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WATER GOVERNANCE AND WATER USE EFFICIENCY: THE FIVE PRINCIPLES OF WUA MANAGEMENT AND PERFORMANCE IN CHINA[1]

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ABSTRACT: In recent years China has attempted to reform water management by decentralizing water management responsibilities. The overall goal of our paper is to better understand the emergence of water user associations (WUAs) in China and assess if they are adhering to the practices spelled out by the Five Principles, a set of recommended practices that are supposed to lead to successful WUA operation. Using four sets of different types of villages to examine implementation and performance, we find that World Bank-supported WUA villages ("Bank villages") can be thought of as operating mostly according to the Five Principles. For example, the Bank villages were endowed with a more reliable water supply; were set up and were operating with a relatively high degree of farmer participation; and leaders were more consultative and the process more formal. When WUAs are run according to the Five Principals, we show that WUAs increase water use efficiency. The study also provides evidence that there is a perception in the Bank villages that water management is improving in general and that there is less conflict both within the village and among villages. Perhaps more importantly, we find that the Bank's effort to promote WUAs extended beyond their own project villages. The openness, consultative nature, and transparency found in the Bank WUAs are also found (albeit at a somewhat lower level) in the non-Bank WUA villages.

(KEY TERMS: water user associations; water governance; evolution; performance; China.)

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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). Unfortunately, many traditional methods (such as increasing water supply and extending water saving technologies) have not been able to overcome the nation's water problems (Lohmar *et al.*, 2003). Because of the difficulties in the implementation of other policies to combat China's growing water crisis, like other countries in the world, policy makers in China have turned to water management reform. Unfortunately, in many places top-down water management reforms have been tried and they have frequently failed (Nian, 2001).

In response, in recent years, China, as in a number of other countries internationally, has attempted to reform water management by decentralizing water

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management responsibilities (Johnson *et al.*, 1995; Meinzen-Dick *et al.*, 2002; Wang *et al.*, 2005). In one incarnation, formal government water organizations have transferred management responsibilities to local water managers. In order to improve the performance of the irrigation system, irrigation officials offer incentives to water managers and encourage the participation of farmers in system management (World Bank, 1993; Merrey, 1996; Bandaragoda and Memon, 1997).

While there have been some successes, not all decentralized water management reforms—either inside or outside of China—have been implemented successfully. The literature has documented many successes. For example, water management reforms in Mexico, Turkey, Colombia, and the Philippines have been considered as successful cases (Groenfeldt and Svendsen, 2000). However, there are cases of decentralizing management control over water that have failed (Easter and Hearner, 1993; Vermillion, 1997; Groenfeldt and Svendsen, 2000). Like similar attempts in other countries, the record in China seems to be mixed, although most evaluations are only based on anecdotes or case studies (Huang, 2001; Nian, 2001; China Irrigation District Association, 2002). While success in implementing pilot water management reform programs has led to calls for their expansion nationwide, effective implementation of the reform has been difficult (Ma, 2001; Management Authority of Shaoshan Irrigation District, 2002). Visits to the field can easily uncover cases in which local water management reforms were implemented and failed. Recent reviews of the literature in the context of Asian agriculture largely concur with these findings. At best success has been modest (Mukherji *et al.*, 2009), although decentralized reforms have worked in situations where irrigation has been central to a dynamic, high-performing agriculture and where benefits from managing the system outweighed the costs of management (Shah *et al.*, 2002).

Facing the challenges of coming up with a viable model to manage water resources in China, the World Bank began to introduce pilot water management programs that have mostly focused on promoting water user associations (WUAs) (World Bank, 2003). According to the water management literature, WUAs are farmer-run, participatory institutions that are created to take the place of traditional, village leader-run water control organizations. Introduced from the experience of the World Bank and other organizations from outside China (Xie, 2007), the initial effort to introduce WUAs was done as a way to increase water management efficiency in a system that was in disarray in the wake of the nation's economic reform. At least in the areas in which the WUAs were initially implemented, they were reported to work well, improving the efficiency of water use, productivity, and income (World Bank, 2003).

The experience of WUAs across China, however, has not always been positive. In one study in Ningxia (of WUAs that were not introduced by the World Bank) WUAs were found to have little impact on water use, crop yields, or income (Wang *et al.*, 2006). The study found that, in fact, participation was quite low and that many of the so-called reforms were only nominal in nature.

Perhaps because of the mixed performance, shortly after the launching of the WUA movement in China, those that believed that WUAs were a way to effectively manage water began to formalize the basic precepts that were needed to run a successful WUA. Specifically, in the mid-1990s World Bank project managers delineated a set of five principles that they believed were necessary for the successful implementation of a decentralized water management reform based on WUAs. Principles 2 to 5 were first explicitly spelled out in the mid-1990s (World Bank, 2003). At a somewhat later date (a couple of years later in the late 1990s), project managers added one more principle (which we have included as Principle 1) (Xie, 2007).

The *Five Principles* are:

- Principle 1—adequate and reliable water supply: A WUA is organized only where an adequate and reliable water supply is available and where on-farm delivery infrastructure is in good condition and can be properly maintained by WUA members;
- Principle 2—legal status and participation: A WUA should be the farmers' own organization, a legal entity and have a leadership elected by its members;
- Principle 3—WUAs organized within hydraulic boundaries: The jurisdiction of a WUA should be the hydraulic boundaries of the delivery system;
- Principle 4—water deliveries can be measured volumetrically: A WUA should be able to receive its water under contract from its water suppliers and water should be able to be measured volumetrically;
- Principle 5—WUA equitably collects water charges from members: A WUA should equitably assess and collect water charges from its members and make payment for the cost of water.

