2,449	1,503	1,191	0	0	0	0
LID-H								
Lowest group (20%)	-	-	-	-	-	-	-	-
Middle group (60%)	2,057	1,645	1,013	1,064	7	30	3	53
Highest group (20%)	4,899	1,935	1,391	1,427	-	-	-	-

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes that below the World Bank's standard (878 yuan).
Data source: Authors' survey.

Importance of irrigation on farmers' income supported by our analysis in six provinces also has been confirmed by our sample in the 4 IDs of Ningxia and the Henan Province when the relationship between irrigation investment and farmers' income is examined. Sample data shows that when irrigation investment per hectare increased from nearly 400 yuan to more than 8,000 yuan, farmers' total income increased nearly 50 percent and also increased agricultrual income and cropping income respectively, by 12 percent and 9 percent (table 6.7, rows 1 to 3). Such results can also be got from most cases in the 4 Sample IDs. For example, in one ID in the Ningxia province, WID-N, farmers' income in both the middle and highest groups are higher than in the first group (table 6.7, rows 4 to 6).

Increasing irrigation investment seems to play a role in pulling more farmers out of poverty. Examining all sample data demonstrates that poverty occurs in the villages having relatively low irrigation investment; in these villages, it is also harder to improve farmers' poverty condition. Either measuring poverty by China's official poverty standard or the World Bank standard, poverty incidence in the lowest group is higher by 7 percent than that in the highest group (table 6.7, rows 1 to 3). Poverty gap in the first group is also higher than that in the third group, higher by 34 percent or 48 percent, when measured by various poverty standards. Most evidence in the sample IDs also indicate an obvious relationship between irrigation investment and poverty. For example in one ID of the Henan Province, when irrigation investment was as high as more than 8,000 yuan per hectare, our field survey did not identify any poverty in these villages; however, when irrigation investment was less than 400 yuan per hectare, poverty incidence was high as 19 percent and poverty gap was also very high, nearly more than 100 percent (table 6.7, rows 10 to 12).

Econometric results also show the significance of the irrigation investment for farmer income. Irrigation investment is positive and statistically significant (table 10.17 and table 10.18 row 5). It implies that increasing irrigation investment in the IDs still has potential to increase farmer income. However, we have not found its significant impact on poverty (table 10.19 to 10.20).

SUMMARY

In this case study, we explore the relationship between irrigation status and yields, crop choices and household cropping revenue. Our study provides evidence of irrigation's strong impact on yield and cropping revenue, both descriptively and in the multivariate analysis. Unlike some of the literature that used aggregate data, we find that irrigation increases yields and cropping revenue when we look at either different crops or examine grain or crops as a whole. Moreover, we find that although the marginal impact of irrigation on revenue appears to be higher in richer areas, since the poor relies more on cropping revenue, our findings suggest that farmers in poor areas increase their incomes relatively more than farmers in richer areas.

The strong findings in our study of the effect of irrigation on agricultural performance relative to previous studies almost surely are in part a function of our data and methods. By using plot-level data, we can account for many of the attributes in the natural environment that also affect yields as well as irrigation. By having more than one plot observation per household, we show that when we use household fixed-effects (versus only controlling for some household effects and village effects or nothing) the effect of irrigation almost always rises. In fact, when we go from controlling of no supra-plot effects to the full model, the impact of irrigation goes from insignificant (zero) to highly significant and positive. Hence, it could be that omitted variable bias may be one reason why previous studies failed to find the strong effect of irrigation on agricultural performance.

If irrigation has such a great effect on agricultural performance it is no wonder why so much of the budget of many countries has gone towards irrigation in the past. Moreover, although the costs of the project must be considered, the disinterest that seems to be pervading the international community in irrigation needs to be questioned. Our findings of the effect of irrigation on the income of those in poor areas mean that poverty alleviation programs, in particular, may need to consider increasing or at least not diminish the role of irrigation in their portfolio of activities.

Based on statistical and multivariate analysis, this chapter further explores the relationship between irrigation and poverty within IDs. Our results show that small and large farmers have relatively equal access to water. By controlling the influence of other factors, larger size of farmers earn more income than smaller farmers. Access to water and water reliability has no significant relationship with the pro-poor in our sample IDs. Even we have not found that irrigation investment can significantly improve the poverty situation; econometric results demonstrate a significant relationship between irrigation investment and farmer income.

CHAPTER 7

Poverty in Irrigation Systems: Status, Characteristics and Distribution

In this chapter we have three objectives. First, we attempt to calculate the extent of poverty that exists in irrigated areas in China. To our knowledge this is the first time in China that a study has attempted to gauge the severity of poverty within China's main IDs. Second, we explore where the poor are located among the IDs within a province. Third, we examine the characteristics of the poor who live in irrigated areas.

Two standards of poverty are used in this study. The first one is China's official poverty standard that is published annually by the CNSB. The other is the international standard used by the World Bank (the so-called $1 per day poverty line). In 2001, the official poverty in rural areas is defined as per capita annual income less than 625 yuan. In purchasing power parity terms this is about 71 cents per day. Hence, China's poverty line is 29 percent lower than that used by the World Bank (878 yuan per capita per year).

Although our household survey was conducted by well-trained enumerators with well-tested survey instruments, obtaining accurate income estimates for calculating poverty incidences is still a challenge. The survey covered a long list of farmer activities and was designed to produce full household income, including farm, non-farm, and other income. During the survey the supervisor tabulated incomes that were recorded on the survey forms and whenever potential problems were encountered a return visit was made the next day to immediately correct the error. In the following analysis, caution should be exercised when comparing poverty incidences to the more formal estimates published by China and other international organizations. We suggest that our estimates should be considered as rough approximations of how many people are relatively poor in China's irrigated areas and not accept the absolute poverty incidences without caution.[19]

INCIDENCE OF POVERTY

Based on China's poverty line, the incidence of poverty in our surveyed households is higher than the national average. According to our data, 7 percent of our households earn per capita incomes under 678 yuan annually (table 7.1, row 1). This level of poverty, while not too high, compared to

[19] Efforts were also made to avoid the undue influence of idiosyncratic shocks in the calculation of income. During the survey we produced estimates of unexpected crop income shocks from natural disasters and livestock losses from disease and other sources. Adjustments were made to income when positive or negative transfers that were considered abnormal were encountered. In this way, our income estimates (especially the variability of income) are similar to those that would have been generated had we access to total annual household expenditure. However, it should be noted that when comparing our estimates of poverty incidents to those generated by the CNSB at the national level many factors differ, most of which inflate poverty rates. In particular, while CNSB uses expenditure, we use income, a livelihood metric that is generally more variable than expenditure. Second, our sample is fairly small. Third, we elicit annual earnings direct, while CNSB asks income from many sources on a monthly basis. All of these will potentially increase the variability of our series and create a distribution with a higher variance, part of which is true variance and part of which is due to measurement error. Given equal means (which are actually similar), a series with a greater variance will generate higher estimates of the incidence of poverty.

many countries, is still about twice the national level (3.4% in 2000--see table 1.1). Such a result (even beyond consideration of the greater variance of our measures) in one sense should be expected since our sample areas are entirely in inland provinces and include many villages that are heavily oriented to agricultural production. According to Rozelle (1996), most of China's inequality is due to inter-regional differences between the coastal and inland provinces and due to the differences in earning between farmers who earn less from agriculture and workers and the self-employed who earn more from non-farm employment. From this result, we should expect that a sample drawn from inland, agricultural areas should be on the low side of income distribution, even though the villages are in an irrigated area. However, before concluding that there are households in China that have access to irrigation and are still poor, it must be remembered that not all households in irrigated areas have land that is irrigated.

Table 7.1. Poverty distribution and durable consumer goods of the sample households in Ningxia and Henan Provinces, 2001.

Income group[a]	Share of households (%)[b]	Value of durable consumer goods (yuan)
Whole sample		
I: the poor I	7	4,711
II: the poor II	7	5,241
III	51	5,136
IV	21	6,444
V	14	11,953
Ningxia		
I: the poor I	7	5,882
II: the poor II	3	7,416
III	46	4,258
IV	26	5,312
V	18	12,436
Henan		
I: the poor I	8	3,393
II: the poor II	11	4,451
III	58	6,013
IV	15	9,009
V	9	10,719

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes that fall between China's official poverty standard and the World Bank's standard (878 yuan). Groups III, IV and V are the non-poor category with per capita annual incomes between 878 yuan and 2,500 yuan, 2,500 yuan and 4,000 yuan, and more than 4,000 yuan, respectively.
[b] May not add to 100 percent due to rounding.

Data source: Authors' survey.

While our estimates of the incidence of poverty within irrigation districts are higher than the national level, they are lower than the provincial averages of the Henan and Ningxia provinces. According to CNSB (2001), the average poverty incidence in the rural areas of Ningxia and Henan is estimated to be around 10 percent in both provinces in 2001. This means that poverty inside irrigation districts is only a fraction of that in non-irrigated areas (since the average for non-irrigated areas must be substantially higher than the provincial average).

Applying the World Bank's poverty standard to our samples, the incidence of the poverty rises to 14 percent (7 percent + 7 percent; table 7.1, column 2, rows 1 and 2). Interestingly, this estimate of the number of people who earn below one dollar per day is close to the 1997 poverty incidence reported by the World Bank (13.5 %--table 1.1). Cross-checking our income data with durable consumer goods shows that they are positively correlated (and the correlation coefficient is significantly different than 0), an indication of the reasonableness of the estimates of income upon which we generated our estimates of poverty incidence.

DISTRIBUTION OF THE POOR

Although the IDs in the two sample provinces have similar rates of incidence of poverty when using China's poverty standard, they differ substantially when using the World Bank poverty line (table 7.1, rows 6 to 15). According to our data, 7 percent of households in the Ningxia IDs and 8 percent of those in the Henan sample do not earn enough to be above China's own poverty line. When moving to the World Bank poverty lines, however, the poverty incidences in Henan and Ningxia diverge. The proportion of households that fall below the one dollar per day line increases to 19 percent in the Henan villages (poor I + poor II). Those in the Ningxia sample only rise marginally to 10 percent. Examining the average incomes in the sample counties in each province helps understand the result. Average incomes of the 6 selected counties in the 2 irrigation districts in Henan are lower than the other 5 counties in Ningxia. These differences between Ningxia and Henan Province are consistent with our expectation of the distribution of poverty along a river basin. Because of the superior access to water in the upstream localities, the incidence of poverty of the upstream areas is less than that in the downstream.

Poverty distribution along the IDs within a province has not presented a consistent pattern as that presented along the overall river basin. Applying national poverty line reveals that poverty incidence in the up-reach of ID (WID-N) in the Ningxia Province is lower than that in the down-reach of ID (QID-N), it is also supported by a larger poverty gap in the down ID; anyway, all these incidences seem to be consistent with the analysis on the distribution along the overall river basin (table 7.2, rows 1 and 2) . However, examining the sample data in Henan province generates the opposite result that more poverty occurred in the up-reach of the ID instead of the down-reach and that poverty is deeper in the up ID than in the down ID (table 7.2, rows 3 and 4). In addition, when we compare poverty incidence calculated by the World Bank Poverty line and analyze farmers' income between up and down IDs, we also cannot get the consistent results as expected by many people that farmers located in the up IDs should benefit more than those in the down IDs.

Table 7.2. Income and poverty in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

	Total income (yuan)	Cropping income (yuan)	Headcount index		Poverty gap index	
			Poor I	Poor II	Poor I	Poor II
Ningxia						
WID-N	2,533	769	5.9	11.8	2.5	6.8
QID-N	2,765	863	7.4	9.5	2.8	7.5
Henan						
PID-H	1,964	713	9.1	15.2	4.9	11.8
LID-H	1,694	778	5.6	25	0.4	5.4

[1] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes below the World Bank's standard (878 yuan).
Data source: Authors' survey.

When analyzing poverty distribution along canals within IDs, evidence from our sample data further indicates that farmers' poverty status is not strongly related to their location in the IDs. For example, poverty incidence in both IDs of Ningxia Province calculated by the national poverty line has almost no differences (table 7.3, rows 1 to 4). Although there are obvious variations of poverty incidence between upper and down reaches of both IDs in the Henan province, the evidence from this Province has not told us one consistent story (table 7.3, rows 5 to 8). Analyzing poverty incidence based on the World Bank poverty line has also not provided a strong clear relationship between poverty and location in the canals.

Table 7.3. Poverty distribution along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Irrigation district	Reaches of irrigation districts	Poor I (%)	Poor II (%)
Ningxia			
WID-N	Upper	5.6	16.7
	Lower	6.3	6.3
QID-N	Upper	3.2	6.4
	Lower	9.4	11
Henan			
PID-H	Upper	16.0	28.0
	Lower	4.9	7.3
LID-H	Upper	0.0	13.3
	Lower	9.5	33.3

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes below the World Bank's standard (878 yuan).
Data source: Authors' survey.

CHARACTERISTICS OF THE POOR

While it could be that access to water and irrigated land accounts for some of the income differences of households, a number of other factors appear to be correlated with income levels of our sample households in the IDs. For example, in our sample, poorer households, rely much more on agriculture than their better-off counterparts (table 7.4, columns 2 to 4). On an average, the poor, which have an average income of only 373 yuan per year during our survey year, receive more than 80 percent of their income from the cropping sector and 7.3 percent of their income from raising livestock (table 7.4, row 1). In contrast, poor farm households receive only 12.4 percent of their income from the non-agricultural sector. For those in progressively higher income categories, however, the share income generated from cropping declines. For the highest income group (V), households with an average annual, per capita income of 5,877 yuan, more than half (53.8 %) of their income comes from off-farm activities (table 7.4, row 5). Such findings are also consistent with various studies that show the importance of off-farm employment in farmer income growth and poverty alleviation (Fan et al. 2001; World Bank 2001).

Table 7.4. Income, structure of income and non-agricultural labor in Ningxia and Henan Provinces, 2001.

Income group[a]	Per capita income (yuan)	Sources of income (%)			Share of non-agricultural labors (%)
		Crop	Livestock	Non-agri	
Whole sample					
I: the poor I	373	80	7	12	3
II: the poor II	735	73	7	21	21
III	1,672	58	10	33	33
IV	3,090	49	11	40	42
V	5,877	35	12	54	48
Ningxia					
I: the poor I	381	82	12	5	0
II: the poor II	715	59	9	32	18
III	1,775	49	15	36	35
IV	3,083	52	16	32	37
V	6,209	34	11	55	49
Henan					
I: the poor I	365	78	1	20	7
II: the poor II	742	78	6	16	22
III	1,570	67	4	29	31
IV	3,107	40	2	58	52
V	5,028	35	13	52	45

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes that fall between China's official poverty standard and the World Bank's standard (878 yuan). Groups III, IV and V are the non-poor category with per capita annual incomes between 878 yuan and 2,500 yuan, 2,500 yuan and 4,000 yuan, and more than 4,000 yuan, respectively.
Data source: Authors' survey.

When examining the structure of incomes, it is worth noting that although the absolute income from agriculture for the non-poor is generally higher than that of the poor, our data shows clearly that the poor generate a higher share of their income from agriculture. In an economy in which the poor rely relatively more on agricultural earnings, if some action of the government (or any other entity) increases agricultural income, it means that it is more likely that there may be a higher proportional increase in the total income of the poor than of the rich farmers. Hence, if the government can implement policies that increase income in agriculture, including measures that increase agricultural income by increasing the amount of newly irrigated areas and by raising the efficiency of the existing irrigated areas, the poor may benefit.

In addition to irrigation and the structure of rural income, some variables vary with income and appear to have a simultaneous affect on rural income, while others do not (table 7.5). For example, the size of farms in terms of cultivated land is very similar among the income groups and between the poor and non-poor (table 7.5, column 4). Likewise, there is little noticeable variation among income categories in cultivated land per capita (table 7.5, column 5). Such an equitable distribution of land, which is perhaps most characteristic of China, even 20 year after its economic reforms, has been shown to play an equity increasing role in China's rural economy (Brandt et al. 2002). In contrast, family size falls and the number of laborers in a household rises (meaning, the number of dependents in the household falls) as households move up the income ladder (table 7.5, columns 1 and 2). Likewise, the average education of families rises with income (table 7.5, column 3).

Table 7.5. Household characteristics and farm size of the sample households in Ningxia and Henan Provinces, 2001.

Income group[a]	Household size	Number of laborers per household	Average education of those in labor force (years)	Cultivated land per household (ha)	Cultivated land per capita (ha)
Whole sample					
I: the poor I	4.3	2.9	5.4	0.7	0.18
II: the poor II	4.9	3.0	7.0	0.4	0.09
III	4.3	3.0	6.4	0.6	0.15
IV	3.9	2.9	6.0	0.7	0.18
V	3.4	3.0	6.3	0.7	0.22
Ningxia					
I: the poor I	3.9	3.0	5.8	0.7	0.22
II: the poor II	5.5	3.3	5.7	0.4	0.08
III	4.3	3.0	6.1	0.7	0.18
IV	3.9	2.9	5.8	0.8	0.21
V	3.5	3.1	5.8	0.8	0.25
Henan					
I: the poor I	4.8	2.9	5.0	0.6	0.13
II: the poor II	4.6	2.9	7.4	0.4	0.10
III	4.3	2.9	6.7	0.5	0.12
IV	3.9	2.7	6.6	0.4	0.11

V	3.2	2.8	7.6	0.4	0.13

[a] Households in the poor I category include those with per capita annual income below China's official poverty standard (625 yuan). Households in poor II include those with incomes that fall between China's official poverty standard and the World Bank's standard (878 yuan). Groups III, IV and V are the non-poor category with per capita annual incomes between 878 yuan and 2,500 yuan, 2,500 yuan and 4,000 yuan, and more than 4,000 yuan, respectively.
Data source: Authors' survey.

SUMMARY

Based on China's poverty line, the incidence of poverty in our surveyed households is higher than the national average, but lower than the provincial averages of Ningxia and Henan provinces. Poverty distribution along the IDs within a province has not presented consistent patterns as that presented along the overall river basin. While it could be that access to water and irrigated land accounts for some of the income differences of households, a number of other factors appear to be correlated with income levels of our sample households in the IDs.

CHAPTER 8

Irrigation System Performance: Implications for the Poor

The assessment of irrigation system performance and its implications for the pro-poor is focused in this chapter. In fact, some major aspects of the irrigation system performance have already been included in the other chapters. In this section, applying field survey data, we will further assess irrigation system performance in terms of water utilization, irrigation investment, output value, land productivity, head-tail equity of output, water productivity[20] and labor productivity.