At least since the late 1990s, then, in China World Bank water project teams and some of their government collaborators have insisted that any successful WUA program would necessarily be based on the so-called Five Principles. Surprisingly, given the high profile that the World Bank's WUA projects have assumed, in fact, there has never been a rigorous evaluation conducted by an independent research team. Since their introduction, no one knows the answer to the question: How have WUAs spread across China? In the areas that have been implemented by the World Bank, how have they been implemented? Have project managers followed the Five Principles? When the World Bank implements WUAs, is there any evidence that China's own water officials have learned from the efforts? Do WUAs matter? Is there evidence that when WUAs are implemented that water use falls, crop yields rise, and efficiency increases?

The overall goal of our paper is to answer these questions about the emergence of WUAs and their effectiveness in addressing China's water management challenges. To meet this goal, we have three specific objectives. First, we document the evolution of WUAs over time. Second, we seek to examine the nature of China's WUAs, and do so by assessing whether or not they are being organized on the basis of the Five Principles. Finally, we want to measure the effect of WUAs that were created on the basis of the Five Principles and those that were not.

It should be noted that the broad nature of this goal and the specific objectives mean that we must narrow the scope of the analysis to be able to focus our analytical efforts and work with the data that we have been able to collect. In simplest terms, after tracking the emergence of WUAs over the past decade, we will examine the differences in the ways that different types of WUAs (and villages without WUAs) organize water control activities. There are four types of water management institutions that will be a part of our analysis: Bank-supported WUAs; WUAs in areas adjacent to the World Bank project sites (non-Bank WUAs); WUAs in non-World Bank areas (in particular, in our Ningxia sample—or Ningxia WUAs); and collective water management institutions (i.e., villages that manage water the traditional way—or villages in China where the village leadership (or, the leaders of the collective)—manages the water). After documenting the differences in the types of ways that villages manage water, we then examine differences in the performance of villages. In other words, our unit of analysis becomes the type of institution (Bank WUAs; non-Bank WUAs; Ningxia WUAs; and collectively managed villages).

To meet these objectives, the rest of the paper is organized as follows. First, we document the evolution of existing and new water management institutional forms over time and across provinces throughout northern China. In the next two sections we discuss the data and then use them to examine how WUAs are organized. In the discussion on the nature of WUA organization, differences among the different types of WUAs are examined. In the Performance section we look at differences in the ways that different types of WUAs have affected performance. In the final section we conclude.

WATER MANAGEMENT REFORM IN NORTHERN CHINA

The North China Water Resource Survey (NCWRS) was used for the analysis in this section. The survey was conducted in January 2005. In order to generate a sample representative of northern China, the study team designed a stratified random sampling strategy. To do so, we first randomly chose six provinces—Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi, and Shanxi. The research team then divided the counties in each study province into four water scarcity categories—very scarce, somewhat scarce, normal, and mountain/desert. Two townships within each county and four villages within each township were then randomly selected. In total, the data collection team visited 60 counties, 126 townships, and 401 villages. In the NCWRS survey we only interviewed village leaders (and did not interview farmers or canal managers—due to limitations in time and budgetary funding). The survey collected data on most variables for 2 years—2004 and 1995.

The scope of the survey was quite broad. The survey instrument included sections that focused on the nature of water resources in the villages, government policies, adoption of water-saving technology, and the condition of village irrigation infrastructure. The key section of the survey for this paper came from the surface water management block. In each village the enumerator asked the respondent a series of questions about how the surface water system was managed in their village. For example, the survey included questions about each major task that was carried out to operate and maintain village canals. We also asked who took on the responsibility for each task. Based on the answers of each respondent, we determined under which type of water management form each village was being operated.

Based on our field surveys, after upper-level officials promoted the reforms, surface water is managed in three general ways. If the village leaders (i.e., the village committee) directly take responsibility for water allocation, canal operation and maintenance, and fee collection, the village's irrigation system is said to be run by *collective management*, the system that essentially had allocated water in most of China's villages during the People's Republic period. In this paper we will refer to the collective management system as the traditional system. In contrast, a WUA is in principle a farmer-based, participatory organization that manages the village's irrigation water. In WUAs a board, which is supposedly elected by villagers, manages the village's water and facilitates farmer participation. *Contracting* is a system in which the village leaders contract the village's canal out to an individual, who will then manage the canal in return for a payment that may or may not be related to the size of water savings he/she can achieve. In the rest of the paper, we will treat WUA and contracting as reform-oriented management system.

The Emergence of WUAs, 1995 to 2004

According to our data, WUAs and contracting have gradually emerged in northern China between 1995 and 2004. However, tracking these changes is complicated by the changing nature of China's water resources (Table 1). In 1995 of the 481 sample villages, 235 had surface water irrigation (column 1, row 9). During the survey the enumerators found that of the 235 villages, 30 had stopped using surface water by 2004 (row 8). During the same period, 17 villages used surface water in 2004 but not in 1995 (row 10). In total, 205 villages (235 minus 30) used surface water in both 1995 and 2004.

When examining the villages that used surface water in both 1995 and 2004, our data reveal a clear tendency in the ways that villages are reforming their water management structure (Table 1, row 1). Of the 181 villages that were being managed under the collective management in 1995 only 143 were still managed in this way in 2004 (columns 1 and 2). This means 38 villages (21%) implemented some form of water management reform.

The reform efforts during the 1995 to 2004 time period were split almost exactly between shifts to WUAs and contracting (Table 1, row 1, columns 3 and 4). Villagers in 14 villages chose to create WUAs (column 4). Villagers in 18 villages shifted into contracting. There were also six villages that reformed only part of their village's surface water system or chose a mix of WUAs and contracting (columns 5 to 8).

While the trends in northern China's villages are clearly reform-oriented, it is interesting to note that in villages that had already reformed by 1995, there is some evidence that villagers are continuing to experiment with different institutional forms and are not afraid of going back to collective management. For example, of the eight villages that had created WUAs to manage their surface water systems in 1995, three had either discontinued or partially

TABLE 1. Transition Matrix of Changes in the Forms of Surface Water Management in Northern China Between 1995 and 2004.

		Water Management Institution in 2004							
	Forms of Surface Water Management in 1995	**(1) Number of Sample Villages**	**(2) Collective Management**	**(3) WUA**	**(4) Contracting**	**(5) WUA and Collective Management**	**(6) WUA and Contracting**	**(7) Contracting and Collective Management**	**(8) WUA, Contracting, and Collective Management**
1	Collective management	181	143	14	18	2	2	1	1
2	WUA	8	2	5		1			
3	Contracting	11	1		9			1	
4	WUAs and collective management	1		1					
5	WUAs and contracting	1		1					
6	Contracting and collective management	2	1		1				
7	WUAs, contracting, and collective management	1		1					
8	Villages that shut down SW irrigation between 1995 and 2004	30							
9	Total villages with SW irrigation in 1995	235	—	—	—	—	—	—	—
10	Villages with new SW irrigation created between 1995 and 2004	17	14	1	1	1			

Source: 2004 NCWRS and 2001-2004 CWIM Panel.
SW, surface water; WUA, Water User Association

discontinued the experiment by 2004 (Table 1, row 2, columns 1, 2, and 5). Two of the 11 villages that chose contracting systems in 1995 decided to either fully or partially go back to collective management by 2004 (row 3, columns 1, 2, and 7). These shifts into and back out of WUAs and contracting may indicate that water management reform is not universally successful. This is of concern to national leaders that are worried about whether or not surface water management reform is suitable to China's villages.

So how should one interpret the trend of water management reforms between 1995 and 2004 in northern China? Our data show that the changes were significant. The share of collective management declined from 90% in 1995 to 73% in 2004. WUAs and contracting have developed at about the same pace. By 2004, 10% of villages managed their surface water through WUAs and 13% through contracting. The mixed systems also rose from 2 to 4% between 1995 and 2004. While collective management still is the dominant form of management, in total 27% of villages in northern China had been affected by water management reform by 2004.

Data Sets for Assessing the Nature of WUAs and Their Effectiveness

The analysis in the paper is based on two surveys. The first survey, the China Water Institutions and Management survey (CWIM), was conducted in 2001 and 2004. Enumerators conducted surveys of village leaders, surface water irrigation managers (including WUA leaders), and households in 32 villages in Ningxia provinces. The study team also conducted a second set of intensive surveys in 2006 in three World Bank sites. Henceforth the survey is called the Bank Survey. The three sets of sites are in three provinces, Gansu, Hubei, and Hunan (Figure 1) (Appendix A). Each of the sites (henceforth, *Bank survey sites*) was situated in one Irrigation District (ID) in each province—except in Gansu in which we worked in three IDs.

For the Bank survey, after the sites were selected we randomly selected the study villages. To do so, in each province we first randomly selected 10 villages from the list of the Bank WUA candidate villages. Henceforth, these are called the Bank WUAs or Bank villages. After these were chosen we then asked for the ID and water bureau personnel to identify a sublist of all villages from the list of non-Bank candidate villages which were in the same physical proximity as the Bank WUAs. We also had them identify a sublist of all villages from the list of collectively managed candidate villages that were in the same physical proximity as the Bank WUAs. Our definition of "same physical proximity" was 10 km or the closest set of 10 villages (if there were not any within the circle with a 10-km radius). From these two sublists (in each of the three sets of IDs) we chose five villages—which made a total of 15 non-Bank WUAs (in 15 non-Bank villages) and 15 collectively managed villages. In total we chose 60 water management institutions in 60 villages, which were made up of 30 Bank WUAs, 15 non-Bank WUAs, and 15 collectively managed villages. It is unfortunate that in the three regions in the three study provinces (Gansu, Hubei, and Hunan) which were studied in this paper we did not find any villages that had adopted contracting. A comparison of WUAs to contracting (in addition to collective management) would be both interesting and informative. However, as there was no contracting in any of the sample regions, it was impossible to study this institutional form. It is for this reason that the interested reader will have to rely on our previous work in other regions of China (Wang *et al.*, 2005; Huang *et al.*, 2008). It should be noted that we use villages as the unit of survey, even though WUAs are sometimes made up of multiple villages. As we randomly select the village within the WUA, we are getting a representative view of the WUA. This design was carried out this way in order to make the Bank study consistent with the previous work.