WATER SCARCITY AND WATER QUALITY

Our sample data clearly shows a trend of increasing water scarcity over a period of time since 1990 and more serious water scarcity in the downstream regions (table 8.1). Except for WID-N, the upper ID of the Ningxia Province due to its predominant location, all other IDs show that water has become short since 1990 (table 8.1, rows 2 to 4). For example, in the lower ID of the Ningxia Province, only 4 villages reported that they were faced with water scarcity issue in 1990; however, this number increased to 17 percent in 1995 and 29 percent in 2001. Similar trends can be found in the Henan Province. At present, within provinces increasing villages in the downstream IDs are faced with severe water scarcity than that in the upstream. For example, water scarcity villages in the QID-N is more by 16 percent than that in the WID-N, and water scarcity in LID-N is more by 13 percent than that in the PID-H. In addition, average water scarcity degree in the Henan Province is more severe than that in the Ningxia Province.

On an average, water quality in the sample villages has tended to deteriorate more seriously since 1990 (table 8.2). In 1990, water quality in 31 percent of villages was not good and this number increased to 38 percent in 2001 (table 8.2, column 4). Since 1995, water quality in the WID has been improved while water quality in QID deteriorated quickly. Currently, water quality in WID is better than that in QID, maybe due to its advantageous location. Water salinity is one of the water quality issues in our sampled villages (table 8.3). On an average, 38 percent of villages have water salinity issues; water salinity in QID is more serious than that in WID. Since 1990, water salinity in our samples has not expanded to more villages though the seriousness of water salinity was not collected by our survey.

Table 8.1. Degree of water scarcity in the sample villages of four sample irrigation districts of Ningxia and Henan Provinces, 2001.

[20] Data applied in analyzing water productivity of the second section is second hand; in this section, we will use field survey data to analyze water productivity.

	Share of villages facing severe water shortage (%)		
	1990	1995	2001
Ningxia Province			
Upper: WID-N	25	13	13
Lower: QID-N	4	17	29
Henan Province			
Upper: PID-H	6	13	25
Lower: LID-H	0	25	38

Data Source: Authors' survey.

Table 8.2. Water quality in the sample villages of four sample irrigation districts of Ningxia and Henan Provinces, 2001.

		Degree of water quality (%)		
		Good	Common	Bad
Ningxia Province				
Upper: WID-N				
	1990	50	25	25
	1995	50	13	38
	2001	50	25	25
Lower: QID-N				
	1990	25	42	33
	1995	21	46	33
	2001	25	33	42
Henan Province				
Upper: PID-H				
	1990	44	50	6
	1995	38	44	19
	2001	31	44	25
Lower: LID-H				
	1990	63	13	25
	1995	63	13	25
	2001	63	13	25

Data source: Authors' survey.

Table 8.3. Water quality in the sample villages of four sample irrigation districts of Ningxia and Henan Provinces, 2001.

		Water salinity (%)
Ningxia Province		
Upper: WID-N		
	1990	25
	1995	25
	2001	25
Lower: QID-N		
	1990	42
	1995	42
	2001	42
Henan Province		
Upper: PID-H		
	1990	0
	1995	13
	2001	13
Lower: LID-H		
	1990	38
	1995	38
	2001	38

Data source: Authors' survey.

WATER UTILIZATION, RELIABILITY AND IRRIGATION INVESTMENT

IDs in the upstream of river basins have been allocated more water than that in the downstream, water use differences between IDs within a province is smaller than that between IDs in different provinces. For example, in one ID of the Ningxia Province, WID-N, water use per capita is nearly four times that of the ID in the Henan Province; in LID-H, water use per hectare is more than 3 times (table 8.4, columns 1 and 2). However, within the Ningxia Province, water use per capita in WID-N is only higher by 30 percent than that in the QID-N, and water use per hectare is higher by nearly 80 percent. While water shortage has emerged as an increasing serious problem in the overall river basin, overuse of water in the upstream has been criticized and reallocating water has been strongly proposed.

Table 8.4. Water utilization and irrigation investment in the four sample irrigation districts (water supply indicators) of Ningxia and Henan Provinces, 2001.

Location	Water use per capita (m^3/person)	Water use per hectare (m^3/ha)	Surface water reliability (%)	Irrigation investment per hectare (yuan/ha)
Ningxia Province				
Upper: WID-N	3,489	25,307	94	3,363
Lower: QID-N	2,746	14,356	92	3,201
Henan Province				
Upper: PID-H	1,304	10,707	88	2,257
Lower: LID-H	898	7,855	95	2,531

Data source: Authors' survey.

It is interesting to find different water allocation patterns between IDs, not all the farmers located in the upper stream of IDs will be allocated more water than that in the lower stream.

Although in some IDs, such as QID-N in the Ningxia Province and PID-N in the Henan Province, water use in the upper canals is higher than that in the lower canals, it is not always true (table 8.5, columns 1 and 2). In the WID-N, water use per capita in the upper reach is lower by nearly 50 percent than that in the lower reach, water use per hectare is lower by 15 percent; similar results can also be found in one ID of the Henan Province, LID-H. Evidence of water allocation along canals in the ID may imply that it is more easy to control water allocation within an ID than that between IDs, especially between IDs in different provinces.

Table 8.5. Water utilization and irrigation investment along canals in the four sample irrigation districts (water supply indicators) of Ningxia and Henan Provinces, 2001.

Location		Water use per capita (m^3/person)	Water use per hectare (m^3/ha)	Surface water reliability (%)	Irrigation investment per hectare (yuan/ha)
Ningxia Province					
WID-N					
	Upper	2,317	23,372	98	3,367
	Lower	4,808	27,484	89	3,359
QID-N					
	Upper	3,064	19,528	96	2,683
	Lower	2,593	11,851	90	3,451
Henan province					
PID-H					
	Upper	1,974	16,325	95	1,546
	Lower	895	7,282	82	2,673
LID-H					
	Upper	694	6,526	89	2,036
	Lower	1,044	8,805	100	2,884

Data source: Authors' survey.

Examining sample data shows that farmers in the upper reach can receive more reliable water supply than those in the lower reach. For example, average water reliability in the IDs of the Ningxia Province is higher than that in the Henan province; within Ningxia Province, water reliability in the upper ID,WID-N, is higher by 2 percent than that in the lower ID, QID-N (table 8.4, column 3). On further examining water reliability along canals within IDs, except for the LID-H in the Henan Province, all the other three IDs show that farmers in the upper canals can irrigate more reliable water than those in the lower canals (table 8.5, column 3). For example, reliability in the upper canals of WID-N in the Ningxia Province is higher by 10 percent than that in the lower canals. The reasons why water reliability in LID-H is higher than that in PID-H maybe due to the fact that for surface water, farmers in the LID-H can also get water from ground river, which is especially true for the downstream of the Yellow River.

In order to improve water supply reliability, more irrigation investment generally has been put in the lower than in the upper reaches. For example, irrigation investment per hectare in WID-N is higher by 5 percent than that in QID-N (table 8.4). Most evidence on irrigation investment along canals further prove the result (table 8.5). For example, irrigation investment in the lower reach of QID-N is more by nearly 30 percent than that in the lower reach; regions in the lower reach of PID-H can get 70 percent of irrigation investment per hectare more than that in the lower reach.

CROPPING INTENSITY, LAND PRODUCTIVITY AND OUTPUT VALUE

Examining data show that differences of cropping intensity between provinces are higher than within provinces or within IDs. For example, cropping intensity in the IDs of the Ningxia Province is about 1.6, while in the Henan Province, this number is more than 1.9, even nearly 2.0 (table 8.6, column 1). However, in the Ningxia Province, QID-N is only higher by 2 percent than WID-N; similar results can be found in the IDs of the Henan Province. Although cropping intensity variation along canals in the WID-N seems large, more than 15 percent; differences in other IDs are very small, about 1 percent to 8 percent (table 8.7, column 1).

Table 8.6. Land productivity in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Cropping intensity	Crop yield (kg/ha)		
		Wheat	Maize	Paddy
Ningxia Province				
Upper: WID-N	1.56	4,596	5,281	7,396
Lower: QID-N	1.60	4,527	5,672	6,962
Henan Province				
Upper: PID-H	1.94	5,295	6,933	6,097
Lower: LID-H	1.98	4,748	5,643	7,018

Data source: Authors' survey.

Although wheat yield in the upper reach both between and within a province is higher than that in the lower reach; consistent results cannot be got from maize and rice. For example, wheat yield in the LID-H is 4,748 kg per hectare, lower than 5,295 kg in PID-H, but still higher than the highest yield of 4,596 in WID-N of the Ningxia Province (table 8.6, column 2). But for maize and rice yield, there are not consistent results to show which province has higher yield (table 8.6, columns 3 and 4). For example, rice yield in WID-N is higher than that in the IDs of the Henan province, while rice yield in QID-N is lower than that in the IDs of the Henan Province. Further, examining crop yield along canals within IDs also reveal that it is hard to conclude whether upper or lower reach farmers along the canals will have higher agricultural productivity (table 8.7, columns 2 to 5).

Table 8.7. Land productivity along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Cropping intensity	Crop yield (kg/ha)

		Wheat	Maize	Paddy
Ningxia Province				
WID-N				
Upper	1.43	4,579	4,991	7,956
Lower	1.70	4,620	5,644	6,836
QID-N				
Upper	1.68	4,872	5,963	7,657
Lower	1.55	4,363	5,548	6,419
Henan Province				
PID-H				
Upper	1.93	4,972	4,425	6,230
Lower	1.95	5,477	7,044	4,905
LID-H				
Upper	1.99	6,010	5,510	n.a.
Lower	1.97	3,661	7,500	7,018

Data source: Authors' survey.

Farmers in the upper provinces generate lower production value than that in the lower provinces, though this is not true within provinces and within IDs. Both gross and net production values in the Ningxia Province are lower than that in the Henan Province (table 8.8, columns 1 and 2). For example, Gross and net production value per hectare in WID-N is separately 10,937 yuan and 5,767 yuan, which are lower than that in the PID-H with 11,969 yuan and 6,360 yuan, respectively. On calculating the ratio of net production value over the gross value, the results show that farmers in Ningxia Province is less profitable than those in the Henan Province. It is interesting to note that despite farmers in the Ningxia Province getting more water than those in the Henan province, they earn less money from agricultural production ability in the Ningxia Province than those in the Henan Province; this maybe due to many other factors and local production conditions. Consistent with the above discussion, farmers in the Ningxia Province get less income from agricultural production than those in the Henan Province (table 8.8, column 3). For example, farmers in one ID of the Ningxia Province, WID-N, earn 41 percent of their income from agricultural production, while this number is 55 percent in PID-H and 69 percent in LID-H of the Henan Province.

Examining data shows that other than production value differences between provinces, within provinces and IDs, farmers in the upper reaches are more profitable than those in the lower reaches. For example, gross production value in WID-N is higher by 16 percent than that in QID-N and net production value is higher by 21 percent; a similar result can be found in the IDs of the Henan Province (table 8.8, columns 1 and 2). In addition, farmers in the upper canals within IDs are more productive and profitable than those in the lower canals (table 8.9, columns 1 and 2). For example, farmers in the upper reach of QID-N has 11 percent more gross production value than those in the lower reach and net production value is higher by 17 percent; Such evidence can also be found in the other IDs within Ningxia or in Henan. By connecting this result with water reliability, it implies that within provinces and IDs, more reliable water in the upper canals are beneficial to farmers' production and profitability under other similar conditions.

Table 8.8. Production value in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Gross value of agricultural production per unit area (yuan/ha)	Net value of agricultural production per unit area (yuan/ha)	Net value of agricultural production as percent of total household income (%)
Ningxia Province			
Upper: WID-N	10,937	5,767	41
Lower: QID-N	9,460	4,772	51
Henan Province			
Upper: PID-H	11,969	6,360	55
Lower: LID-H	11,747	7,007	69

Data source: Authors' survey.

Table 8.9. Production value along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Gross value of agricultural production per unit area (yuan/ha)	Net value of agricultural production per unit area (yuan/ha)	Share of net value of agricultural production over total household income (%)
Ningxia Province			
WID-N			
Upper	11,092	6,212	40
Lower	10,763	5,267	41
QID-N			
Upper	10,118	5,281	45
Lower	9,140	4,526	54
Henan Province			
PID-H			
Upper	12,728	6,123	63
Lower	11,506	6,505	50
LID-H			
Upper	11,968	7,396	57
Lower	11,589	6,729	78

Data source: Authors' survey.

HEAD-TAIL EQUITY OF OUTPUT

Although the above analyses on agricultural production show some differences between head and tail regions, compared with the other countries, especially, the southeast Asian countries, distribution of output exihibits relatively equal characteristics. For example, the largest head-tail ratio of output occurs in the LID-H of the Henan Province for wheat; the difference is nearly 40 percent (table 8.10, column 1). On an average, the yield difference for wheat, maize and rice between head and tail regions are about 1 to nearly 20 percent. In some Southeast Asian countries, the head-tail ratio is as high as 200 percent (Intizar 2002). Relatively equal output distribution maybe due to equal land allocation.

Table 8.10. Head-tail equity ratio of output in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Head-tail equity ratio of output		
	Wheat	Maize	Paddy
Ningxia Province			
Upper: WID-N	0.95	0.75	1.23
Lower: QID-N	1.16	1.08	1.19
Henan Province			
Upper: PID-H	0.86	0.78	0.99
Lower: LID-H	0.63	1.04	1.06

Data source: Authors' survey.

WATER PRODUCTIVITY

Water is more productive in the down-reach of rivers than the up-reach. Since we know that generally farmers in the upper reaches will be allocated more water than those in the lower reaches, differences of agricultural production between up and downstream are not very large; it is not hard to understand that water productivity in the downstream is higher than that in the upstream. For example, in the LID-H of the Henan province, every cubic meter of water can produce 2.1 kg wheat, i.e, \$0.25; while in the WID-N of Ningxia Province, only 0.8 kg or \$0.09 can be produced by one cubic meter water, less than 30 percent of that in PID-H (table 8.11, columns 1 and 4). Except for wheat, water productivity for both maize and rice in the Henan Province are higher than that in the Ningxia Province (table 8.11, columns 2 and 3, 5 and 6). For example, water productivity of rice in WID-N and QID-N of the Ningxia province is only half of that in PID-H and 20 percent of that in LID-H of the Henan province. Most of the evidence along the canals in the IDs also shows that water in the lower canals is more productive than that in the upper canals (table 8.12). Differences of water productivity along river reach imply the possibility to reallocate water among regions to optimize water utilization.

Table 8.11. Water productivity along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Water productivity (kg/m^3)			Water productivity (US\$/m^3)		
	Wheat	Maize	Paddy	Wheat	Maize	Paddy

Ningxia Province						
Upper: WID-N	0.8	0.9	0.3	0.09	0.08	0.04
Lower: QID-N	1.0	1.5	0.3	0.12	0.13	0.06
Henan Province						
Upper: PID-H	1.4	2.3	0.6	0.17	0.19	0.10
Lower: LID-H	2.1	2.2	1.4	0.25	0.19	0.22

Data source: Authors' survey.

Water productivity also differs by crops which implies the necessity to optimize the cropping structure. Most cases indicate that among the three major grain crops, rice water productivity is the lowest and the differences between wheat and maize seem not large, especially, when comparing their water productivity by value (table 8.11). For example, in the IDs of Ningxia Province, per cubic meter of water can only produce 0.3 kg of rice, while water productivity for maize can be as high as 1.5 kg and wheat can reach 1 kg (table 8.11, rows 1 and 2). Although by physical standards, wheat productivity in QID-N is only nearly 70 percent of maize water productivity, difference of water productivity value between wheat and maize is less than 10 percent. Similar results also can be found in the Henan Province (table 8.11, columns 3 and 4) and in all IDs when examining data along canals (table 8.12).

Table 8.12. Water productivity along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Water productivity (kg/m^3)			Water productivity ($US\$/m^3$)		
	Wheat	Maize	Paddy	Wheat	Maize	Paddy
Ningxia Province						
WID-N						
Upper	1.0	0.9	0.3	0.11	0.08	0.04
Lower	0.5	0.9	0.3	0.06	0.08	0.04
QID-N						
Upper	0.8	1.5	0.3	0.10	0.13	0.05
Lower	1.1	1.5	0.4	0.13	0.12	0.06
Henan Province						
PID-H						
Upper	1.6	1.4	0.6	0.20	0.12	0.10
Lower	1.3	2.4	0.3	0.16	0.20	0.05
LID-H						
Upper	1.6	2.1	n.a.	0.20	0.17	n.a.
Lower	2.5	4.5	1.4	0.29	0.38	0.22

Data source: Authors' survey.

LABOR PRODUCTIVITY

Examining data shows that labor is more productive in the downstream than that in the upstream within provinces. No consistent conclusion can be got from the sample data as to which province has higher labor productivity. However, our sample data shows that in the Ningxia Province, though marginal, labor productivity in the lower reach is higher than that in the upper-reach; while it is the inverse in the Henan Province (table 8.13). For example in the Ningxia province each labor can produce 40 kg or $4.72 of wheat, which is lower by nearly 10 percent of QID-N in the lower ID (table 8.13 rows 1 and 2). Maize and rice labor productivity differences between the two Ids in the Ningxia Province is about 5%; while in the Henan Province labor is more productive in PID-H in the upper ID, than that in the lower ID, LID (table 8.13, rows 3 and 4). For example, wheat labor productivity in the PID-H is higher by more than 40 percent than that in the LID-H, labors for producing maize and rice are more productive by nearly or more than 20 percent. Most cases also demonstrate that apart from the Henan Province, farmers in the lower canals of IDs are more productive in labor input than those in the upper canals.

Table 8.13. Labor productivity along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Labor productivity (kg/labor)			Labor productivity (US$/labor)		
	Wheat	Maize	Paddy	Wheat	Maize	Paddy
Ningxia Province						
Upper: WID-N	40	38	26	4.72	3.19	4.22
Lower: QID-N	45	40	27	5.35	3.31	4.38
Henan Province						
Upper: PID-H	61	48	23	7.29	3.99	3.72
Lower: LID-H	43	41	19	5.09	3.42	3.03

Data source: Authors' survey.