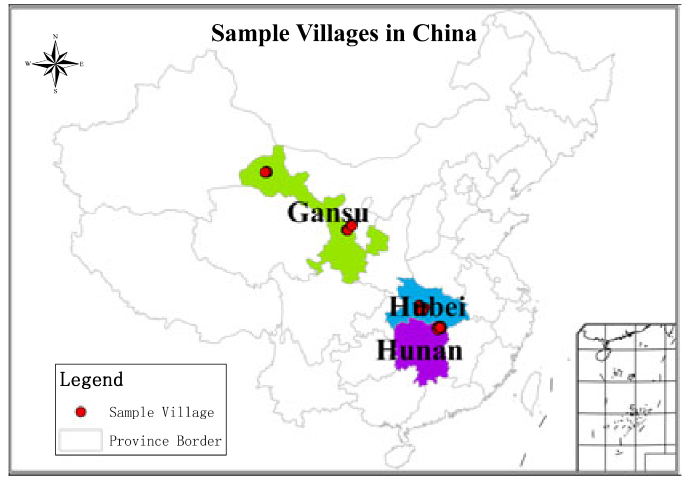


FIGURE 1. Sample Location of Bank Survey.

In each of the villages, we implemented a survey aimed at understanding the organization of water management institutions in each village and the impact that it may have had on agricultural production and incomes. There were two kinds of respondents. The first is the village leaders and the head of the WUA executive committee who are most familiar with water management issues at the village level. The second one is farmers whose agricultural production is directly influenced by the water management in the village. For the farmers' survey, we have adopted the pattern of focus group discussion. In each group, five farmers are included.

The CWIM and Bank surveys were structured in a similar way and were both quite broad. Each of the survey instruments included more than 10 sections, including sections focusing on the nature of rural China's surface water resources and groundwater problems. Several sections examined government policies and regulations, such as the extent of the effort of the government to promote water management reform, in general, and WUAs, in particular. It was important to collect information on these other factors as it is possible that these factors affect water use, crop choice, yields, and income, and as a result need to be controlled for. These data can be used to compare the differences between villages that were chosen to be Bank WUA villages and villages that were not. Other sections examined issues of water-saving technology and the infrastructure of the village water sector. The two surveys were structured in a similar way so the results from the Bank Survey could be compared to the results of the CWIM survey (as the villages in the CWIM survey serve as one of the control groups).

ORGANIZING CHINA'S WUAS: THE FIVE PRINCIPLES?

In this section we use data from the CWIM and Bank Surveys to document the nature of China's WUAs. Because of the alleged importance of the Five Principles, we will use this as the way to organize the analysis. We also examine ways in which different types of WUAs are treated differently—in ways not related to the implementation of the Five Principles.

The Underlying Logic of the World Bank Principles

In two of Elinor Ostrom's most well-known papers on the determinants of success of collective action (Ostrom, 2000, 2009), she discusses the elements that are needed for institutions that require collective action to succeed and survive. In fact, these treatises can help identify the more general, underlying logic of the Five Principles of the World Bank's WUA development efforts. First, Ostrom emphasizes that the nature of a resource system's current productivity is an important determinant of whether or not collective action is feasible (Ostrom, 2009). According to Ostrom (2000), if a water resource is already exhausted, local users will not see a need to manage the resource. Hence, in this way Ostrom's logic can help explain why the World Bank made "access to an adequate and reliable water supply" their first principle for organizing WUAs. If there is not a reliable water supply, or if the water system's delivery infrastructure is in poor condition, the high cost and low potential benefit from the effort needed to organize an active WUA will discourage participation.

The second principle proposed by the World Bank is also consistent with the ideas of Ostrom. In order for WUAs to succeed, Principle 2 states that the WUA should be the farmers' own organization and it should have a leadership elected by its members. In defining a successful model of collective action, Ostrom (2000) states that most individuals in the resource command system should be a part of the system that makes and modifies the rules (Ostrom, 2000). When users have full autonomy to craft and enforce their own rules, the collective body will face lower transaction costs in managing the resource (as well as lower costs in defending a resource against invasion by others). In addition, according to Ostrom, most long-surviving resource regimes select their own monitors (or leaders), who are accountable to the users or are users themselves and who keep an eye on resource conditions as well as on user behavior (Ostrom, 2000). This, too, is a transaction cost-based argument as when leaders are respected, and themselves are local users and are known to the group and have legitimacy, self-organization is more likely to be sustained (Ostrom, 2009).

Ostrom's work can also be used to explain the inclusion of Principle 3 in the World Bank's WUA prescription (which states that WUAs should be organized within hydraulic boundaries of the delivery system). In fact, when discussing the principles of long-surviving, self-organized resource regimes, the presence of clear boundary rules has been listed as the first principle (Ostrom, 2000). Under this principle, participants can know clearly who is in and who is out of a defined set of relationships and thus with whom the members should cooperate. In the case of a surface water irrigation system, if a WUA manages all of the water within a single, well-defined hydrological boundary, it will be easier for the members of the WUA to realize who is inside and outside and why they need to integrate decisions about water allocation and water delivery coordination. When all of the water that enters a single catchment is the extent of the resource that needs to be managed, the information problems are lessened and management decisions are made clearer.

Finally, Principles 4 and 5 are also consistent with the ideas of Ostrom's collective action theory. The World Bank suggests that WUAs should be able to receive their water under contract from their water suppliers and that the water should be able to be measured volumetrically when receiving water from water suppliers (Principle 4). It also suggests that the WUA should equitably assess and collect water charges from its members in a way that the amount of the water payments is sufficient to cover the costs of the resource management and delivery (Principle 5). In her theory of successful collective action, Ostrom believes that it is important that local rules-in-use should be able to restrict the amount, timing, and technology of harvesting the resource, allocate benefits proportional to required inputs and that rules of access to the resource (and payment for the resource) are crafted in such a way that they take local conditions into account. When this happens, there is a sustainable balance of inputs and outputs that relieves stress on the organization. In many ways this is what is accomplished when WUAs sign the formal contracts with the Irrigation District for delivering a certain amount of water (that can be measured volumetrically). The payment scheme of farmers for the water is also important for these reasons. When the amount of water that is to be delivered is known and the payment for the water is borne by the members, better decision making can be made (as savings are shared; and expansions are jointly financed and enjoyed).

Principle 1—Adequate and Reliable Water Supply

The data that we collected in the Bank WUA, non-Bank WUA, collectively managed, and Ningxia WUA villages demonstrate that the Bank villages were not randomly chosen in terms of access to reliable supplies of irrigation water. According to our findings, Bank villages had a number of characteristics that endowed them with more reliable supplies of water (Figure 2, panel A). For example, in a number of ways the infrastructure of Bank village was better. While 90% of the cultivated land in Bank villages was irrigated, only 63% of the cultivated land was irrigated in collectively managed villages. The canal system itself was also better. In 93% of the villages, the branch canals had lining. In contrast, only 79% of non-Bank, 50% of collectively managed, and 22% of Ningxia villages had lined branch canals. Moreover, more than 85% of the length of the branch canals was lined; while the share was lower in all of the other villages and less than half in most of the other villages.

The nature of the scarcity of water also differed among the types of villages (Figure 2, panels A and B). According to our data, the farmers in Bank villages faced less water shortages and had access to more abundant and flexible water resources. While

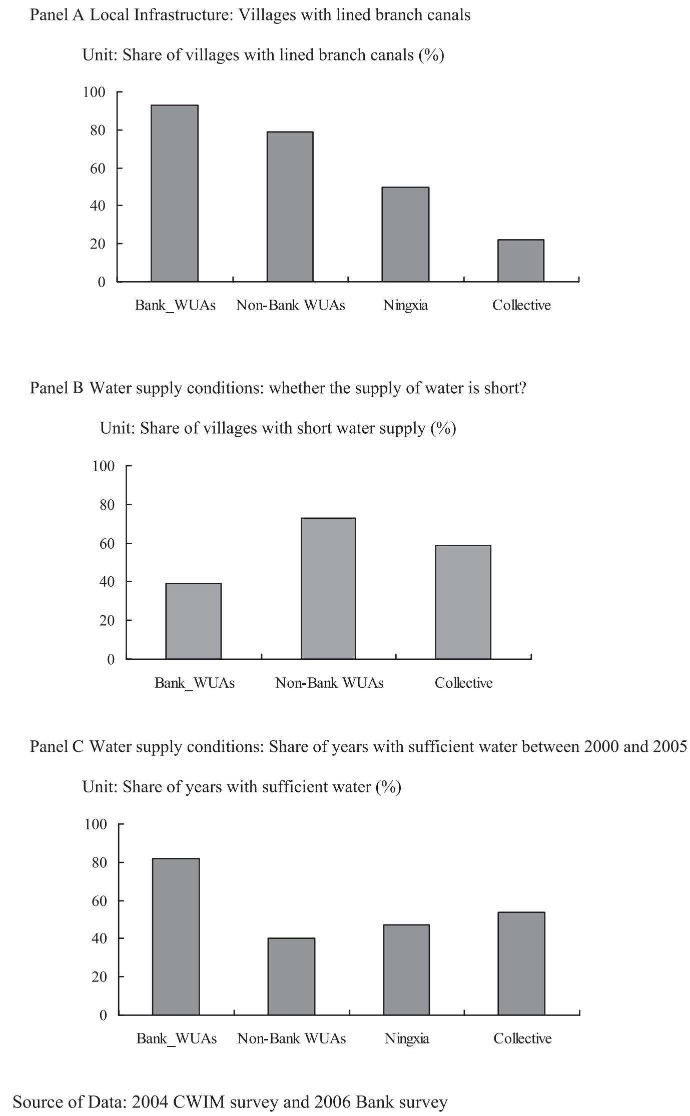


FIGURE 2. Local Infrastructure and Water Supply Conditions.

farmers in 93% of non-Bank villages claimed water was scarce, those in 60 to 67% of Bank and collective villages said water was scarce. When a follow-up question was asked about the perception of the share of years between 2000 and 2005 that water was in sufficient supply, the responses by farmers in Bank villages suggest that water was more abundant in these villages (80%) than when compared with the non-Bank, collective, and Ningxia villages (40 to 60%).

Although for space constraints, we do not show the data here, the perception of village leaders was consistent with the perception of farmers. While in 46% of collectively managed villages, in 53% of Ningxia villages, and in 60% of non-Bank villages leaders and WUA managers stated that there were years of water shortages in the early 2000s (between 2002 and 2005), village leaders and WUA managers in only 19% of Bank villages stated that there were years without enough water. Moreover, according to village leaders, there was better access to conjunctive water use (i.e., there were groundwater resources available even if there were shortages in deliveries of surface water) in Bank villages (47%) than in collectively managed villages in the Bank survey sites (0%) or the Ningxia villages (3%).

Principle 2—Legal Status and Participation

The legal status also differs between Bank villages and villages outside of the Bank site (i.e., in Ningxia—Table 2). For example, WUAs inside Bank sites are somewhat more formal than other WUAs. In 100% of Bank and non-Bank villages, the WUA has a constitution (row 1). In contrast, fewer Ningxia WUA villages (80%) have constitutions.