Similar to land productivity, labor productivity also differs by crops and rice has the lowest physical labor productivity but not right for value of labor productivity. Rice not only consumes more water than other crops like wheat and maize, it also needs more labor input, that result in relatively low labor productivity. For example, in the WID-N of the Ningxia Province, physical labor productivity of rice is lower than wheat by nearly 40 percent, while value of labor productivity is less than 10 percent (table 8.13, row 1). Although labor productivity differences between wheat and maize seems smaller than that with rice, wheat seems to be more labor productive than maize (table 8.13, columns 1 and 2, 4 and 5). For example, in the PID-H of the Henan Province, each labor can produce 61 kg of wheat or $7.29, while it can only produce 48 kg of maize or $3.99. Further examining labor productivity along canals also reveal sinilar results (table 8.14).

Table 8.14. Labor productivity along canals in the four sample irrigation districts of Ningxia and Henan Provinces, 2001.

Location	Labor productivity (kg/labor)			Labor productivity (US$/labor)		
	Wheat	Maize	Paddy	Wheat	Maize	Paddy
Ningxia Province						

WID-N						
Upper	36	33	26	4.26	2.74	4.15
Lower	45	45	27	5.33	3.75	4.30
QID-N						
Upper	39	38	21	4.64	3.22	3.45
Lower	48	40	32	5.69	3.35	5.11
Henan Province						
PID-H						
Upper	93	26	24	11.06	2.17	3.87
Lower	43	49	15	5.15	4.07	2.39
LID-H						
Upper	51	41	n.a.	6.1	3.5	n.a.
Lower	35	34	19	4.2	2.8	3.0

Data source: Authors' survey.

MULTIVARIATE ANALYSIS

Irrigation system performance can also be econometrically analyzed by introducing the dummy variable of irrigation districts into the outcome models. In the specified econometric models of determinants of water use, production, income and poverty in chapter four, we included all the dummy variables of irrigation districts (D_k). The variable D_k measures differences of water use, production, income and poverty between IDs, implying different performances of sample irrigation districts.

Our results show that water use in the upper IDs both within and across provinces along the YRB is higher than that in the lower, which is consistent with statistic description. Compared with the base ID (WID-N), in upper Ningxia Province, coefficients of all other IDs are negative and statistically significant at 1 percent (table 10.5, rows 17 to 19). The water use differences between IDs across provinces are larger than that within provinces. For example, WID-N delivers more than 8,500 cubic meters of water per hectare than the QID-N; however, the water use difference between WID-N and IDs in the Henan Province is as high as 10,000 to 15,000 cubic meters per hectare. Similar evidence can also be found when examining water use by crop (table 10.14).

Despite the significant differences of water use among IDs, our results have not demonstrated significant differences in crop yield among IDs. Almost all the coefficients of IDs are not significant (table 10.16, rows 16 to 18). The only significant difference of yield is for wheat, i.e., wheat yield in the IDs of Henan is higher than that in WID-N. Similar to yield, we have also not found significant variations in income and poverty among IDs along the YRB, which are also consistent with our statistical description (table 10.17 to 10.22).

SUMMARY

In this chapter, based on the statistical description and econometric analysis, we assessed the irrigation system performance mainly from water and productivity aspects. Our data demonstrates increasing water scarcity over a period of time especially in the downstream regions. Water quality in the sample IDs also tend to deteriorate. IDs in the upper reach have been allocated more water than those in the lower reach, the difference is more obvious across provinces. However, distribution of output exhibits relatively equal characteristics which greatly differ from other Southeast Asian countries. As a result, water productivity in the lower IDs is obviously higher than that in the upper IDs.

CHAPTER 9

Water Rights, Allocation and Financing Issues:

Implications for the Poor

In this chapter, we have three obejctives. At first, we will examine the water rights status in China. Secondly, regulation and procedures of water allocations at the level of river basin, IDs and villags canals will be identified. Finally, variations of water pricing and water fee collection will be addressed.

WATER RIGHTS

According to China's Water Law that was decreed in 1988, water ownership belongs to the State and water rights are not associated with land rights. According to the law, all water users are required to apply for water use license from their local governments. In practice, however, this is not needed. Moreover, the licensing policy is not implemented for a variety of reasons (some of the reasons are related to water supply and others are related to water demand). In addition, according to the law, water rights are not transferable. Curiously, despite this ban, in recent years, officials have encouraged water transfer and currently it is being promoted as one of the models of reform that has potential to provide another tool to water officials who are trying to influence water use in China. In fact, one sign that the current law is outdated is the increasing pressure to pass a new water law. As a result of the outdated nature of China's Water Law and the propensity for China's localities to interpret and implement laws in their own idiosyncratic ways, we focus most of our attention on the more informal rules, norms, and institutions that affect water management.

However, despite narrowing the focus to examine institutions, it is still difficult to study them because they are changing so fast. Specifically, water institutions, like the institutions and policies in the rest of economy, are under transition (although it could be argued that liberalization of the water sector is behind that of most other sectors). Moreover, during the transition process the institutions are changing in many directions. For example, the water sector transition has been moving to a more market-oriented scheme. But the pace of transition is slow, partly because of the high transaction costs that are associated with almost every aspect of trying to move water between buyers and sellers. Looking ahead to the prospects for future liberalization, there are two growing forces that are shaping the institutional reform of water. On the one hand, there is a force for lowering transaction costs. Most of these would be consistent with an increasing emergence of the market in the water sector. On the other hand, are the externalities that are associated with water demands in which the government plays an important role.

WATER ALLOCATION IN THE YRB

Water Allocation among Provinces along the YRB

In response to increasing water use conflicts among upstream and downstream IDs and other users, China has been trying various means to deal with the problems that have been created by its open-access water resources in the YRB. Unfortunately, few of these efforts have been successful, mainly due to lack of enforcement and due to the poor systems of incentive in the earlier government programs. With increasing water shortages in the downstream regions of the YRB, in 1999, China initiated a new program called the Annual Allocation and Main River Water Quantity Control Program. With the experience and lessons learned from the past, this new program emphasizes the importance of enforcement and incentive policies to induce water authorities in the upstream regions to participate in the program and adhere to the national government's directives and their own agreements.

Under the new program, water allocated to each province in the upstream regions will be reduced gradually. The volumes to be reduced are based on the reasonable demands claimed by the provincial officials in the lower reaches of the YRB, and feasibility of being able to save water in each of the upstream provinces. After an overall water demand increase target in the lower reaches is reached, the Yellow River Commission (YRC--the organization that runs the Annual Allocation Program) starts negotiations on how much water needs to be cut in each of the upstream provinces.

According to the officials from the Ministry of Water Resource, this allocation process, a process that uses both direct administrative intervention (cuts in water in the upstream regions) and market measures (by increasing water prices in upstream areas), has been successful. Compared with the 1995 to 1998 period when water in the Yellow River did not reach the ocean (that is there was a complete cut-off of water flow at some point upstream) for an average of 126 days, since the implementation of the program, the Yellow River only stopped flowing for eight days in 1999 and none in 2000 and 2001.

However, the experience of the new Annual Allocation Program has not been without critics and there are concerns about the sustainability of the process in the long run. First, as cuts have begun and are being increased, upstream users are beginning to object. For example, compared with 1999, total water use drawing from the Yellow River reduced by 0.53 billion cubic meters in 2000. To date, the downstream regions have not had to pay compensation for the incremental units of water that they have received that were given up by upstream users. Moreover, because water sales in the upstream regions have fallen, the IDs are beginning to experience a fall in revenues. In interviews in 2001, we were told that a significant amount of maintenance would have to be delayed or cancelled because of the revenue shortfall. If such practices continue and become more severe, the entire irrigation system could suffer serious damage.

In response, upstream users have demanded that they should be allowed to raise prices for water to maintain revenues. Although initially there was some opposition by the central government, after the introduction of the YRB Water Allocation Program, water prices in the upstream were allowed to rise. For example, the Ningxia Government doubled the price of water in agriculture from 0.006 yuan/m^3 to 0.012 yuan/m^3 in 2000. With the rise in price, the water authorities have regained some of their lost revenues. However, as soon as the revenues began to be balanced, there were more cuts in water that began to cause concern for the Ningxia water officials. The concerns were increased in 2001 when officials kept water prices constant. Any visitor to Ningxia (or any other upstream province) will hear complaints about the unfair transfer of water to downstream users for which they are now receiving compensation.

In terms of the effect on the poor, the formulation of such agreements between upstream and downstream provinces may have important policy implications. In general, the re-allocations that are occurring are from poorer ones (such as Ningxia and Gansu) to richer ones (such as Shandong). Most likely, the shift of water access away from the upstream provinces will have a negative effect on some producers in the ID and (as discussed above) could adversely affect the operation of the ID itself and have an effect on the future of the effectiveness of the ID. As such, to mitigate these negative effects, central government leaders who are concerned about the equity and poverty impacts of such policies can devise compensation methods.

WATER ALLOCATION WITHIN A PROVINCE: THE CASE OF NINGXIA

Allocation among and within the main and branch canals

The issues surrounding water allocation among the provinces are similar to those among the main and branch canals within an ID. Water allocation at the main or first-level canals and the second-level canals within a province's ID are controlled by one of the following government agencies--the provincial, prefectural or county's Water Management Bureau—depending on the size and reach of the ID. By regulation, the general principle for water allocation is to give first priority to those downstream, lift irrigation (vs. gravity irrigation), give priority to the canal's high offlets (versus the lower offlets), to agriculture (versus forestry), to more vulnerable groups, and large consolidated tracts of land (versus fragmented land).

Hence, while water allocation regulations in Ningxia Province fully acknowledge the primacy of efficiency, they still attempt to encourage equity at the same time. Unfortunately, due to lack of data, we cannot conduct a systematic assessment on the implementation of allocation regulations. However, based on our field interviews and certain parts of our data from our survey, we can provide partial and fragmentary evidence on the actual implementation of the water allocation principles to see which ones are pursued and which ones are relatively ignored.

The basic water allocation rule is to allocate water by comprehensively considering water volume, canal capacity, water quota and water delivery efficiency while abiding with the allocation principles. Among all these issues, water quota is one of the important indices to guide the water allocation practices. In China a water quota is an engineering standard developed by the water conservancy bureau that indicates the amount of water that is needed by crops. The water quota differs by crop type, the availability of water supply, a surface water system's water delivery efficiency, location in the canal, rainfall, climate, soil, and other local characteristics that influence the crop water demand. The purpose of the water quota is to provide IDs with a way to allocate water and limit the overuse of an area's water resources.

Although the quota-based water allocation rules have been designed so that all areas should be able to irrigate their crops with the volume of water specified by the quota, some areas exceed their quotas. For example, the average quota in the WID-N is only 1.1 times that in the QID-N (table 9.1). The actual water use in WID-N is 1.8 times that in QID-N (table 9.1). To the extent that areas that exceed their quotas are being allowed to by ID officials, the pattern of water distribution may indicate that the upstream ID, WID-N, has priority in its water allocation over the downstream ID, QID-N. Moreover, the ability to obtain water above the quota may have a large impact on a region's cropping structure. For example, due to the prioritization in water allocation, farmers in the WID-N can plant more rice (because rice demands more water - table 9.1) in its rice area than the farmers in the QID-N (table 9.2).

Table 9.1. Irrigation water quota in the Ningxia Province, 2001.

Irrigation District / County	Water quota (m^3/ha)					
	Paddy			Dry crops		
	>333 ha	67-333 ha	<67 ha	>333 ha	67-333 ha	<67 ha
WID-N						
Zhongwei (upper)	31,500	30,000	28,500	11,250	10,500	9,750
Zhongning (lower)	31,500	30,000	28,500	11,250	10,500	9,750
QID-N						
Qingtongxia (upper)	33,000	31,500	30,000	12,000	11,250	10,500
Helan (middle)	28,500	27,000	25,500	10,500	9,750	9,000
Pingluo (lower)	27,000	25,500	24,000	9,750	9,000	8,250

Data source: Ningxia Water Resources Bureau (2001).

Unlike the differences that occur in the execution of water allocation regulations among IDs, in some cases water managers allocate water more evenly among upstream and downstream areas within IDs. For example, within the WID-N, the lower reaches actually use more water than the upper reaches of the ID (table 8.5). In this case, the allocation of water across regions within an ID occurs even though there is no difference in the water quotas between the upper and lower regions (table 9.1). One reason for the observed pattern may be that officials have implemented the provincial's regulation that downstream water has priority.

However, officials do not always implement all of the regulations. For example, the actual water use in the upstream region of the QID-N is more than 1.7 times that in the downstream region (table 8.5). The water quota in this region is even less than this number (1.2 times--table 9.1). This indicates that unlike the WID-N, officials in the QID-N do not implement the provincial water allocation regulations; instead upstream farmers obtain more water over their allocation quotas and this results in a larger share of rice area being in the upper region (table 9.2).

Table 9.2. Cropping patterns in the four sample irrigation districts, Ningxia and Henan Provinces, 2001.

Irrigation District	Share of sown area (%)		
	Wheat	Rice	Maize
WID-N	25	27	24
Upper	22	27	21
Lower	29	27	28
QID-N	37	19	34
Upper	35	23	37
Lower	38	17	32
PID-H	48	21	18
Upper	48	50	1
Lower	49	4	29
LID-H	50	12	10
Upper	52	0	21
Lower	49	21	3

Data source: See table 5.

The above analysis shows that the implementation effects of water allocation regulations in the Ningxia province are complicated; some regions implement the allocation rules as they are written while most regions do not. To the extent that poorer people live in the downstream areas of the ID, there is mixed evidence that official regulations are promoting poverty alleviation. The official regulations certainly read as if officials are supposed to send more water to downstream regions and give priority to vulnerable groups, such as the poor. The record in our regions, however, is mixed. Officials in one area follow the downstream first rule; those in other areas do not. There is no evidence, on a district-wide scale, except, that water officials purposely give priority to the poor.

Allocation among and within the tertiary canals (within the village)

At the tertiary canal level, local water managers are responsible for water allocation. In the following sections we will more systematically examine the equity and poverty implications of the different water management forms. Our field survey found various allocation rules that managers used in the course of their water allocation duties. During our survey, we identified four kinds of water allocation approaches: equity, efficiency, payment capacity, and no-rule allocations. The way in which each village decides to allocate water most likely has evolved due to a complex set of characteristics of the village, the nature of its water resources and the local cropping patterns. Explaining why a certain village allocates water in a certain way is beyond the scope of this report. Instead, what we are able to do is to describe the fundamental characteristics of the allocation rules and examine how many villages have adopted different approaches.

Equity allocation means that water resources equally allocated to all water users along the canal. The implication of such a rule is that it allows the poor and other vulnerable groups to get access to water. In practice, rules are often promulgated to provide water to those farmers at the end of the canals first, and those nearest last. In our sample, we find that 13 percent of villages use this method of water allocation.

In contrast, the efficiency criteria are adopted in other villages. According to these criteria, village water managers irrigate as water flows into the canal. When the nearest fields are irrigated first, it is physically the most efficient way to allocate water. Interestingly, despite the emphasis of IDs on equity, a much greater number of villages (70%) claim they use the efficiency method of water allocation.

Finally, some villages use other methods. According to the first come/first served method, villages are supposed to provide water to those that ask for it first. We find no villages operate this way. However, there are small number of villages that provide water on a first pay/first served basis. This happens, according to our survey, in only 2 percent of the villages. In the rest of the villages, there are no established rules.

AGRICULTURAL WATER PRICING

Despite continuously increasing water prices over the past several decades, China's agricultural water is believed to be much under-priced (Liu 1997; Wang 1997). In 1997, the national O&M cost recovery rate of agricultural water was only 28 percent, while the number for industry water and urban domestic water was over 100 percent (Ministry of Water Resources 2002).[21] Although increases in water prices must certainly reflect the rising scarcity of water over time, the current level of prices in most agricultural areas cover only a part of the cost of the O&M of China's irrigation systems (Ministry of Water Resources 2002). There is also reason to believe that the price of water is far below its shadow price, or actual value (Ministry of Water Resources 2002). Across regions, water prices vary substantially. For example, in 1997, agricultural water price was 0.015 yuan/m^3 only in Zhejiang province, one of the richest provinces in water resource, while it reached 0.075 yuan/m^3 in the most water-scarce province – Hebei (Ministry of Water Resources 2002).

[21] The O&M cost recovery rate is the ratio of water price (yuan/m^3) over the water supply cost (yuan/m^3).

These variations in water prices across space arise for a variety of reasons. Unlike agricultural commodity prices that are increasingly determined by integrated national markets, the price of water, which is almost always too costly to transport outside the immediate locality, frequently depends on local supply and demand conditions. Moreover, instead of establishing water prices for each province, the central government provides general guidelines for the local price bureaus and water authorities, the two agencies that are most frequently authorized to set the price of surface water.

Water prices also vary considerably among sectors. In the same location, the difference in water prices for agriculture and industry could be several-fold. In general, reflecting the high value of water in non-agriculture and the reluctance of the government to raise prices in the agricultural sector that has a population that is by far poorer than those in the cities, China's water prices generally increase as water moves from agriculture to industry and from rural to urban. For example, in 1997, the average price of water in industry was 4.7 times that in agriculture and 3.8 times that in domestic use. In this way, government policy can be seen to be subsidizing the agricultural population, which by itself can be thought of as a pro-poor policy.

Although the above facts are not new, beyond this little is known about how prices are determined locally and what their impact may be on the poor. Hence, in the rest of this section, we discuss agricultural water pricing in our study areas. Given the complex nature of water pricing in China, changes in water price policies in our study area may reflect some common trends in the rest of China, but it should be noted that such generalizations should be made with caution since China is a relatively decentralized place.

WATER PRICING STRUCTURE IN NINGXIA AND HENAN PROVINCES

Measuring water use is a universal problem in all countries. More difficulty is encountered when the users are millions of small farmers. Early in the 1980s, in order to improve the water use efficiency, China's Government had begun to encourage local governments to adopt the volumetric water pricing approaches (Ministry of Water Resources 2002). However, due to high transaction costs and rigorous requirement of the measurement facilities, this policy has not been implemented in most provinces, especially at the farm-gate.

With the inherent difficulties involved with pricing water volumetrically, a number of ways have emerged in the Yellow River Basin to price agricultural water. At the farm level, water is most frequently priced on the basis of total area irrigated. In our sample, 79 percent of the villages have their farmers pay for their surface water on this basis. Although there is no distinction made between the type of crop grown on the plot at the farm level, since the water fee is calculated by the mix of the volumetric water fee and fixed water fee in the Ningxia Province; the per land unit water fee of the villages in Ningxia Province is higher for water-using crops, such as rice, due to higher volumetric water fee for rice than for dry crops (table 9.3). In a few villages a number of other price rules are used, such as a water fee based on the number people in the household (13% of the villages), the amount of time it took to irrigate (12% of the villages).[22]

Table 9.3. Water prices in gravity irrigation systems in Ningxia Province, 1981 to 2000.