Greater differences appear when looking beyond the relatively simple formality of having a written constitution (which can often be copied from a publically available document). According to our data, 100% of Bank villages and 80% of non-Bank villages have registered their organizations with the local Civil Affairs Bureau as an "official WUA" (Table 2, row 2). For Ningxia WUAs this is only 30%. Moreover (and in part because of their more formal legal status), in terms of written contracts that guide water transactions between villages/WUAs and the ID, the Bank villages are also somewhat more formal (row 3). In 86% of Bank villages, WUA managers have a written contract with the ID. This is true of 67% of non-Bank villages. However, the share of villages in Ningxia with water delivery contracts with the ID is much lower (only 20%).

TABLE 2. The Difference of Water User Associations (WUAs) in Different Types of Villages.

	Bank Village WUA	Non-Bank Village WUA	Ningxia Village WUA
Share of WUAs having written constitution (%)	100	100	90
Share of WUAs that registered (%)	100	80	30
Share of WUAs having written contract with irrigation districts (%)	86	67	20
Share of WUAs in which farmers participate in meetings (%)	96	93	19
Share of village farmers participating in meetings (%)	25	11	2
Share of WUAs in which the chair is village leader (%)	19	20	85

Source: 2004 CWIM survey and 2006 Bank Survey.

In the same way that there are differences between Bank WUAs and WUAs in non-Bank sites in procedures that are involved with setting up WUAs, there also are sharp differences in participation once the WUAs are in operation (Table 2, rows 4 and 5). In both Bank and non-Bank villages (96 and 93%, respectively), farmer-respondents confirmed that WUA management and operation meetings were open to the participation of farmers. In only 19% of villages in Ningxia, however, did farmer-respondents say meetings were open. The rules on meeting openness translated into higher farmer attendance in management meetings—especially in the case of Bank villages. The rate of participation by farmers was 25% in Bank villages (i.e., one of four farmers in the village attended at least one meeting during the year). The share of participation was 11% in non-Bank villages. It was only 2% in Ningxia villages.

Finally, the differences in participation rules and rates between villages in the Bank site and villages in Ningxia also are correlated with differences in governance. In 85% of the villages in Ningxia the village leader is also the formal head of the WUA. During many interviews with farmers we discovered that when the village leader was the head of the WUA many farmers believed that there was only a change in the name of the water management institution and that there was no substantive change. In the case of the Bank (non-Bank) villages, however, only 19 (20) % of WUAs were headed by the village leader. Clearly, it appears as if there were true governance differences between villages inside and outside of Bank project sites.

Principle 3—WUAs Organized Within Hydraulic Boundaries

We can also use our data to show that there are differences in the principle used to set up WUAs with regard to the hydraulic boundaries of the delivery system. In the Bank villages and in the non-Bank villages (within the Bank project site) all (100%) of the villages are in WUAs that are created within the hydraulic boundaries of the irrigation delivery system. The Ningxia non-Bank WUAs, however, violate this principle. In more than 50% of Ningxia WUAs, the hydraulic boundaries do not completely align with WUA boundaries. In a majority of the villages, the WUA is superimposed on a single village while the village's water delivery system is shared with another village. Of course, in some sense, this difference in the execution of Principle 3 may be responsible for the observed differences in governance. When more than one village is involved in a single WUA, there are many reasons why a village leader (who might be perceived as favoring his/her villagers over others) would not be elected WUA chair.

Principle 4—Water Deliveries Can Be Measured Volumetrically

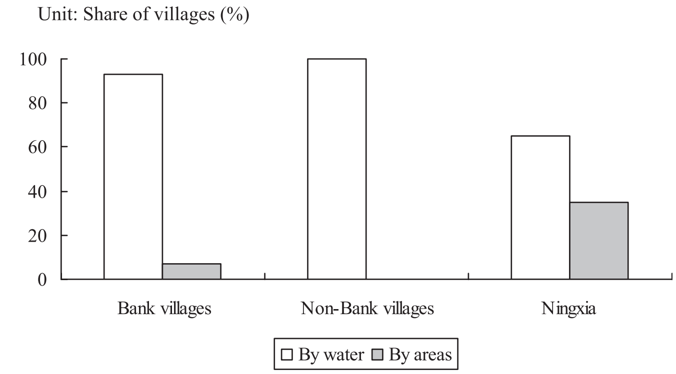
Similar to the other three principles, the organizers of WUAs in the Bank sites (in the case of WUAs in both the Bank and non-Bank villages) also have been successful in implementing Principle 4. According to our survey, water managers in Bank (non-Bank) villages pay for water by water use in 93 (100) % of the villages (Figure 2). This means that in most or even all villages, water can be measured (and charged for) volumetrically. Because of this, of course, in these villages there should be large incentives to save water. In the Ningxia villages, however, this number is lower. Only 65% of WUA villages can pay the ID for water according to how much water was used, and 35% of villages still pay for water deliveries by area.

Principle 5—Nature of the Way in Which WUA Collects Water Charges From Members

In assessing differences in the ways that WUAs and other water management organizations manage the collection of water fees there are a number of fundamental differences. One of them, however, is not "if water fees are collected." All villages in our sample—100% of Bank WUAs, non-Bank WUAs, Ningxia WUAs, and collectively managed villages—collect water fees from farmers (Figure 3).

Beyond the fact that water fees are collected, however, villages differ in the other ways that fees are managed. Bank and non-Bank WUAs in Bank sites exerted effort to make the size and basis of the water fee charge (from the WUA to the farmer) transparent (Figure 4, panel A). More than 90% of farmers in the WUAs in Bank sites said they knew that the nature of the water charge from the WUA to them was well publicized. Only 5% of Ningxia WUA farmers and no farmers in the collectively managed villages (in Bank project sites) were aware that information on water fees was being displayed in the village.

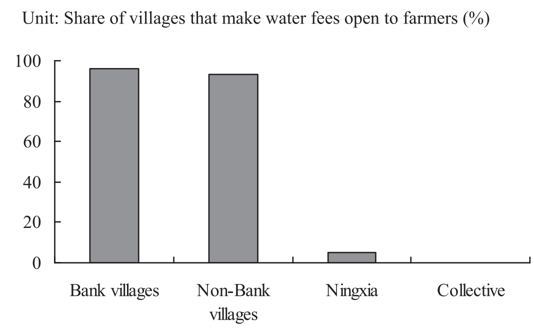
Likewise, farmers in most Bank WUA villages (67%) and non-Bank WUA villages (57%) had their water fee reduced if they used less water (Figure 4, panel B). This occurred in only 5% of Ningxia WUAs. In other words, WUA officials in the Bank sites provided an incentive (or at least compensation) to farmers when they used less water.



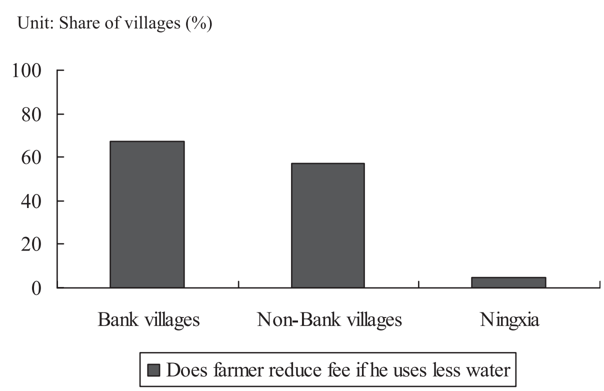
Source of Data: 2004 CWIM survey and 2006 Bank survey

FIGURE 3. Way of Charging Water Fee from ID to Village/WUA.

Panel A Transparency of WUA management



Panel B Water fee-based incentives for farmers to participate



Source of Data: 2004 CWIM survey and 2006 Bank survey

FIGURE 4. Nature of Way in Which WUAs Collect Water Charges From Members.

A Summary: The Five Principles and Best Practice

When summarizing the findings from the previous two subsections we, in fact, find that the Bank WUAs (as well as non-Bank WUAs in the Bank sites) are being implemented largely—though not fully—in ways that are consistent with best practice or the Five Principles (Table 2). According to the Five Principles, WUAs have access to adequate and reliable water supply (row 1); they should have clear legal status and encourage farmer participation (row 2); they should be organized within hydraulic boundaries (row 3); they should be able to receive water from the ID that is measured volumetrically (row 4); and they should have clear and reasonable water fee systems—between the WUA and its members (row 5). As seen from our summary table, the WUAs in the Bank villages—when compared with non-Bank villages and—especially Ningxia villages—are using best practice (at least in a relative sense). There is room for improvement—particularly in the implementation of Principle 4. However, our data make it clear that the ranking of the types of villages is clear: The Bank villages in the Bank sites are implementing WUAs in closest compliance with the Five Principles. Remarkable (perhaps) is that the non-Bank WUAs in the Bank sites are a close second. Clearly, there is either learning or extension efforts that are spilling over from the Bank to the non-Bank villages. The Ningxia villages rank far lower.

In the literature, there is evidence that WUAs require ongoing support to survive. Therefore, one concern is that the measured differences in performance between Bank WUAs and other institutional forms may be due to the ongoing support and not to differences from applying the Five Principles (or the spillover from applying the Five Principles). According to our survey, while the earliest WUA was established in 1998, by 2005 all of the WUAs in the sample had been established and the implementation phase of the project was completed. Moreover, although there was a Bank project office still in existence after 2005, these were mostly staffed by local water officials, who received relatively little external assistance and were charged with carrying on all of their other responsibilities. As our survey was organized in 2006, we believe that by far most of the marginal differences among Bank, non-Bank, and collectively managed villages are mostly explained by the spread of ideas about the Five Principles. There may be a bit of residual effect from special, ongoing extension support, but, it is most likely only minimal.

PERFORMANCE

In this section we have two distinct parts. The first part looks at how the WUAs in the different types of villages have performed in terms of "implementing their procedures and changing their management approaches." Because of the obvious possibility that WUA managers may exaggerate the extent of the changes that they have made, in this section we rely on the observations and opinions of farmers only. In the second part, we examine the impact that different types of WUAs have had on how water is managed and impact on water use, yields, income per capita, and the cropping patterns. Although we include the descriptive analysis here, in Appendix B, we refer to multivariate analysis that, for the most part, is consistent with our descriptive findings.