Year	In current prices			In real prices (2000 prices)		
	Volumetric price (yuan/m^3)		Basic fee (yuan/ha)	Volumetric price (yuan/m^3)		Basic fee (yuan/ha)
	Within quota	Over 30% quota		Within quota	Over 30% quota	
1981	0.0005	\	15	0.002	\	56.4
1983	0.001	na	15	0.004	na	54.2
1989	0.002	na	21	0.004	na	41.7
1994	0.006	0.010	37.5	0.008	0.013	47.5
2000	0.012	0.017	60	0.012	0.017	60.0

Note: na = not available.
Data source: Ningxia Water Resources Bureau (2000).

The policy has had more effect at the point where water is transferred from the ID to the village. For example, since 1983, in both the Ningxia IDs, officials implemented a volumetric water-pricing policy and set up a two-tier water pricing system. The first part is volumetric water price measured at outlets of the main or branch canals and is set at a level that is supposed to cover the variable costs associated with the supply of water. The second part, the basic water fee, is set at a level that is equal to the value of the labor required for canal maintenance. The first part of water fee is mainly used to cover the salaries of the ID staff and for other expenses associated with the operation and maintenance of the main and branch canals; the second part is mainly used to pay the wages of those hired to maintain the canals.

When setting water fees before 2000, Ningxia provincial level officials did not include a part to cover the maintenance of the system's tertiary canals. At that time tertiary canal O&M expenditure mainly came from the budgetary allocations of local governments and from the water fees collected by the leaders of the collectives directly from the farmers. However, this part of the maintenance fees depended on the financial strength of local governments. In the case of many poor areas that were chronically in deficit, such work was often delayed or completely ignored. As a result, the maintenance of canals has not always performed well.

In 2000, however, the structure of water pricing was changed to address the problem of China's deteriorating infrastructure, especially in tertiary canals. To do so, officials allowed local government officials to raise the basic water fee to include an additional part. However, limits were placed on the magnitude of the fee increase. Water maintenance and management fees could not exceed 90 yuan per hectare. The County Water Resources Bureaus got to keep 40 percent of the new fee; the Township Water Management Stations got to keep the other 60 percent. The

[22] Mainly for pump irrigation.

collection of the additional fees was designed not only to improve the O&M of the tertiary canals (from that part collected by the township water management station), but also was supposed to be used to promote water management reforms that were scheduled to be implemented in 2001.

Based on table 9.1, we calculated the average water quota for rice and dry crops in Ningxia, as 29,000 m^3 and 10,250 m^3 per hectare, respectively. Assuming that each year's water quota is same, we transferred the volumetric price into the per hectare water fee. Based on this calculation, we found that the share of rice volumetric water fee over the total water fee increased from 49 percent in 1981 to 70 percent in 2000, the number for the dry crops was from 25 percent to 45 percent in the same year. The increasing share of the volumetric water pricing implies that volumetric water pricing has become a more and more important economic instrument in adjusting water use behaviors. Applying water pricing incentive mechanism to realize the water saving objective has been an important water policy in the Ningxia Province, especially after 2000.

In order to reduce waste of water resources, Ningxia provincial officials have also gradually adopted a progressively priced water pricing structure since 1983. Under this system, when water is used in excess of a certain amount for a certain type of crop or in a certain area, a higher price in charged for the water used in excess of the standard. Initially, however, the use of progressive pricing was scattered and not implemented regularly. In 1994, however, a series of policy measures clarified the policy and the government began to encourage its use. Regulations stipulated that if water use exceeded the quota by more than 30 percent, the volumetric water price would increase by 67 percent, from 0.006 yuan/m^3 to 0.01 yuan/m^3. Encouraged by the results, in 2000, the gap between the quota and above-quota price increased from 0.004 to 0.005 (although since both the quota and above quota prices were raised to 0.012 yuan/m^3 and 0.017 yuan/m^3, the relative price of the above-quota prices fell to 42% (table 9.4).

Table 9.4. Water fees measured on a per land unit basis (yuan/ha) in the Liuyuankou Irrigation District, Henan Province, 1983 to 2000.

Year	In current prices		In real prices (2000 prices)	
	Paddy	Dry crop	Paddy	Dry crop
1983	75	30	271	108
1987	120	75	334	209
1990	135	90	257	171
1995	270	150	291	162
2000	330	180	330	180

Data source: Management Agency of the Liuyuankou Irrigation District (2000).

In contrast with the relatively complex water pricing structure in the Ningxia province, water prices in Henan are set on the basis of a relatively simple formula. In the LID-H, for example, the price is only based on the cropped cultivated area. Part of the reason for relying on such a simple pricing structure may be related to the lack of means to measure water volumetrically. Moreover, the sandy soil that is common in the ID compounds the difficulties in making accurate measurements. Another reason may be that since the Henan Province is located in the downstream part of the YRB, the government is putting less pressure on them to save water to be freed up for the provinces in the lower reaches.

The division of the water fees in Henan by the agencies that use the funds for funding the various water-related services is just as complicated as in Ningxia. Since one of the Henan IDs, LID-H, is directly managed by the county water resources bureau, the water fees are divided among the township government, county water resources bureau, and upper level government. In 2000, after being collected by the village and remitted to the township, 30 percent of the water fees was retained by the township government to be used for supporting the maintenance of facilities and staff salaries. The other 70 percent is submitted by the township to the county water resources bureau. Of the amount sent to the county, 4 percent is used for providing bonuses to township irrigation staff if they meet irrigation fee collection; 50 percent is paid to the YRB commission as a Yellow River water resources fee; 15 percent is used for the provincial and municipal price differences (since the water fee in the LID-H is lower than that at the provincial and municipal levels); and 31 percent is used for the O&M of the system. Although the share of fees that is used for maintenance of the tertiary canals, (which belong to the township government), is much the same as in Ningxia prior to 2000. Local governments facing chronic budget shortfalls tend to shirk on their maintenance work. When shrinking government investment is combined with relatively low prices and lack of progressive pricing, the system produces a low O&M cost recovery rate (19%).

OVER TIME AND CROSS VARIATION OF WATER PRICE IN NINGXIA AND LID-H

As policies towards prices vary both over time and across provinces, water charges also vary considerably across time and space (table 9.5). Prices in both Ningxia and Henan have risen over time. Most notably, the upward trend in prices has accelerated since the 1990s, a reflection of the fact that policies have encouraged higher water prices during the 1990s. Clearly, as leaders have begun to understand better markets and farmer response to price signals, their willingness to raise prices to encourage the more efficient use of water has risen.

Water prices also vary across IDs for a number of reasons, the greatest being due to variation in cropping patterns (table 9.2). For example, water fees differ between the upper and lower reaches of IDs within provinces and among provinces. In particular, water fees are higher in the upper reaches than those in the lower reaches. Most likely these fee differences are due to cropping pattern differences. Among our 4 IDs, our data shows that the share of rice area is higher in the upper reach than in the lower reach. Since the price of water for rice is higher than that of the dry crops, it is not hard to understand why water fees are higher in the upstream areas.

Table 9.5. Water fees (yuan/ha) in the four sample irrigation districts, Ningxia and Henan Provinces, 1990 to 2001.

	Irrigation district			
	WID-N	QID-N	PID-H	LID-H
In current prices				
1990	240	202	212	135
1995	428	300	253	164
2001	556	489	279	212
In real 2001 prices				
1990	460	386	405	259
1995	465	325	275	178
2001	556	489	279	212

Data source: Authors' survey.

WATER FEE COLLECTION

One of the major problems facing water management in China's villages is the difficulty of collecting water fees. Based on our field survey, for most collectives, nearly 20 percent of water fees cannot be collected. Especially as tax and fee collection regulations have become more common and stricter (in essence, limiting the amount and way that village leaders collect fees from farmers), collecting water fee has become an increasing burden on village leaders, especially when they manage water collectively. Although we do not have data to show this, conversations with farmers and leaders show that the problem is complicated. From the farmers' point of view, their unwillingness to pay stems from the poor services that they believe they have received. From the village leader's point of view since they face few incentives and since farmers are frequently reluctant to pay for water (at least without a great amount of effort on their part), they feel that farmers do not deserve any special service.

Moreover, the lack of ability to collect fees on time sometimes becomes a long-term problem that creates problems in subsequent periods and further complicates water management. When farmers do not pay, in order to meet the village's obligation to the ID (which is required if the village wants to get water deliveries in the next period), some villages draw on their general funds, borrow from local enterprises or individuals or have to take a loan from the bank or local rural credit cooperative. To service the interest on the loan, however, leaders frequently must add the interest payments onto the farmer's water charge, an action that invariably leads to higher water fees and more complaints by farmers. In some cases, in which the villages have not paid the ID in a timely manner, the ID cuts water deliveries or at least gives the village less water or less timely service.

Given the pervasiveness and magnitude of the problem, water management reform is often triggered by the fee collection difficulties. It is thought that compared with collective water management, the contracting and the Water Users Association (WUA) institutions facilitate the problem of fee collection. However our field data indicate that the WUA only collects a slightly higher percentage than the collective. Contracting water managers, in contrast, collect all but six percent.

Although our research team needs to do more rigorous research before anything definitively can be proved, we believe that alternative water organizations facilitate water fee collection for two reasons. First, as part of the new water management package, water fees are frequently reduced, which almost certainly contributes to easier fee collection. Likewise, to the extent that water management is improved, fees will also be easier to collect. Most poignantly, however, one of the most important reasons for better fee collection is that when private individuals have their compensation based on fee collection, there is more effort that is put into this task. Moreover, when private individuals deliver services, the entitlement to access to service weakens. In other words, farmers may believe that village leaders in their role as collective heads, would never cut delivery of a critical service, such as water for the crops. In our field survey only 5 percent of villages adopted such an approach to deal with this issue. Private water managers, however, have less of an incentive to keep delivering water, should a farmer not pay. Our field survey indicates that 14 percent of WUAs and 9 percent of contractors would like to cut the farmers' water delivery if farmers cannot pay the water fee. Therefore, evidence show that the private managers tend to adopt some strict measures to constrain farmers' water fee behaviors.

SUMMARY

Water rights, allocation and pricing issues are major concerns of this chapter. In China, water ownership belongs to the State and water rights are not associated with land rights. In response to increasing water use conflicts among upstream and downstream IDs and other users, China has been trying various means to deal with the problems that have been created by its open-access water resources in the YRB. Faced with increasing water scarcity, policy makers intend to adopt measures combining both direct administrative intervention (cuts in water in the upstream regions) and market measures (by increasing water prices in upstream areas).

The issues surrounding water allocation among the provinces are similar to those among the main and branch canals within an ID. The basic water allocation rule is to allocate water by comprehensively considering water volume, canal capacity, water quota and water delivery efficiency while abiding with the allocation principles. Although the quota-based water allocation rules have been designed so that all areas should be able to irrigate their crops with the volume of water specified by the quota, some areas exceed their quotas. At the tertiary canal level, local water managers are responsible for water allocation. Our field survey found various allocation rules that managers used in the course of their water allocation duties. During our survey, we identified four kinds of water allocation approaches: equity, efficiency, payment capacity, and no-rule allocations.

Despite continuously increasing water prices over the past several decades, China's agricultural water is believed to be much under-priced. Water prices vary considerably among sectors and over time. With the inherent difficulties involved in pricing water volumetrically, a number of ways have emerged in the Yellow River Basin to price agricultural water. Given the pervasiveness and magnitude of the problem, water management reform is often triggered by the fee-collection difficulties.

CHAPTER 10

Water Management Reforms: Implications for the Poor

In this chapter, we have three purposes.[23] First, we track the evolution of water management reforms and seek to identify the incentive mechanisms that encourage water managers to more efficiently use water. Second, we identify the impact of water management reforms on crop water use, the primary motivation of the policy. Finally, the paper explores how changes in China's water management institutions also affect agricultural production, farmer income and poverty.

REFORM AND THE EVOLUTION OF WATER MANAGEMENT

Based on our field surveys, after upper-level officials began implementing the reforms, surface water is managed in three ways. If the village leadership through the village committee directly takes responsibility for water allocation, canal operation and maintenance (O&M) and fee collection, the village's irrigation system is said to be run by 'collective management', the system that essentially has allocated water in most of China's villages during the People's Republic period. A WUA is theoretically a farmer-based, participatory organization that is set up to manage the village's irrigation water. In WUAs a member-elected board is supposed to be assigned the control rights over the village's water. 'Contracting' is a system in which the village leadership establishes a contract with an individual to manage the village's water.

According to our data, since the early 1990s and especially after 1995, reform has successively established WUAs and contracting in the place of collective management (table 10.1). The share of collective management declined from 91 percent in 1990 to 64 percent in 2001 (table 10.1, column 5). Across our sample, contracting has developed more rapidly than WUAs. By 2001, 22 percent of villages managed their water under contracting and 14 percent through WUAs. Assuming that the results from our sample reflect the more general trends across north China, the somewhat more rapid emergence of contracting may be due to the ease of setting the system up and the similarities of the reforms to the other reforms that have unfolded in rural China (Nyberg and Rozelle 1999).[24]

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[23] Data applied in this chapter are from 51 villages instead of 56 villages; since there is no surface water irrigation in the other 5 villages we dropped them. Finally, data from 51 villages, 189 households and 378 plots have been used in this section's analysis.

[24] During China's economic reforms, many government services have been contracted out to private individuals, including grain procurement, extension and health services.

Table 10.1. Surface water management in the sample villages of the four selected irrigation districts, Ningxia and Henan Provinces, 1990 – 2001.

	Ningxia		Henan		Total
	WID-N	QID-N	PID-H	LID-H	
1990			(percent)		
Collective	100	81	100	100	91
WUA	0	5	0	0	3
Contracting	0	14	0	0	6
1995					
Collective	100	72	100	100	87
WUA	0	10	0	0	6
Contracting	0	18	0	0	7
2001					
Collective	27	51	92	100	64
WUA	50	14	0	0	14
Contracting	23	35	8	0	22

Data source: Authors' survey.

While there has been a shift from collective management to WUAs and contracting during the past 5 years, water management reform still varies across the four sample IDs. WUAs and contracting have developed more rapidly in Ningxia than in Henan (table 10.1). For example, in 1995, the collective ran 100 percent of the water management institutions in one of Ningxia IDs (WID-N) (table 10.1, column 1). By 2001, however, the collective managed water in only 27 percent of the sample villages. WUAs managed water for about 23 percent of the villages and contracting managed water in approximately 50 percent. In Ningxia's other sample ID (QID-N), the share of villages under WUAs and contracting approached 49 percent, almost the same as those under collective management (table 10.1, column 2). In contrast, significantly less reform occurred in Henan. Only eight percent of the villages in one of the sample IDs (PID-H) and none in the other (LID-H) have moved to either contracting or WUAs (table 10.1, columns 3 and 4).

Based on our field survey, although some of the differences in water management among the IDs may be due to the characteristics of local villages and local water management initiatives, the dramatic differences between Ningxia and Henan Provinces suggest that upper-level government policy may be playing an important role. In 2000, in order to promote water management reform, Ningxia provincial water officials issued several documents that encouraged localities to proceed with water management reform (Wang 2002). Regional water officials exerted considerable effort to promote water management reform in a number of experimental areas. The sharp shift away from collective management is consistent with the interpretation that these measures were effective in pushing (or at least relaxed the constraints that were holding back) reform.

The differences among the villages in Ningxia and variations in the way that different regions implemented the reforms (i.e., some moved to contracting while others shifted to WUAs), however, show that the reforms are far from universal. In fact, this is what would be expected in China, a nation that often allows local governments considerable room in making their own decisions on the exact form and timing of institutional changes (Jin, Qian and Weingast 2000). In contrast, neither the Henan provincial government nor any of the prefectural governments have issued directives mandating reforms.

VARIATION IN GOVERNANCE OF VARIOUS WATER MANAGEMENT FORMS

While the shift in China's water management institutions demonstrate that the nation's communities are following policy directives that are being developed and issued from upper-level governments, when local leaders set up their organizational frameworks in their villages, practice often varies from theory. For example, in practice, at least in the early stages of the development of WUAs (the only stage of the organizations that we are observing since this type of management is so new), the organization of most WUAs varies sharply from theory. In most cases (70% of the WUAs), the governing board of the WUA was the village leadership itself. In a minority share of the cases (30% of the WUAs), village leaders appointed a chair or manager to carry out the day-to-day duties of the WUAs. In many of these WUAs that had village-appointed leaders, however, the manager actually had close ties with the village leadership, more than half being a leader in an earlier time period. In other words, at least in terms of the composition of the management team, most WUAs differ little from collective management.

An examination of the way managers are compensated perhaps shows the greatest difference between theory and practice. To show this, however, we need to understand the way farmers pay fees, managers are compensated and how IDs are paid. In fact, water management reform has created a complicated system of fees, payments and charges that embody the primary incentives for the managers to save water. Water fees collected from farmers include two parts: basic water fees associated with the fixed quantity of land in the village and volumetric water fees associated with the volume of water use. Set by water bureau officials, the farmer is required to pay the basic water fee (which is based on his land holdings) and part of the basic water fee belongs to the water manager after it is collected. This part of the manager's compensation is paid to him as a fixed payment and provides little or no direct incentives to save water.[25]

Upper-level officials, however, can use the other part of the water fee to provide managers with more direct incentives. Prior to the farming year, ID officials determine (on the basis of historic use patterns and other criteria) a targeted amount of water that a village should use (called the target quantity). Based on a per cubic meter charge, the total value of the expected water use

[25] Once the manager collects that total fee from the farmer, he turns the basic fee part to the village accountant who in turn sends it to the township that is supposed to use the funds to maintain the township's canal infrastructure.

for the village is then divided by the village's total quantity of land and this volumetric water fee is added to the basic water fee to create the farmer's total water fee. As can be seen, the volumetric water fee also provides the farmer no incentives to save water since he pays a fixed fee for each hectare of land. The water manager in some communities, in contrast, does have an incentive. In implementing water management reform ID officials agree that the water manager only has to pay the per cubic meter charge for the water that is actually used (actual quantity). If the actual quantity of water delivered to the village (at the request of the water manager) is less than the targeted quantity, the difference between the volumetric fee that is collected from the farmers and that which he pays for the water is his excess profit. The excess profit is an amount that is earned by the manager beyond the fixed payment.

According to our data, there are sharp differences in the way that villages have implemented the incentives part of the reform packages, regardless of whether they are WUAs or contracting (table 10.2). For example, in 2001, on an average, leaders in only 41 percent of villages offered WUA and contracting (or non-collective) managers with incentives that could be expected to induce managers to exert efforts to save water in order to earn an excess profit (table 10.2, row 1). In the rest of the villages, although there was a nominal shift in the institution type (that is leaders claimed that they were implementing WUAs or contracting), in fact, from an incentives point of view, the WUA and contracting managers faced no incentives (table 10.2, row 1). In these villages, water managers are like village leaders in a collectively managed system, in that, they do not have a financial incentive to save water. The incentives offered to the managers also differed across IDs (table 10.2, rows 2 to 6). Hence, to the extent that the incentives are the most important part of the reform, the differences across time and space mean that it would not be surprising if in some villages WUAs and contracting were more effective at saving water than in other villages.

Table 10.2. Incentives mechanism of WUAs and contracting in the sample irrigation districts, 2001.

	Percentage of samples (%)		
	With incentives	Without incentives	Total
Whole samples			
WUA and Contracting	41	59	100
Ningxia Province			
WID-N			
WUA	25	75	100
Contracting	0	100	100
QID-N			
WUA	25	75	100
Contracting	76	24	100
Henan Province			
PID-H			
Contracting	0	100	100

Data source: Authors' survey.

WATER MANAGEMENT AND CROP WATER USE

Statistic Description

Although the major objective of water management reform is to save water, descriptive statistics using our data show that water use in some areas that have established WUAs and contracting is lower than those areas still under collective management, and higher in others (table 10.3). For example, in the QID-N in Ningxia (ID2), the water use per hectare in areas that have reformed (WUAs and contracting) is lower than those areas in which the collective still manages the water (table 10.3, rows 5 and 6 versus row 4). However, in Ningxia's other ID (WID-N) and in Henan, water use per hectare is higher in those villages that have shifted to WUAs or contracting (table 10.3, rows 1 to 3; 7 and 8).

Table 10.3. Relationship between surface water management and crop water use in the four sample irrigation districts, Ningxia and Henan Provinces, 2001.

		Water use (m^3/ha)
Ningxia Province		
WID-N		
	Collective	21,924
	WUA	23,460
	Contracting	30,969
QID-N		
	Collective	16,549
	WUA	15,483
	Contracting	11,351
Henan Province		
PID-H		
	Collective	13,052
	Contracting	17,113
LID-H		
	Collective	8,450

Data source: Authors' survey.

While the effectiveness of changing from collective to non-collective management in terms of water saving is not clear, our data shows the importance of policy implemention. In particular, the importance of incentives in making the reforms work is shown when comparing water use in those villages that provide their water managers with incentives as against those that do not (table 10.4). After reform, when managers face incentives to earn profits by saving water, water use per hectare fell by nearly 10 percent when compared to collectively managed systems across our Ningxia sample (table 10.4, row 1, columns 1 and 3). In contrast, when leaders implement water management reform without providing incentives, water use rises (table 10.4, column 2). When examining the individual IDs in Ningxia, we also find that in both cases water use falls more (or does not rise as much) when incentives are provided during reform than when they are not. In QID-N, for example, water use falls in both non-collective systems with and without incentives, but it falls further for those with incentives (table 10.4, row 3). In WID-N, although water use in both the non-collective systems rises, it rises less for those with incentives (table 10.4, row 2). We also find that the same patterns occur when examining individual crops (table 10.4, rows 4 to 6).

Table 10.4. Relationship between incentive mechanism and crop water use in the sample irrigation districts of Ningxia Province, 2001.

	Crop water use (m^3/ha)		
	Non-collective with incentives	Non-collective without incentives	Collective
Ningxia Province			
Whole samples	12,729	20,598	14,003
WID-N	25,055	26,583	21,924
QID-N	11,188	14,711	16,549
Wheat	5,619	7,416	7,489
Maize	7,004	7,704	7,266
Paddy	31,307	31,688	36,949

Data source: Author's survey.

While our descriptive analysis shows that there is a positive correlation between incentives and water savings, in fact, there can be many other factors that are correlated with incentives that are creating the tendency of incentives and water savings to move together. In particular, it can be that cropping structure, the nature of the canal system's investment and the scarcity of water may affect the managerial type, the way that reforms are implemented and water use. As a result, multivariate analysis is required to analyze the relationship between water management reform and water use and other outcomes.

MULTIVARIATE EMPIRICAL MODEL AND RESULTS

Based on the above discussion, the link between water use per hectare and its determinants can be represented by the following equation:

$$w_{jk} = \alpha + \beta M_k + \gamma Z_{jk} + D_{jk} + \varepsilon_{jk} \qquad \text{(equation 10.1)}$$

where w_{jk} represents average water use per hectare for household j in village k. The rest of the variables are those that explain water use: M_k, our variable of interest, measures either the type of the water management institution or the nature of the incentives faced by the water manager; Z_{jk}, a matrix of control variables, represents other village and household factors that affect water use. Specifically, we include a number of variables to hold constant the nature of the village's production environment and its cropping structure. We include variables such as the source of water (either surface or ground), the degree of water scarcity and the level of irrigation investment per hectare to measure the production environment. Cropping structure is measured as the proportion of the village's sown area that is in rice. Household characteristics include age and education of the household head and land endowment. Finally, our model also includes D_{jk}, a dummy variable representing the ID that serves the household. The symbols α, β, and γ are parameters to be estimated and ε_{jk} is the error term that is assumed to be uncorrelated with the other explanatory variables in our initial equations, an assumption that we subsequently relax.

Our empirical estimation performs well for our water use model (table 10.5). The goodness of fit measure, the adjusted R^2, around 0.45, is sufficiently high for analyses that use cross-sectional household data. Many coefficients on our control variables have the expected signs and are statistically significant. For example, we find that after holding constant other factors, households that are in villages with more rice area use more water per hectare than other crops. We also find that those villages that face more severe water shortages use less water per hectare.

Table 10.5. Determinants of crop water use at the household level.

	Water use per hectare				
	OLS	2SLS	OLS	2SLS	OLS
Share of WUA	-1,311.036 (0.70)	-1,919.847 (1.00)			
Share of contracting	-703.677 (0.49)	-2,468.590 (1.34)			
Share of non-collective with incentives			-2,843.730 (1.72)*	-6,355.798 (1.99)**	
Share of non-collective without incentives			275.206 (0.18)	1,107.587 (0.43)	
Share of WUA with incentives					-1,437.970 (0.36)
Share of WUA without incentives					-1,183.625 (0.62)
Share of contracting with incentives					-3,136.275 (1.74)*
Share of contracting without incentives					1,996.519 (1.06)
Share of surface water irrigation in the village	2,390.651 (0.99)	2,560.447 (1.08)	2,141.794 (0.90)	2,494.746 (1.06)	1,661.746 (0.69)
Dummy of village water scarcity	-3,574.071 (3.13)***	-3,463.464 (3.03)***	-3,811.787 (3.34)***	-3,533.920 (3.13)***	-3,872.363 (3.38)***
Irrigation investment per hectare in the village	-0.107 (1.01)	-0.114 (1.11)	-0.055 (0.52)	0.032 (0.23)	-0.104 (0.66)
Share of village paddy area in 1995	10,592.172 (4.18)***	10,655.043 (4.23)***	10,430.425 (4.17)***	10,437.281 (4.18)***	10,017.102 (3.92)***
Age of household head	519.380 (1.17)	551.829 (1.25)	447.423 (1.02)	517.174 (1.18)	424.895 (0.96)
Squared age of household head	-6.282 (1.28)	-6.705 (1.37)	-5.610 (1.15)	-6.296 (1.29)	-5.230 (1.07)
Education of household head	-81.947 (0.50)	-79.195 (0.48)	-78.691 (0.48)	-58.589 (0.36)	-62.044 (0.38)
Arable land per hectare of household	-10,486.693 (2.23)**	-8,964.478 (1.89)*	-7,920.360 (1.64)	-6,326.932 (1.26)	-7,574.179 (1.56)
QID-N	-9,888.333 (6.50)***	-9,968.427 (6.69)***	-8,921.639 (5.97)***	-8,512.471 (4.90)***	-8,886.488 (5.66)***
PID-H	-11,151.005 (4.94)***	-11,587.766 (5.12)***	-10,468.396 (4.81)***	-10,214.118 (4.19)***	-10,914.394 (4.87)***
LID-H	-15,752.440 (5.68)***	-16,105.004 (5.82)***	-15,126.321 (5.60)***	-14,819.640 (5.12)***	-15,523.975 (5.64)***
Constant	14,261.399 (1.43)	13,821.536 (1.39)	15,130.403 (1.53)	12,514.529 (1.27)	15,861.024 (1.59)
Observations	189	189	189	189	189
Adjusted R-squared	0.44	0.45	0.45	0.45	0.45

Absolute value of t statistics in parentheses

* significant at 10% ** significant at 5% *** significant at 1%

After holding constant other factors, our results show that the mere fact of shifting management from the collective to either a WUA system or contracting by itself does not lead to water savings (table 10.5, column 1). In fact, the signs on the coefficients of the WUA and contracting variables are negative, suggesting that water use is lower in villages that have moved to non-collective management (table 10.5, rows 1 and 2). However, the standard errors are all large relative to the magnitude of the coefficients, which implies that nominal institutional reform has no significant impact on saving water.

When officials provide water managers with incentives, regardless of whether they shifted to WUA or contract management, managers appear to reduce water deliveries in the village (table 10.5, column 2). Econometric results show that the coefficient on the incentive indicator variable is negative and significant (although only at the 10% level), when compared to the collective management, the omitted institutional type (table 10.5, row 3). In other words, without regard to the form of the water management institution, if managers face positive incentives, water use per hectare can be reduced by nearly 3,000 cubic meters, about 20 percent of their typical water use. Significant incentive can also be found when examining water management type separately (table 10.5, column 5)

Although interesting, it is possible that the estimated parameter is biased since water use per hectare and water management may be determined simultaneously with water use or that the estimated coefficient is affected by unobserved heterogeneity. For example, it is possible that in areas that are facing rising demand for water from cities, farmers naturally reduce water use in anticipation of future water restrictions. At the same time, village leaders in the areas may also be trying to forestall the shortages by adopting new institutional arrangements to show that they are concerned about the pending water crisis. In such a situation, the coefficient on the water management institution (or incentive) variable could be negative, even if the institution itself has no effect.

In order to control the potential endogeneity of water management types and incentives in the water use equation, we adopt an instrumental variable approach. To do so, prior to estimating equation (10.1), we can regress a set of variables on the water management institution variable, M_k:

$$M_k = \alpha + \beta IV_k + \gamma Z_k + \varepsilon_k \qquad \text{(equation 10.2)}$$

where the predicted value of M_k from equation (10.2), $\hat{M}_k$, would replace W_k in equation (10.1). Equation (10.2) includes Z_k, which are measures other village-level control variables (which are the same as those in equation 1 – e.g., measures of the village's production environment and cropping structure).

This *IV* procedure, however is only valid if the variables in the *IV* matrix in equation (10.2) meet the definition of instruments. The key *IV* in equation (10.2) that we use to address the endogeneity problem is a variable (Pk) that measures the effect of the decision of regional policymakers to push water management reform in village *k*. Such a measure should function well as an instrument, especially in our setting, since the officials that were responsible for promoting water management reform believed that at least in the short run they were choosing villages on a fairly random basis. An official in one ID told us that initially he went to villages in which he personally knew the local officials. If the spectrum of the aquaintances of the typical water system officials are independent of the amount of water used in the village, our policy variable should meet the criteria of an instrumental variable: it is correlated with the decision of a village to participate in water management reform but does not have an effect on water use (or income or crop production) except through the influence of the reform. We also include the age and education of the village leader as *IV*s.[26]

Examining the results of equation (10.2) by itself, the model performs well (table 10.6). The adjusted R-squares range from 0.23 to 0.94. Importantly, the results show that water policy intervention variable, P_k, is positive and statistically significant; the variable meets the first criteria of an *IV*. Although the coefficient on the variables measuring village leader characteristics are insignificant, the Hausman test of exclusion restrictions that are designed to test the validity of the instruments show that our instruments are statistically valid and meet the second criteria of *IV*s.[27]

When putting the predicted value of the water management variable into the water use model in equation (10.1), our results change a little and largely support the findings from the OLS model (table 10.5, columns 3 and 4). Compared with the OLS estimation, the statistic of the estimated coefficient on the incentive variable actually rises (table 10.5, row 3). The magnitude of the coefficient also suggests that the savings from providing incentives are large, and in fact even greater. Holding other variables constant, in the villages in which leaders offer managers positive incentives, water use declines more than 6,000 cubic meter per hectare, about 40 percent of average water use (table 10.5, row 3, column 4).

[26] We include village leader characteristics as IVs, following Brandt et al. (2003) and Li (1998). In these papers, the authors claim that village leader characteristics may affect reform in the village, but their characteristics would not have an independent effect on production decisions (in our case, water use).

[27] To test if the set of identifying instruments are exogenous, a Lagrange multiplier test can be used (Hausman). The chi-square-distributed test statistic with three degree of freedom, is $N*R^2$, where N is the number of observations, and R^2 is the measure of goodness-of-fit of the regression of the residues from the institutional equation (4.2) on the variables which are exogenous to the system. The test statistics are 0.00 for WUAs, 0.05 for contracting, 1.36 for non-collective with incentives and 2.27 for non-collective without incentives. The test results indicate the null hypothesis that there is no correlation between the exogenous instruments and the disturbance term from institutional equation (2) cannot be rejected.

Table 10.6. Determinants of water management institution at the village level.

	Share of WUA	Share of contracting	Share of non-collective with incentives	Share of non-collective without incentives
Dummy of government intervention	0.864 (22.43)***	0.670 (7.72)***	0.212 (2.10)**	0.424 (4.53)***
Age of village leader	0.000 (0.21)	-0.017 (3.32)***	-0.013 (1.80)*	-0.003 (0.47)
Education of village leader	0.002 (0.45)	-0.005 (0.37)	-0.029 (1.43)	0.021 (1.13)
Share of surface water irrigation in the village	0.004 (0.08)	0.182 (1.23)	-0.078 (0.38)	0.263 (1.39)
Dummy of village water scarcity	-0.001 (0.06)	0.086 (1.16)	0.015 (0.15)	0.060 (0.63)
Irrigation investment per hectare in the village	0.000 (10.43)***	0.000 (0.54)	0.000 (2.40)**	0.000 (0.28)
Share of village paddy area in 1995	0.016 (0.27)	-0.051 (0.32)	-0.055 (0.25)	0.043 (0.21)
QID-N	-0.038 (1.01)	-0.162 (1.53)	0.208 (1.45)	-0.464 (3.49)***
PID-H	-0.032 (0.60)	0.092 (0.64)	0.042 (0.20)	-0.095 (0.48)
LID-H	-0.037 (0.57)	-0.002 (0.01)	0.038 (0.15)	-0.176 (0.74)
Constant	-0.067 (0.53)	0.716 (2.00)*	0.770 (1.53)	-0.001 (0.00)
Observations	51	51	51	51
Adjusted R-squared	0.94	0.65	0.23	0.42

Note: Absolute value of t statistics is in parentheses.

* significant at 10% ** significant at 5% *** significant at 1%

WATER MANAGEMENT, PRODUCTION, INCOME AND POVERTY

Statistic Description

Water management reform, at least when implemented as designed, leads to water saving and meets the primary goal of water sector officials. However, it is possible that the success from such a policy can only come at a cost, either in terms of falling production or income or increased poverty. In this section, we examine how water management reform affects agricultural production. We then examine its impact on income and the incidence of poverty.

Descriptive statistics from our data show that water management reform negatively influences agricultural production (table 10.7, rows 1 to 3). Compared with collective management, in the villages that provide incentives to managers to save water, wheat yields decline by nearly 10 percent. Maize and rice yields also decline by 9 and 12 percent, respectively. The negative effect of incentives on production is even clearer when comparing the yields between villages that nominally implement reforms but do not provide incentives to water managers, with those that do provide incentives (table 10.7, rows 1 to 3, column 1 versus 2). In the case of wheat and maize yields, while production in villages with managers that have positive incentives, those in villages that have moved to WUAs and contracting but have not provided incentives actually rise marginally. In the case of rice, yields fall for villages that only reform nominally, but not as far as for villages that provide incentives to their managers. Since the pattern in production is consistent, though in the opposite direction, the correlations between water management and water use, suggest that water savings through management reform may only be able to come at a cost of lower yields. Similar evidence can be found when examining the yield under various water management type (table 10.8).

Table 10.7. Incentives, production, income and poverty in the sample irrigation districts, Ningxia and Henan Provinces, 2001.

	Non-collective with incentives	Non-collective without incentives	Collective
Wheat yield (kg/ha)	4,340	4,827	4,800
Maize yield (kg/ha)	5,328	6,031	5,801
Rice yield (kg/ha)	6,288	6,499	7,155
Income (yuan)	2,334	1,966	1,646
Cropping income (yuan)	1,073	784	726
Poverty incidence (%)	11.1	6.5	7.5

Data source: Authors' survey.

Table 10.8. Relationship between water management and crop yield in the sampled irrigation districts, Ningxia and Henan Provinces, 2001.

	Crop yield (kg/ha)		
	Wheat	Maize	Paddy
Ningxia Province			
WID-N			
Collective	4,723	5,750	6,750
WUA	4,677	5,644	6,764
Contracting	4,653	4,700	8,182
QID-N			
Collective	4,671	5,415	7,748
WUA	4,738	6,667	8,125
Contracting	4,220	5,697	6,324
Henan Province			
PID-H			
Collective	5,453	7,295	6,298
Contracting	4,757	5,625	5,381

Data sources: Authors' survey.

In contrast, the negative influence of water management reform on production does not appear in the descriptive statistics when examining farmer income (table 10.7). Evidence from our survey reveals that in villages in which leaders reformed their water management system and provided incentives to managers, farmers actually earn higher income (table 10.7, row 4). Surprisingly, crop income is also higher in villages that have provided managers with incentives (table 10.7, row 5). Part of the explanation for the difference between yields and income may be due to the fact that water fees also fall in villages that have reformed. It may also be that farmers are also shifting their production decisions and allocating labor to other enterprises in villages that provide water managers with incentives. Econometric analysis is needed to isolate the effect of reform on income. Econometric analysis also appears to be needed to distinguish between income and poverty effects; in contrast to the case of income, our descriptive data shows that poverty is worse in those villages that provide managers with incentives (table 10.7, row 6). Similar evidence can also be found when either examining the incentive separately by water management type or directly by examining the relationship between income, poverty and water management type (tables 10.9 and 10.10).

Table 10.9. Relationship between incentives mechanism, income and poverty in the sample irrigation districts, Ningxia Province, 2001.

		Income (yuan)	Cropping income (yuan)	Poverty incidence (%) Poor I	Poverty incidence (%) Poor II	Poverty gap (%) Poor I	Poverty gap (%) Poor II
Whole samples							
	Non-collective with incentives	1,646	1,073	11.1	13.9	4.0	63.1
	Non-collective without incentives	1,966	784	6.5	10.9	22.6	44.4
	Collective	1,646	726	7.5	15.0	13.3	43.6
Ningxia Province							
WID-N							
WUA							
	With incentives	2,821	1,290	0.0	0.0	0.0	0.0
	Without incentives	2,137	665	8.3	8.3	18.2	39.3
Contracting	Without incentives	1,833	792	0.0	20.0	0.0	24.2
Collective		1,628	636	12.5	12.5	39.0	70.6
QID-N							
WUA							
	With incentives	4,517	1,021	0.0	0.0	0.0	0.0
	Without incentives	2,103	737	9.1	9.1	19.4	42.4
Contracting							
	With incentives	1,952	1,049	14.3	17.9	39.0	81.1
	Without incentives	2,249	1,036	0.0	0.0	0.0	0.0
Collective		2,063	723	4.7	7.0	8.5	25.8

Data sources: Authors' survey.

Table 10.10. Relationship between water management, income and poverty in the sample irrigation districts, Ningxia and Henan Provinces, 2001.

	Income (yuan)	Cropping income (yuan)	Poverty incidence (%) Poor I	Poverty incidence (%) Poor II	Poverty gap (%) Poor I	Poverty gap (%) Poor II
Ningxia Province						
WID-N						
Collective	1,628	636	12.5	12.5	39.0	70.6
WUA	2,308	821	6.25	6.25	13.6	29.5
Contracting	1,833	792	0	20	0.0	24.2
QID-N						
Collective	2,063	723	4.7	7.0	8.5	25.8
WUA	2,747	812	6.7	6.7	14.2	31.1
Contracting	2,025	1046	10.8	13.5	29.5	61.4
Henan Province						
PID-H						
Collective	1,387	732	10.0	13.3	22.3	52.3
Contracting	767	690	25.0	25.0	152.4	215.6

Data sources: Authors' survey.

MULTIVARIATE EMPIRICAL MODEL AND RESULTS

In addition to water management reform, other socio-economic factors also influence agricultural production, income and poverty. In order to answer the question of whether water management reform affects outcomes, it is necessary to account for these other factors.

To do so, we specify the link between agricultural production and its determinants as

$$Q_{ijk} = \alpha + \beta W_{ijk} + \gamma X_{ijk} + \delta Z_{ijk} + D_{ijk} + \varepsilon_{ijk} \qquad \text{(equation 10.3)}$$

where Q_{ijk} represents the yields of wheat, maize or rice from the *i*th plot of household *j* in village *k*. In equation (10.3), yields are explained by the variable of interest, W_{ijk}, which measures water use per hectare, X_{ijk}, which measures other inputs to the production process, Z_{ijk} which holds other factors constant, including characteristics of the production environment of the village, household and plot, and the irrigation district dummy, D_k. Agricultural production inputs include measures of per hectare use of labor (measured in man-days), fertilizer (measured in aggregated physical units[28]) and expenditure on other inputs, such as fees paid for custom services. The control variables for village and household characteristics are the same as for equation (10.1) except that we do not use the village level cropping structure. We also add five plot characteristics, including measures of soil types; plot location (distance from the plot to the farmer's house); whether the crop on the plot is planted in rotation with another crop or not (single season equals one, or not); and production shocks (measured as yield reduction on a plot due to floods, droughts or other "disasters").

The impact of water management reform is measured through the water use variable. If production responds positively to water use, then we can deduce that water management reform will have an effect in the opposite direction, because of its water reducing effect that we found in table 10.5. However, because table 10.5 combined all crops together at the household level and in our production analysis we examined wheat, maize and rice separately at the plot level, we need to have separate measures of the effect of water management reform on water use by crop. The results of these alternative water use equations are included in tables 10.11 to 10.14 and show that in the case of all crops, the coefficient on the variable measuring the presence of incentives in local water management institutions is negative (and is significantly so for wheat and rice).[29] Predictions from table 10.14 are used in the estimation of equation (10.3).

[28] To measure fertilizer, we decomposed each type of fertilizer by nutrients, N, P and K, and then summed across nutrients and fertilizer types. We also aggregated fertilizer by value and our main results of interest do not change.

[29] The analysis uses plot-level data for estimating the equation in tables 10.11 to 10.14. We also use predicted values of water management reform for the estimation of the equations in tables 10.11 to 10.14 because of our concerns of endogeneity.

Table 10.11. Determinants of crop water use.

	Water use per hectare (OLS)		
	Wheat	Maize	Paddy
Share of WUA	2,255.986	3,395.103	-3,075.444
	(2.79)***	(3.01)***	(0.49)
Share of contracting	-2,205.524	-1,320.208	-11,914.241
	(3.87)***	(1.54)	(2.21)**
Share of surface water irrigation in the village	86.764	-1,744.847	7,958.702
	(0.09)	(0.76)	(0.72)
Dummy of village water scarcity	-1,787.228	-3,271.617	-12,168.564
	(3.79)***	(4.35)***	(2.94)***
Irrigation investment per hectare in the village	-0.039	-0.067	-2.720
	(0.80)	(1.02)	(2.57)**
Share of village paddy area in 1995	-3,843.133	-1,817.755	10,722.165
	(3.41)***	(0.91)	(0.92)
Age of household head	-158.844	-476.665	2,066.124
	(0.90)	(1.66)*	(1.26)
Squared age of household head	1.296	4.915	-25.898
	(0.67)	(1.56)	(1.43)
Education of household head	-220.928	-140.816	-685.201
	(3.38)***	(1.34)	(1.17)
Arable land per hectare of household	-2,288.728	-6,788.718	16,390.889
	(1.19)	(2.45)**	(1.12)
Dummy of loam soil	-112.444	-765.201	-130.032
	(0.22)	(0.93)	(0.03)
Dummy of clay soil	-67.363	-372.336	211.629
	(0.13)	(0.46)	(0.05)
Distance to home	-127.374	945.883	-256.863
	(0.37)	(1.40)	(0.13)
Dummy of single season	673.435	1,399.946	-1,979.556
	(0.86)	(1.29)	(0.15)
QID-N	-3,104.925	-2,372.109	-8,834.134
	(4.69)***	(2.60)**	(1.57)
PID-H	-3,940.947	-4,615.587	-20,701.239
	(4.39)***	(2.90)***	(1.27)
LID-H	-5,829.946	-6,980.665	-33,627.756
	(5.37)***	(2.77)***	(2.10)**
Constant	16,687.821	24,459.819	8,110.669
	(4.14)***	(3.60)***	(0.21)
Observations	234	163	114
Adjusted R-squared	0.46	0.37	0.28

Note: Absolute value of t statistics is in parentheses.

* significant at 10% ** significant at 5% *** significant at 1%

Table 10.12. Determinants of crop water use.

	Water use per hectare (OLS)		
	Wheat	Maize	Paddy
Share of non-collective with incentives	-1,722.905	-149.290	-5,855.974
	(2.38)**	(0.15)	(1.08)
Share of non-collective without incentives	-646.837	66.540	-14,936.392
	(1.01)	(0.07)	(2.37)**
Share of surface water irrigation in the village	-120.083	-1,816.533	12,699.424
	(0.12)	(0.75)	(1.06)
Dummy of village water scarcity	-1,902.652	-3,559.408	-9,766.863
	(3.79)***	(4.48)***	(2.23)**
Irrigation investment per hectare in the village	0.072	0.030	-3.048
	(1.41)	(0.43)	(2.72)***
Share of village paddy area in 1995	-3,267.589	-1,040.433	14,989.560
	(2.77)***	(0.50)	(1.27)
Age of household head	-22.885	-244.316	2,512.957
	(0.12)	(0.81)	(1.52)
Squared age of household head	-0.035	2.630	-29.986
	(0.02)	(0.80)	(1.64)
Education of household head	-223.285	-156.614	-723.308
	(3.22)***	(1.41)	(1.24)
Arable land per hectare of household	-1,658.672	-6,800.339	8,818.276
	(0.80)	(2.26)**	(0.59)
Dummy of loam soil	267.724	-250.803	2,749.737
	(0.50)	(0.29)	(0.65)
Dummy of clay soil	399.216	92.347	1,702.526
	(0.76)	(0.11)	(0.41)
Distance to home	-50.080	1,041.071	-529.377
	(0.14)	(1.46)	(0.26)
Dummy of single season	830.038	1,521.156	-3,069.680
	(1.00)	(1.33)	(0.23)
QID-N	-4,193.431	-3,574.588	-16,851.772
	(6.17)***	(3.76)***	(2.78)***
PID-H	-5,438.175	-6,156.671	-27,861.832
	(6.01)***	(3.73)***	(1.75)*
LID-H	-7,231.488	-8,003.792	-39,427.152
	(6.46)***	(3.03)***	(2.55)**
Constant	14,008.835	19,544.812	229.366
	(3.30)***	(2.76)***	(0.01)
Observations	234	163	114
Adjusted R-squared	0.39	0.30	0.28

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.13. Determinants of crop water use.

	Water use per hectare (2SLS)		
	Wheat	Maize	Paddy
Share of WUA	1,527.027	3,060.689	-7,883.709
	(1.86)*	(2.70)***	(1.23)
Share of contracting	-3,535.795	-1,401.277	-20,337.877
	(4.69)***	(1.28)	(3.04)***
Share of surface water irrigation in the village	-17.148	-1,751.480	5,921.161
	(0.02)	(0.75)	(0.58)
Dummy of village water scarcity	-1,654.577	-3,168.910	-9,057.027
	(3.53)***	(4.15)***	(2.12)**
Irrigation investment per hectare in the village	-0.026	-0.047	-2.642
	(0.55)	(0.73)	(2.57)**
Share of village paddy area in 1995	-3,853.002	-1,893.904	9,734.531
	(3.46)***	(0.95)	(0.85)
Age of household head	-132.378	-451.026	2,577.742
	(0.76)	(1.55)	(1.58)
Squared age of household head	1.046	4.707	-31.792
	(0.54)	(1.47)	(1.77)*
Education of household head	-203.618	-133.710	-744.190
	(3.13)***	(1.25)	(1.30)
Arable land per hectare of household	-1,249.648	-6,820.605	21,716.580
	(0.64)	(2.39)**	(1.49)
Dummy of loam soil	-66.753	-703.324	527.892
	(0.13)	(0.85)	(0.12)
Dummy of clay soil	0.020	-362.936	1,232.452
	(0.00)	(0.44)	(0.30)
Distance to home	-74.864	1,018.589	-311.140
	(0.22)	(1.49)	(0.16)
Dummy of single season	775.484	1,401.578	-1,688.249
	(1.00)	(1.27)	(0.13)
QID-N	-3,309.064	-2,528.298	-11,432.373
	(5.13)***	(2.78)***	(2.09)**
PID-H	-4,636.372	-4,957.582	-27,406.790
	(5.20)***	(3.08)***	(1.71)*
LID-H	-6,374.350	-7,106.642	-39,381.044
	(5.91)***	(2.80)***	(2.52)**
Constant	16,223.262	23,743.035	2,473.249
	(4.04)***	(3.45)***	(0.07)
Observations	234	163	114
Adjusted R-squared	0.46	0.36	0.31

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.14. Determinants of crop water use.

	Water use per hectare (2SLS)		
	Wheat	Maize	Paddy
Share of non-collective with incentives	-3,802.375	-2,107.654	-23,149.103
	(2.83)***	(1.09)	(2.24)**
Share of non-collective without incentives	-1,054.236	992.491	-5,943.309
	(0.96)	(0.63)	(0.64)
Share of surface water irrigation in the village	61.923	-1,555.108	1,018.291
	(0.06)	(0.64)	(0.10)
Dummy of village water scarcity	-1,911.910	-3,510.065	-11,202.815
	(3.90)***	(4.45)***	(2.75)***
Irrigation investment per hectare in the village	0.110	0.090	-1.948
	(1.79)*	(1.02)	(1.83)*
Share of village paddy area in 1995	-3,210.399	-1,106.899	11,146.211
	(2.79)***	(0.54)	(0.96)
Age of household head	29.091	-251.383	2,779.020
	(0.16)	(0.84)	(1.68)*
Squared age of household head	-0.560	2.725	-32.915
	(0.28)	(0.82)	(1.80)*
Education of household head	-198.481	-144.878	-687.514
	(2.91)***	(1.31)	(1.18)
Arable land per hectare of household	-218.531	-5,470.061	25,745.862
	(0.10)	(1.76)*	(1.61)
Dummy of loam soil	347.962	-309.517	1,619.001
	(0.66)	(0.36)	(0.38)
Dummy of clay soil	358.484	-44.854	1,204.337
	(0.68)	(0.05)	(0.29)
Distance to home	-51.871	1,119.131	190.460
	(0.15)	(1.57)	(0.10)
Dummy of single season	841.530	1,429.926	-2,000.727
	(1.04)	(1.25)	(0.15)
QID-N	-4,141.450	-3,090.040	-10,489.498
	(5.35)***	(2.86)***	(1.64)
PID-H	-5,666.515	-5,686.672	-29,838.197
	(5.59)***	(3.21)***	(1.81)*
LID-H	-7,374.123	-7,398.282	-44,115.553
	(6.16)***	(2.70)***	(2.77)***
Constant	12,469.815	18,713.794	-3,738.899
	(3.00)***	(2.64)***	(0.10)
Observations	234	163	114
R-squared	0.41	0.31	0.30

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

We also establish the following equation to examine the relationship between income and other factors:

$$y_{jk} = \alpha + M_{jk}\beta + Z_{jk}\gamma + D_{jk} + \varepsilon_{jk} \qquad \text{(equation 10.4)}$$

where y_{jk} represents either total or cropping income per capita or total income per capita for household j, and the other variables, including M_{jk}, our interested variable (a measure of incentives) are the same as in equation (10.1). In examining the effect of water management reform on poverty, we proceed in largely the same way. Because we are measuring poverty in terms of income, one would use largely the same specifications and expect similar results, albeit with opposite signs.

Almost all the models specified on production, income and poverty perform well and produce robust results that largely confirm our priority expectations (tables 10.15 to 10.22). The goodness of fit measure for production and income models, the adjusted R^2, arrange from 0.16 to 0.40. Many coefficients of our control variables in these models were of expected sign and statistically significant. For example, the production shock not only negatively influences agricultural production, but also reduces farmer income and adversely affects the household's poverty status. Higher levels of land holdings also positively affect incomes.[30]

Our results show that reforming water management reduces wheat yield which has no significant impact on the yields of maize and rice. From the wheat water use model, when villages provide water managers with incentives, managers reduce water use per hectare about 3,800 cubic meter, a decline of about 50 percent (table 10.14, column 1, row 1). At the same time, the coefficient on the predicted water use variable in the wheat yield equation is positive and statistically significant (table 10.16, column 1, row 1). The estimated water use elasticity for wheat yield is 0.226. Overall, our estimates of the size of the decline in water use and the responsiveness of wheat yields to water use imply that water management reform reduces wheat yields by about 11 percent. In contrast, although we find that incentives have a negative association on water use, the estimated water use elasticities for maize and rice are indistinguishable from zero (table 10.16, columns 2 and 3, row 1).

Table 10.15. Determinants of crop yield.

	Log of crop yield (OLS)		
	Wheat	Maize	Rice

[30] Although the coefficients on the fertilizer variable in the maize and rice yield equations are positive, significant and similar to results found elsewhere in the literature (e.g., Putterman and Ciacu 1995), as found in much of the literature on cross- section production analysis at the household level, our other coefficients are insignificant due to measurement problems (e.g., we observe labor days, not effort), multicollinearity (e.g., when farmers use high levels of one input, they often use high levels of all other inputs), and endogeneity (management ability and weather shocks are not measured completely).

Log of water use per hectare	0.122	0.118	0.032
	(3.68)***	(2.42)**	(0.67)
Log of label use per hectare	-0.025	0.069	0.004
	(0.70)	(1.05)	(0.09)
Log of fertilizer use per hectare	0.031	0.087	0.188
	(0.67)	(1.40)	(2.61)**
Log of other production fee per hectare	0.004	-0.004	0.015
	(0.38)	(0.49)	(1.31)
Share of surface water irrigation in the village	0.240	-0.003	0.066
	(3.02)***	(0.02)	(0.41)
Dummy of village water scarcity	0.022	0.077	0.074
	(0.51)	(1.01)	(1.06)
Irrigation investment per hectare in the village	0.000	0.000	0.000
	(0.80)	(1.16)	(2.01)**
Age of household head	-0.023	-0.011	-0.020
	(1.48)	(0.43)	(0.76)
Squared age of household head	0.000	0.000	0.000
	(1.87)*	(0.56)	(0.46)
Education of household head	0.015	0.008	-0.019
	(2.35)**	(0.78)	(1.86)*
Dummy of loam soil	0.098	0.134	0.083
	(2.17)**	(1.81)*	(1.24)
Dummy of clay soil	0.107	0.146	0.039
	(2.33)**	(2.01)**	(0.60)
Distance to home	-0.005	0.017	-0.013
	(0.15)	(0.28)	(0.40)
Dummy of single season	0.074	-0.001	-0.042
	(1.01)	(0.01)	(0.18)
Yield reduction due to production shock	-1.323	-0.991	-1.465
	(9.68)***	(4.89)***	(7.32)***
QID-N	-0.019	0.033	-0.048
	(0.36)	(0.43)	(0.66)
PID-H	0.319	0.242	-0.013
	(4.21)***	(1.72)*	(0.05)
LID-H	0.309	0.095	0.338
	(3.15)***	(0.40)	(1.18)
Constant	7.243	6.716	7.775
	(12.48)***	(8.12)***	(8.14)***
Observations	234	158	113
Adjusted R-squared	0.41	0.19	0.36

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.16. Determinants of crop yield.

	Log of crop yield (2SLS)		
	Wheat	Maize	Paddy
Log of water use per hectare	0.226	0.043	0.148
	(3.15)***	(0.32)	(1.05)
Log of label use per hectare	-0.009	0.099	-0.003
	(0.26)	(1.51)	(0.07)
Log of fertilizer use per hectare	0.020	0.110	0.182

	(0.44)	(1.75)*	(2.53)**
Log of other production fee per hectare	-0.001	-0.002	0.018
	(0.09)	(0.21)	(1.49)
Share of surface water irrigation in the village	0.197	-0.027	0.103
	(2.39)**	(0.13)	(0.62)
Dummy of village water scarcity	0.086	0.029	0.133
	(1.63)	(0.23)	(1.38)
Irrigation investment per hectare in the village	0.000	0.000	0.000
	(0.51)	(1.18)	(2.21)**
Age of household head	-0.028	-0.020	-0.029
	(1.74)*	(0.76)	(1.04)
Squared age of household head	0.000	0.000	0.000
	(2.13)**	(0.85)	(0.77)
Education of household head	0.023	0.006	-0.016
	(3.04)***	(0.55)	(1.45)
Dummy of loam soil	0.081	0.137	0.077
	(1.75)*	(1.80)*	(1.16)
Dummy of clay soil	0.095	0.154	0.039
	(2.04)**	(2.08)**	(0.60)
Distance to home	-0.008	0.016	-0.016
	(0.24)	(0.25)	(0.49)
Dummy of single season	0.061	-0.010	-0.029
	(0.82)	(0.09)	(0.13)
Yield reduction due to production shock	-1.411	-1.026	-1.469
	(10.37)***	(4.94)***	(7.45)***
QID-N	0.063	0.015	-0.030
	(0.94)	(0.14)	(0.41)
PID-H	0.392	0.215	0.099
	(4.68)***	(1.18)	(0.33)
LID-H	0.392	0.016	0.615
	(3.48)***	(0.05)	(1.44)
Constant	6.365	7.310	6.698
	(7.96)***	(4.73)***	(4.27)***
Observations	234	158	113
Adjusted R-squared	0.40	0.16	0.37

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.17. Determinants of farmer income.

	Total income		Cropping income	
	OLS	2SLS	OLS	2SLS
Share of WUA	103.073 (0.29)	236.087 (0.65)	-191.709 (1.37)	-130.485 (0.91)
Share of contracting	-16.683 (0.06)	163.743 (0.46)	-79.765 (0.74)	-36.535 (0.26)
Share of surface water irrigation in the village	333.054 (0.72)	302.994 (0.66)	-102.181 (0.57)	-120.987 (0.67)
Dummy of village water scarcity	137.652 (0.62)	136.974 (0.62)	-9.863 (0.11)	-6.801 (0.08)
Irrigation investment per hectare in the village	0.070 (3.45)***	0.070 (3.49)***	0.013 (1.68)*	0.012 (1.56)
Share of village paddy area in 1995	186.339 (0.38)	168.896 (0.35)	-38.340 (0.20)	-48.109 (0.26)
Age of household head	175.109 (2.04)**	170.340 (1.98)**	55.381 (1.66)*	54.189 (1.61)
Squared age of household head	-1.680 (1.77)*	-1.623 (1.70)*	-0.642 (1.73)*	-0.629 (1.69)*
Education of household head	21.680 (0.69)	21.766 (0.69)	-7.830 (0.64)	-7.928 (0.65)
Arable land per hectare of household	3,391.259 (3.09)***	3,262.361 (2.95)***	3,244.717 (7.47)***	3,219.093 (7.34)***
Production asset per capita	0.112 (3.51)***	0.112 (3.50)***		
Agricultural production asset per capita			0.085 (1.86)*	0.080 (1.76)*
Number of plots per household	-118.612 (3.63)***	-120.898 (3.70)***	-4.704 (0.37)	-5.461 (0.43)
Dummy of production shock	-231.967 (1.24)	-225.979 (1.21)	-183.512 (2.53)**	-182.815 (2.51)**
QID-N	-209.746 (0.71)	-178.612 (0.61)	-206.507 (1.79)*	-180.654 (1.59)
PID-H	-968.544 (2.17)**	-912.979 (2.04)**	-99.217 (0.57)	-76.784 (0.44)
LID-H	-857.204 (1.59)	-804.823 (1.50)	-94.152 (0.45)	-69.873 (0.33)
Constant	-2,590.195 (1.35)	-2,520.228 (1.32)	-557.297 (0.75)	-540.841 (0.72)
Observations	189	189	189	189
Adjusted R-squared	0.24	0.24	0.36	0.35

Note: Absolute value of t statistics in in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.18. Determinants of farmer income.

	Total income per capita		Cropping income per capita	
	OLS	2SLS	OLS	2SLS
Share of non-collective with incentives	175.109	688.980	-136.262	69.719
	(0.53)	(1.08)	(1.06)	(0.28)
Share of non-collective without incentives	-18.277	-108.274	-61.382	-95.177
	(0.06)	(0.21)	(0.54)	(0.47)
Share of surface water irrigation in the village	337.665	301.020	-112.871	-125.975
	(0.73)	(0.66)	(0.62)	(0.70)
Dummy of village water scarcity	157.467	144.952	-15.764	-3.154
	(0.70)	(0.66)	(0.18)	(0.04)
Irrigation investment per hectare in the village	0.069	0.056	0.012	0.007
	(3.37)***	(2.08)**	(1.54)	(0.65)
Share of village paddy area in 1995	198.901	198.012	-56.991	-59.428
	(0.41)	(0.41)	(0.30)	(0.32)
Age of household head	183.491	178.580	49.640	51.933
	(2.13)**	(2.07)**	(1.48)	(1.53)
Squared age of household head	-1.759	-1.710	-0.587	-0.609
	(1.84)*	(1.79)*	(1.57)	(1.62)
Education of household head	21.984	19.876	-7.920	-8.093
	(0.70)	(0.63)	(0.65)	(0.66)
Arable land per hectare of household	3,291.145	3,034.111	3,270.769	3,167.299
	(2.99)***	(2.71)***	(7.48)***	(7.07)***
Production asset per capita	0.111	0.110		
	(3.49)***	(3.45)***		
Number of plots per household	-124.052	-127.845	-3.112	-7.441
	(3.68)***	(3.79)***	(0.24)	(0.56)
Dummy of production shock	-229.269	-219.720	-183.171	-180.501
	(1.23)	(1.18)	(2.52)**	(2.47)**
QID-N	-285.847	-353.283	-144.761	-181.364
	(0.96)	(1.01)	(1.24)	(1.31)
PID-H	-1,044.013	-1,086.376	-36.442	-73.217
	(2.37)**	(2.17)**	(0.21)	(0.37)
LID-H	-924.558	-967.621	-35.554	-64.471
	(1.74)*	(1.68)*	(0.17)	(0.28)
Agricultural production asset per capita			0.081	0.080
			(1.76)*	(1.74)*
Constant	-2,707.916	-2,458.543	-472.618	-459.997
	(1.41)	(1.29)	(0.63)	(0.61)
Observations	189	189	189	189
Adjusted R-squared	0.24	0.25	0.35	0.35

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.19. Determinants of poverty incidence.

	Dummy of poverty incidence (OLS)		Dummy of poverty incidence (2SLS)	
	Poor I	Poor II	Poor I	Poor II
Share of WUA	0.058	0.026	0.025	-0.018
	(0.75)	(0.27)	(0.32)	(0.18)
Share of contracting	0.067	0.151	0.045	0.118
	(1.12)	(2.07)**	(0.59)	(1.25)
Share of surface water irrigation in the village	-0.186	-0.365	-0.174	-0.340
	(1.86)*	(2.99)***	(1.74)*	(2.79)***
Dummy of village water scarcity	-0.005	-0.045	-0.009	-0.054
	(0.10)	(0.77)	(0.18)	(0.92)
Irrigation investment per hectare in the village	-0.000	-0.000	-0.000	-0.000
	(0.83)	(0.49)	(0.73)	(0.44)
Share of village paddy area in 1995	0.007	0.138	0.013	0.148
	(0.06)	(1.07)	(0.12)	(1.14)
Age of household head	0.006	0.004	0.007	0.005
	(0.32)	(0.19)	(0.36)	(0.23)
Squared age of household head	-0.000	-0.000	-0.000	-0.000
	(0.46)	(0.40)	(0.50)	(0.44)
Education of household head	-0.009	-0.009	-0.009	-0.010
	(1.38)	(1.14)	(1.39)	(1.17)
Arable land per hectare of household	-0.289	-0.526	-0.270	-0.496
	(1.22)	(1.81)*	(1.12)	(1.68)*
Production asset per capita	-0.000	-0.000	-0.000	-0.000
	(0.76)	(0.90)	(0.72)	(0.86)
Number of plots per household	0.013	0.013	0.014	0.014
	(1.89)*	(1.56)	(1.95)*	(1.65)
Dummy of production shock	0.095	0.100	0.096	0.102
	(2.35)**	(2.03)**	(2.35)**	(2.06)**
QID-N	0.035	0.012	0.022	-0.003
	(0.54)	(0.15)	(0.35)	(0.04)
PID-H	0.046	-0.078	0.038	-0.079
	(0.47)	(0.66)	(0.39)	(0.67)
LID-H	-0.043	-0.008	-0.054	-0.017
	(0.37)	(0.06)	(0.46)	(0.12)
Constant	0.099	0.415	0.089	0.401
	(0.24)	(0.82)	(0.21)	(0.79)
Observations	189	189	189	189
Adjusted R-squared	0.01	0.10	0.01	0.08

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.20. Determinants of poverty incidence.

	Dummy of poverty incidence (OLS)		Dummy of poverty incidence (2SLS)	
	Poor I	Poor II	Poor I	Poor II
Share of non-collective with incentives	0.086	0.136	0.057	-0.022
	(1.21)	(1.56)	(0.41)	(0.13)
Share of non-collective without incentives	0.032	0.073	-0.040	0.053
	(0.52)	(0.95)	(0.36)	(0.39)
Share of surface water irrigation in the village	-0.175	-0.344	-0.167	-0.328
	(1.75)*	(2.80)***	(1.68)*	(2.68)***
Dummy of village water scarcity	0.001	-0.034	-0.008	-0.046
	(0.03)	(0.57)	(0.16)	(0.78)
Irrigation investment per hectare in the village	-0.000	-0.000	-0.000	-0.000
	(1.07)	(1.12)	(0.85)	(0.36)
Share of village paddy area in 1995	0.012	0.137	0.018	0.141
	(0.12)	(1.07)	(0.17)	(1.09)
Age of household head	0.007	0.002	0.009	0.002
	(0.40)	(0.10)	(0.45)	(0.08)
Squared age of household head	-0.000	-0.000	-0.000	-0.000
	(0.53)	(0.34)	(0.60)	(0.32)
Education of household head	-0.009	-0.010	-0.010	-0.010
	(1.39)	(1.16)	(1.40)	(1.14)
Arable land per hectare of household	-0.297	-0.520	-0.261	-0.427
	(1.24)	(1.78)*	(1.07)	(1.42)
Production asset per capita	-0.000	-0.000	-0.000	-0.000
	(0.76)	(0.87)	(0.72)	(0.77)
Number of plots per household	0.012	0.013	0.013	0.016
	(1.70)*	(1.43)	(1.83)*	(1.78)*
Dummy of production shock	0.095	0.101	0.095	0.099
	(2.36)**	(2.04)**	(2.33)**	(1.98)**
QID-N	0.017	0.020	-0.004	0.030
	(0.26)	(0.25)	(0.05)	(0.32)
PID-H	0.032	-0.056	0.004	-0.048
	(0.33)	(0.48)	(0.03)	(0.36)
LID-H	-0.055	0.015	-0.086	0.017
	(0.48)	(0.11)	(0.68)	(0.11)
Constant	0.083	0.455	0.087	0.439
	(0.20)	(0.89)	(0.21)	(0.86)
Observations	189	189	189	189
Adjusted R-squared	0.01	0.09	0.01	0.07

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.21. Determinants of poverty gap.

	Poverty gap (OLS)		Poverty gap (2SLS)	
	Poor I	Poor II	Poor I	Poor II
Share of WUA	17.338	26.036	6.006	4.907
	(0.78)	(0.65)	(0.26)	(0.12)
Share of contracting	35.489	62.402	25.021	44.733
	(2.05)**	(2.00)**	(1.11)	(1.10)
Share of surface water irrigation in the village	-24.589	-93.682	-18.456	-82.965
	(0.85)	(1.79)*	(0.64)	(1.59)
Dummy of village water scarcity	-8.516	-15.893	-10.463	-19.470
	(0.61)	(0.64)	(0.75)	(0.77)
Irrigation investment per hectare in the village	-0.001	-0.001	-0.001	-0.001
	(0.52)	(0.58)	(0.45)	(0.51)
Share of village paddy area in 1995	-3.644	24.919	-1.158	29.470
	(0.12)	(0.45)	(0.04)	(0.53)
Age of household head	0.718	1.629	0.900	2.023
	(0.13)	(0.17)	(0.17)	(0.21)
Squared age of household head	-0.014	-0.035	-0.017	-0.041
	(0.24)	(0.33)	(0.28)	(0.38)
Education of household head	-3.528	-6.123	-3.598	-6.253
	(1.79)*	(1.72)*	(1.81)*	(1.75)*
Arable land per hectare of household	-109.819	-219.884	-100.923	-204.486
	(1.60)	(1.77)*	(1.44)	(1.62)
Production asset per capita	-0.001	-0.003	-0.001	-0.003
	(0.73)	(0.88)	(0.68)	(0.83)
Number of plots per household	3.925	7.403	4.163	7.817
	(1.92)*	(2.00)**	(2.01)**	(2.10)**
Dummy of production shock	31.953	54.843	32.302	55.477
	(2.73)***	(2.60)**	(2.73)***	(2.60)**
QID-N	8.981	17.713	4.786	10.051
	(0.48)	(0.53)	(0.26)	(0.30)
PID-H	40.045	37.121	38.785	34.572
	(1.43)	(0.74)	(1.37)	(0.68)
LID-H	-2.224	-5.397	-5.044	-10.712
	(0.07)	(0.09)	(0.15)	(0.17)
Constant	18.800	93.659	16.326	87.970
	(0.16)	(0.43)	(0.13)	(0.40)
Observations	189	189	189	189
R-squared	0.04	0.04	0.03	0.03

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

Table 10.22. Determinants of poverty gap.

	Poverty gap (OLS)		Poverty gap (2SLS)	
	Poor I	Poor II	Poor I	Poor II
Share of non-collective with incentives	32.856	60.794	30.298	32.138
	(1.59)	(1.63)	(0.75)	(0.44)
Share of non-collective without incentives	21.979	33.829	-11.054	-10.078
	(1.22)	(1.04)	(0.34)	(0.17)
Share of surface water irrigation in the village	-20.680	-85.551	-15.730	-77.746
	(0.71)	(1.63)	(0.54)	(1.49)
Dummy of village water scarcity	-6.657	-11.760	-9.101	-16.946
	(0.47)	(0.46)	(0.65)	(0.67)
Irrigation investment per hectare in the village	-0.001	-0.002	-0.002	-0.002
	(0.91)	(1.06)	(0.90)	(0.77)
Share of village paddy area in 1995	-2.834	26.202	-0.084	30.216
	(0.09)	(0.48)	(0.00)	(0.55)
Age of household head	0.440	1.286	1.191	2.092
	(0.08)	(0.13)	(0.22)	(0.21)
Squared age of household head	-0.012	-0.034	-0.021	-0.044
	(0.21)	(0.31)	(0.35)	(0.40)
Education of household head	-3.587	-6.220	-3.661	-6.301
	(1.82)*	(1.75)*	(1.84)*	(1.75)*
Arable land per hectare of household	-108.348	-218.730	-98.948	-191.879
	(1.56)	(1.75)*	(1.39)	(1.49)
Production asset per capita	-0.001	-0.003	-0.001	-0.003
	(0.71)	(0.86)	(0.66)	(0.79)
Number of plots per household	3.840	7.086	4.012	7.862
	(1.81)*	(1.85)*	(1.87)*	(2.03)**
Dummy of production shock	31.969	55.014	31.974	54.615
	(2.72)***	(2.60)**	(2.70)***	(2.56)**
QID-N	8.909	16.442	-2.824	4.023
	(0.48)	(0.49)	(0.13)	(0.10)
PID-H	42.563	40.835	29.073	25.135
	(1.53)	(0.82)	(0.91)	(0.44)
LID-H	0.634	-0.901	-13.708	-18.614
	(0.02)	(0.01)	(0.37)	(0.28)
Constant	25.006	102.947	23.221	99.627
	(0.21)	(0.47)	(0.19)	(0.46)
Observations	189	189	189	189
R-squared	0.04	0.04	0.02	0.02

Note: Absolute value of t statistics is in parentheses.
* significant at 10% ** significant at 5% *** significant at 1%

If our plot-level analysis of water management and production are correct, then this would mean that in our sample areas the main trade-off between the water savings from management reform and production occurs for wheat and is less severe or absent for maize and rice. The conclusion is plausible and, although its validity may only be valid for our sample region, it is consistent with many of the observations we made in the field. Wheat is the crop that depends, more than any other, on irrigation because its growth period is almost entirely during the dry season. Water cutbacks should be expected to reduce yields. Maize, in contrast, is grown during the wet season and water managers who have an incentive to save water may be able to time their use of irrigation water with the rains while those who have no interest in saving water might adhere to a predetermined water delivery schedule, no matter what the weather. In the case of rice, although the crop is dependent on large volumes of irrigation water, experiments by domestic and international water scientists have shown that there are many new ways of managing rice irrigation (e.g., alternative wetting and drying – see Barker et.al 2002) that can lead to water savings but do not have significant yield effects in many cases. New water management technologies, however, require efforts to learn and implement. Our results, then, may demonstrate that it is managers with incentives who have been able and are willing to use these new technologies that have brought water savings without large-yield declines.

Our research results also demonstrate that water management reform has no impact on farmer income status (tables 10.17 and 10.18). When we use either OLS or 2SLS approaches, the incentive variable in both the total and cropping income models is not statistically significant. Consistent with the descriptive statistics (which find no obvious fall in income in those villages that give water managers incentives), our results may suggest that whatever negative income effect there is from falling wheat production, it is being offset partially by reductions in water fees (water fees on an average drop by around 9%). It could also be that the average reduction in income due to lower wheat yields are small enough, 89 yuan (11% of average wheat yield, 4,740 kg per hectare, that they cannot be detected statistically. Moreover, since the fall in household income is less than 1.2 percent, the losses in cropping are likely to be offset by other actions taken by households (e.g., because water management is better, they can focus more on other economic activities).

Similar results can also be found in the poverty model (tables 10.19 to 10.22). Since we measure poverty status as "under the poverty line or not," our results say that there is no effect of a village's decision to provide water managers with incentives on a household poverty status. If universally true, such a finding would be important, since critics of water management reforms often point out that one possible adverse consequence of using incentives to induce water reform is that managers may cut back on water deliveries to marginal users, who may also be those on the poorest land. Our results here, however, should be interpreted with caution. First, we have not identified what may be behind this result. In many villages, leaders have specified strict rules in their agreements with water managers that they cannot exclude households from water allocation schedules. Second, as seen by examining the estimated equations in table 10.20, only a few of the coefficients are significant, a sign that our sample may be too small to identify poverty effects. In short, though interesting, we believe our current results may be more important as raising awareness of possible associations rather than as definitive. Future research should try to pinpoint the source of this effect and use larger data sets to strengthen our understanding of these issues.

SUMMARY

In this chapter, we have sought to understand the evolution of China's surface water management systems and their effect on water use, output, income and poverty. Research results show that since 1990, especially after 1995, collective management has been replaced by non-collective, WUAs or contracting. In some regions, non-collective management forms have become the dominated pattern. Innovation of water management has reflected many stakeholders' interests, such as upper and local governments, village leaders and farmers; in particular, policy makers' intervention in the reform seems to play an important role that made the spatial variation of the reform.

Designing the reform is one issue, implementing it is another issue. Despite the fact that the reform has been considered by governments as being designed well, effectively implementing the reform seems to be out of policy makers' control and should be highly emphasized. The major difference between non-collective and collective is the incentives faced by managers. Proving the importance of incentives mechanism for water management is one of our important results. Research shows that if managers are provided with positive incentives to earn money by saving water, they will try to improve water management, water delivered to farmers will be significantly reduced. More importantly, our analysis found that even water management with incentives will reduce water use, it will not produce negative impacts on farmers' output (except for wheat), income and poverty. Although this result needs to be further explored in the long term, at least in the short term, the concern on potential negative impact of water management seems to be un-necessary.

Overall, we propose that the government should continue to support the water management reform. However, contrary to the beginning stage, more emphasis should be put on the effective implementation of the reform. Although the negative impact on farmers have not been found in the short term, in the long term, government still needs to focus on this issue and take some measures to promote the healthy development of water reform. Since reform will lead to water saving under the directives of policy makers' design, how a large scope of water should be saved and how to efficiently reallocate the saved water to some water-short regions that can maximize social benefits, are the other two important issues that need to be further explored by researchers and policy makers.

CHAPTER 11

Summary and Conclusions

Based on the field survey in the four sample IDs of the Ningxia and the Henan Provinces along the YRB, we systematically examined the relationship between irrigation, water management and poverty. We also compared the various pro-poor implications under irrigation and non-irrigation conditions applying the data collected from six provinces. Through both statistical description and multivariate analysis, our research provides many interesting and important results, which have significant policy implications in guiding future pro-poor strategy by reforming water management. We summarize our conclusions in the following several points:

1. Reforming water management with well-implemented incentives can increase water use efficiency with no adverse impact on poverty. Research results show that since 1990 especially after 1995, collective management has been replaced by non-collective management, WUAs or contracting. The major difference between non-collective and collective is the incentives faced by managers. Research shows that if managers are provided with positive incentives to earn money by saving water, they will try to improve water management, and water delivered to farmers will be significantly reduced. More importantly, our analysis found that even water management with incentives will reduce water use; it will not produce negative impacts on farmers' output (except for wheat), income and poverty. Although this result needs to be further explored in the long term, at least in the short term, the concern regarding potential negative impact of water management seems to be un-necessary.

2. There is scope for improving performance of irrigation systems under existing conditions, with effective and improved institutional arrangements. Government should continue to support the water management reform while, more emphasis should be put on the effective implementation of the reform. Although the negative impact on farmers have not being found in the short term, in the long term, government still needs to focus on this issue and take some measures to promote the healthy development of water reform. Since reform will lead to water saving under the directives of the policy makers' design, how large scope of water should be saved and how to efficiently reallocate the saved water to some water-short regions that can maximize social benefits are the other two important issues that need to be further explored by researchers and policy makers.

3. Faced with increasing water scarcity, pro-poor strategies combining market measures water right innovation, water allocation improvement and increasing water pricing also should be emphasized by the policy markers. Our results show that water ownership belongs to the State and reforming water rights system is necessary but needs to consider its potential influence on the poor. Although policy markers consider the equity aspects of water allocation, practices show that the effective implementation of equal allocation seems to be hard. Despite continuously increasing water prices over the past several decades, China's agricultural water is believed to be much under-

priced and should be increased. Due to time and financial limit, our research has not in detail identified the impacts of reforming water rights, allocation and pricing on the pro-poor, however, these important issues will be focused in future related research.

4. Our results show that command areas of specific canal reaches receiving less irrigation water per hectare will not necessarily have lower productivity and a higher incidence of poverty. IDs in the upper reach have been allocated more water than those in the lower reach, the difference is more obvious across provinces. However, distribution of output exhibits relatively equal characteristics that greatly differ from other Southeast Asian countries. As a result, water productivity in the lower IDs is obviously higher than that in the upper IDs. In addition, poverty distribution along the IDs has not presented consistent patterns regarding their access to water. While it could be that access to water and irrigated land accounts for some of the income differences of households, a number of other factors appear to be correlated with income levels of our sample households in the IDs.

5. Our results demonstrate that under existing conditions, small, marginal and poor farmers will not necessarily receive less benefit from irrigation than large and non-poor farmers. Our research shows that small and large farmers have relatively equal access to water. It is worthy to note that the equal water accessibility among farmers (or even in favorable of the poor) is not only achieved through water related institutions and water policies. It may be that there are several policies that are working together to achieve this result (a finding that could have lessons for other developing countries). These policies include equal distribution of land, rapid expansion of off-farm employment, and the allocation and distribution of irrigation water based on the size of a farm's cultivated land. By controlling the influence of other factors, the large-size farmers earn more income than smaller farmers. Access to water and water reliability have a significant relationship with the pro-poor in our sample IDs. Even we have not found that irrigation investment can significantly improve the poverty situation, econometric results demonstrate the significant relationship between irrigation investment and farmer income.

6. By comparing the differences between irrigation and non-irrigation conditions, our study provides evidence of irrigation's strong impact on yield and cropping revenue, both descriptively and in the multivariate analysis. Unlike some of the literature that used aggregate data, we find that irrigation increases yields and cropping revenue when we look at either different crops or examine grain or crops as whole. Moreover, we find that although the marginal impact of irrigation on revenue appears to be higher in richer areas, since the poor relies more on cropping revenue, our findings suggest that farmers in poor areas increase their incomes relatively more than farmers in richer areas.

If irrigation has such a great effect on agricultural performance it is no wonder why so much of the budget of many countries has gone towards irrigation in the past. Moreover, although the costs of the project must be considered, the disinterest that seems to be beginning to pervade the international community in irrigation, needs to be questioned. Our findings of the effect of irrigation on the income of those in poor areas mean that poverty alleviation programs, in particular, must consider increasing or at least not diminish the role of irrigation in their portfolio of activities.

CHAPTER 12

Key Interventions and Actions: The Way Forward

According to our major results, we propose the following pro-poor interventions and action plans to improve the performance of irrigation systems while simultaneously benefiting the poor farmers in the IDs:

Table 12.1. Major issues, pro-poor intervention and action plan.

Issues	Pro-poor intervention	Action plan
Unbalanced development of water management reform	Promote water management reform based on local conditions	1) Analyzing system performance gaps, understanding what changes are required and feasibility of water management reform; 2) Conducting extensive discussion with upper and local governments, farmers and other stakeholders, mobilizing extensive political and legal support; 3) Visiting the reformed regions, learning the experience and lessons 4) Based on full discussions and analyses, drafting and issuing policy documents on the reform; 5) 5) Facilitating teams to work on the process and evaluation.
Poor incentive mechanism to managers	Establish and perfect incentive mechanism to managers	1) Setting objectives of the reform: Objectives generally include increasing water use efficiency, improving irrigation infrastructure conditions, timely supply of water, increasing agricultural productivity and farmer income, pulling farmers out of poverty status; 2) Putting the objectives of the reform into a formal contract, based on the agreed performance standards and actual performance, decide how much profit or welfare managers can get, i.e., connecting the welfare of managers with their performance. 3) Monitoring and evaluating the performance of management by governments, farmers and other stakeholders. If the performance is far lower than the standard, contracting with managers should be stopped.
No or not enough farmer participation	Encourage farmer participation in water management	1) Conducting extensive discussions with farmers on the feasibility of the reform, benefiting from an open exchange of ideas; 2) Building consensus among stakeholders on the choice of management type and possible institutional change; 3) Selecting representatives of farmers and stakeholders to elect the management board of the new management organization; 4) Under the guidance and assistance of upper-level government, the management board and representative of farmers should be involved in drafting the management rules of the organization; 5) Organizing regular meetings to discuss some management issues to make sure that organizations keep up with the changing needs and demands in the external environment. 6) Farmers or their representatives should actively participate in the evaluation and monitoring of the performance of the management.

Weak legal support and poor definition of water right	Strengthen the establishment of legal system for supporting water management reform	1) Issuing regulations to formally adopt the water management policies; 2) Providing legal status to water management organizations; 3) Legally identifying the rights and responsibilities of water management organizations; 4) Legally defining the resolution procedure for water conflict; 5) Legally defining water rights; 6) Granting clear water rights to water management organizations and then to the users 7) Promoting and encouraging the development of water markets while fully considering the potential negative influence on the poor farmers
Absence of capacity building on water management	Provide training on the technical and management ability for managers	Government should provide the following training for water managers: 1) Water measurement 2) Canal operation and maintenance 3) O&M audits 4) Rehabilitation and modernization Water saving technologies
Low water charges	Increase water charge and reform water fee structure	1) Gradually increasing water charge level to promote water savings while providing certain subsidies to poor farmers; 2) Reforming the structure of water fee, adopting the combination of basic and volumetric water fee structure.
Fragmentation of water management	Promote integrated river basin management	1) Strengthening the integrated river basin water management through empowering the river basin commission; 2) Efficiently allocating water among regions and sectors while fully considering the equity issues through applying some policy measures; 3) Assessing the potential of real water saving in the river basin and assessing the overall welfare of water management reform.
Poor physical condition	Improve physical condition by increasing investment and subsidies	Government should continue to provide investment and subsides for periodic rehabilitation of the irrigation system to stimulate, not discourage, investment in maintenance by the water users.

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Appendix A: Calculation of crop water use.

At first, we checked the variable of water use per irrigation by crops estimated by canal managers and village leaders, then we averaged their information to get an average water use per irrigation by crops in the village. According to our survey, near 80 percent of village leaders and canal managers can give a relative accurate estimation on this number, which are generally consistent with local officials' estimation or their experimental results. If existing some heretical data, we will adjust them by the secondary source data and other villages' estimation those having similar physical and water conditions. For the rest of the villages that are hard to estimate water use by crops, they can provide the information on irrigation hours per mu and water depth in the field by crops. Since these information are also provided by those villages that have water use estimation, we will compare these information and then get an estimation of water use per irrigation by crops if these villages have similar physical and water conditions. Finally, each village will get one estimation on average water use per irrigation by crops. We apply this information to each sample household and mutiply it by irrigation times of crops per year in certain land plot answered by farmers and then get annually total water use in the sample land plots of farm households. Household average water use of certain crop is the average water uses of all the plots that planting this crop.

Appendix B: Statistic Description of Major Variables.

	Mean	Standard deviation	Minimum	Maximum
Dummy of WUA management	0.14	0.34	0	1
Dummy of Contracting	0.22	0.39	0	1
Dummy of non-collective with incentives	0.16	0.36	0	1
Dummy of non-collective without incentives	0.20	0.39	0	1
Dummy of governmental intervention for WUA	0.14	0.35	0	1
Dummy of government intervention for Contracting	0.30	0.46	0	1
Age of village leader (year)	43	7	29	55
Education of Village leader (year)	9	3	0	15
Dummy of village surface water irrigation	0.73	0.41	0	1
Dummy of village water scarcity	0.27	0.45	0	1
Village irrigation investment (yuan/ha)	2,824	4,881	0	33,943
Share of village rice area in 1995 (%)	0.19	0.21	0	0.80
Household crop water use per hectare (m^3/ha	15,365	8,739	627	44,580
Wheat water use per hectare (m^3/ha)	5,937	3,909	300	21,000
Maize water use per hectare (m^3/ha)	6,936	4,802	360	27,750
Rice water use per hectare (m^3/ha)	28,882	18,572	1,381	89,072
Household total income (yuan)	1,855	1,426	-42	11,087
Household cropping income (yuan)	806	604	-135	4,285
Dummy of poverty	0.08	0.27	0	1
Age of household head (year)	44	9	24	66
Education of household head (year)	6	3	0	15
Arable land per hectare of household (ha)	0.17	0.12	0.03	1.03
Production asset per capita (yuan)	1,434	2,972	2	32,533
Agricultural production asset per capita (yuan)	906	857	1	4,800
Number of plots per household (number)	7	4	1	23
Dummy of production shock	0.52	0.50	2	1
Wheat yield (kg/ha)	4,740	1,253	375	8,625
Maize yield (kg/ha)	5,760	1,770	600	10,125
Rice yield (kg/ha)	6,900	1,740	1,125	12,855

Data source: Authors' survey.

Appendix C: Number of Plots by Irrigation Type.

	1 Total Plots (2)+(5)	2 Irrigated Plots [a]	3 Surface Water Plots	4 Ground Water Plots	5 Non-irrigated Plots
Major Grains -Aggregate					
Rice	1,813	1,688	1,609	42	125
Wheat	1,097	721	379	315	376
Maize	1,218	552	257	274	666
Major Grains – by Season					
Single Season Rice	1,169	1,053	1,000	33	116
Early Season Rice	197	194	192	1	3
Late Season Rice	197	194	192	1	3
Single Season Wheat	149	18	9	9	131
Wheat-Rice Rotation	239+239	237+237	215+215	6+6	2+2
Wheat-Maize Rotation	495+495	339+339	118+118	210+210	155+155
Wheat-Other Crop Rotation	224	136	46	89	88
Single Season Maize	486	87	34	48	399
Maize-Other Crop Rotation	237	126	105	16	111
Coarse Grains [b]	348	134	47	84	214
Tubers [c]	612	255	230	16	357
Cash Crops					
Cotton	152	133	19	114	19
Peanut	126	81	12	68	45

Data Source: Authors' survey.

[a] Number of irrigated plots include plots irrigated by surface water, by groundwater and by both (conjunctively). Number of plots irrigated conjunctively is not reported here because it is less than 2% of total number of plots. Thus column (3) and column (4) does not sum up to column (2).

[b] Coarse grains includes sorghum, millet, pearl millet, buckwheat and others.

[c] Tubers includes white potatoes and sweet potatoes.

Appendix D: The Impact of Irrigation on Crop Yield with Village fixed effect.

	Dependent Variables: Crop Yield [b]											
	Wheat		Maize		Cotton		Coarse Grain		Tuber			
	Equation1	Equation2	Equation1	Equation2	Equation1	Equation2	Equation1	Equation2	Equation1	Equation2	Equation3	
Irrigation Status												
Irrigated (by Surface Water	0.115		0.149		-0.08		0.145		-0.26		0.019	
or Groundwater)	(2.97)***		(4.24)***		-0.56		-1.05		(2.50)**		-0.17	
Irrigated by Surface Water		0.073		0.107		-0.084		0.395		-0.242		0.044
		(2.08)**		(2.77)***		-0.54		(2.33)**		(2.31)**		-0.4
Irrigated by Groundwater		0.057		0.172		-0.067		-0.198		-0.336		-0.202
		-1.11		(3.55)***		-0.28		-0.99		-0.79		-0.5
Land Characteristics												
Good Soil Quality	0.138	0.14	0.125	0.123	0.56	0.561	-0.13	-0.113	0.171	0.171	0.172	0.173
	(4.88)***	(4.93)***	(3.91)***	(3.85)***	(4.59)***	(4.54)***	-1.31	-1.12	-1.61	-1.61	(1.69)*	(1.70)*
Topography-Plain	0.062	0.06	0.089	0.094		0.271	0.483	0.598	0.026	0.019	0.107	0.115
	-0.77	-0.74	-0.94	-1		-0.92	-1.13	-1.39	-0.08	-0.06	-0.36	-0.38
Topography-Hill	0.035	0.031	0.114	0.114			0.593	0.684	-0.021	-0.015	0.056	0.064
	-0.71	-0.62	-1.38	-1.38			-1.45	(1.66)*	-0.07	-0.05	-0.2	-0.23
Distance from Home	0.022	0.019	-0.024	-0.021	0.193	0.193	0.003	-0.024	-0.019	-0.019	-0.02	-0.021
	-1.57	-1.37	-1.11	-0.98	(2.71)***	(2.70)***	-0.05	-0.35	-0.33	-0.32	-0.37	-0.37
Shock: Severity of Disaster [c]	-0.008	-0.008	-0.012	-0.012	-0.003	-0.003	-0.013	-0.013	-0.003	-0.003	-0.003	-0.003
	(10.43)***	(10.32)***	(17.23)***	(16.91)***	-1.54	-1.52	(5.89)***	(5.76)***	-0.9	-0.91	-0.98	-1
Crop growing length [d]	0.093	0.091	-0.091	-0.086	0.062	0.062	-0.067	-0.075	0.216	0.221	0.288	0.288
	(1.71)*	(1.67)*	(2.12)**	(1.98)**	-0.54	-0.53	-0.47	-0.54	(1.85)*	(1.88)*	(2.55)**	(2.55)**
South Non-irrigated Potato											1.243	1.261
											(6.24)***	(6.32)***
Number of Plots	1027	1027	1112	1112	141	141	277	277	509	509	509	509
Number of Villages	43		47	47	10	10	38	38	50	50	50	50
R-square	0.15	0.14	0.28	0.28	0.26	0.26	0.17	0.19	0.03	0.03	0.11	0.11

[a] Absolute value of t statistics in parentheses. * significant at 10% ** significant at 5% *** significant at 1%

[b] Dependent variable in log form. Estimate using fixed effect model at household level.

[c] Severity of Disaster means percentage reduction of production.

[d] A dummy variable that is 1 if the crop is not grown in conjunction with other crops during the year and is 0 if it is cultivated in rotation with other crops.