It is possible, of course, that the differences that we measure between Bank WUAs and non-Bank WUAs and between Bank WUAs/non-Bank WUAs and villages managed by traditional collective management institutions are due not just to the adoption of the Five Principles of WUA management. It may be that there is something unobservable that may be creating the measured difference (i.e., there may be a problem of endogeneity due to unobserved heterogeneity). We recognize this danger. And, as a result in our paper, we believe that we did as much as possible—given that the Bank and non-Bank WUAs were not randomly assigned. We used multivariate analysis, holding constant a number of observable factors before examining the effect of the Five Principles (and/or of WUAs as a management entity). We chose our sample carefully in order to minimize unobserved heterogeneity (at least that which is due to the location of the villages) by choosing the non-Bank WUA villages and collectively managed villages that were geographically close to Bank WUA villages. We also compare the Bank WUAs with WUAs in another environment (those in Ningxia). All of these efforts were made to minimize the problems of endogeneity due to the existence of unobserved heterogeneity. But, it also is important to remember that that while the results may be still affected by some unobserved heterogeneity, when comparing our results against the previous literature on WUAs (where there is almost no effort to consider these problems), our results are likely one of the strongest efforts to yet appear in the literature.

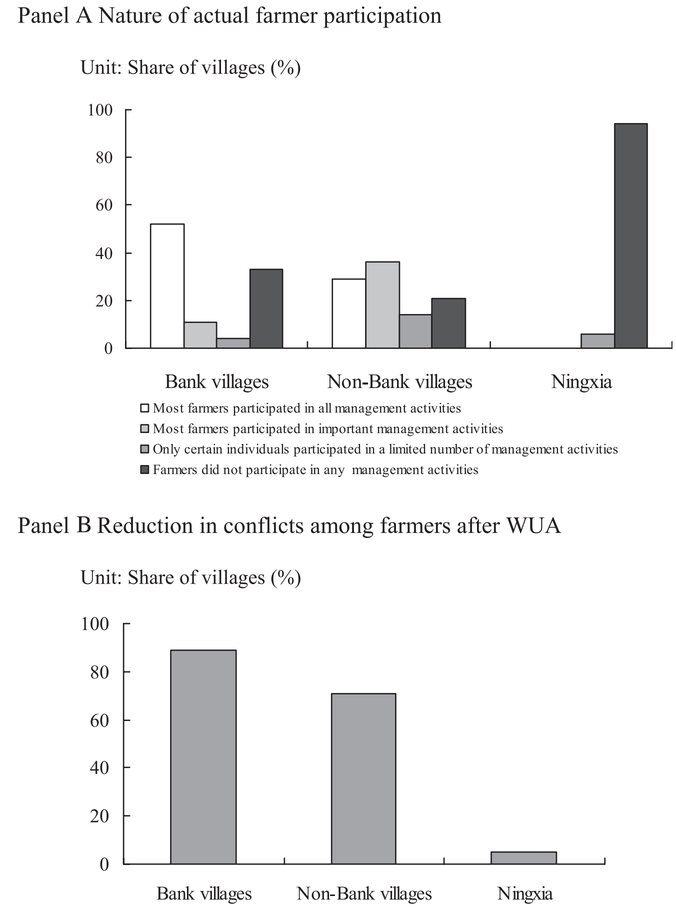
Impact on Management Practices and Outcomes

Our findings are able to make the point that the promotion of Bank WUAs, in fact, has made a significant and material difference in the way that WUAs execute management practices. This can be seen in two ways. First, we can compare Bank WUAs with non-Bank WUAs in terms of how they use each individual management practice. When doing this, we can see that the differences are significant. Specifically, in the case of 30% of the Bank villages, farmers reported that there were new management procedures (which resulted in improved coordination of irrigation deliveries). While low, it is true that this number is only 17% for non-bank WUAs. The difference is about 43% [(30 − 17)/30]. Similar differences can be found in comparing the other management practices, such as new canal maintenance activities (100% difference), new water saving practices (64% difference), and “concrete” changes on management (42% difference). In relative terms, our study found consistently measured differences in management practices.

Second, we can also see the differences when we create a more comprehensive measure for the change of any management practice. In total, at least one change (new ways of coordinating deliveries; canal maintenance; new water saving practices; or change management procedures) was made in 93% of Bank villages and 43% of non-Bank villages. When examined in this way, the difference between Bank and non-Bank villages is both significant in relative terms [54% (93 − 43)/93] and in absolute terms [i.e., 50 percentage points (93 − 43)]. Hence, based on this empirical evidence, we do not believe that it is erroneous to conclude that the implementation of Bank WUAs has led to better management practices.

While specific changes in water management practices were not perceived by farmers in all villages (most, but not all), there was an overwhelming perception by farmers that some of the ways of doing business improved. In 96% of Bank villages and 93% of non-Bank villages farmers reported that information on the volume of water use was communicated to the members of the WUA in a transparent manner. Farmers in most villages—both Bank villages (77%) and non-Bank villages (100%)—also told enumerators that the WUA leadership shared with the membership in an open way information on the total area that was irrigated (a number that is important in some villages to keep track of and calculate water charges). Hence, while some villages may not have changed the exact technical activities by which they managed water, according to our data, almost all villages began to change the way that they do business and relate to the farmers in the village.

The perception by farmers about the degree to which they participated in irrigation management (as opposed to the physical act of attending meetings, which was reported in Table 2 above) also shifted—especially in Bank villages (Figure 5, panel A). Farmers in more than half of the Bank villages reported that most farmers in the villages (any that wanted to) actually participated in (and could in part influence) all of the management activities. Farmers in another 11% of villages said that most farmers participated in what they believe were the important



Source of Data: 2004 CWIM survey and 2006 Bank survey

FIGURE 5. Performance of WUAs.

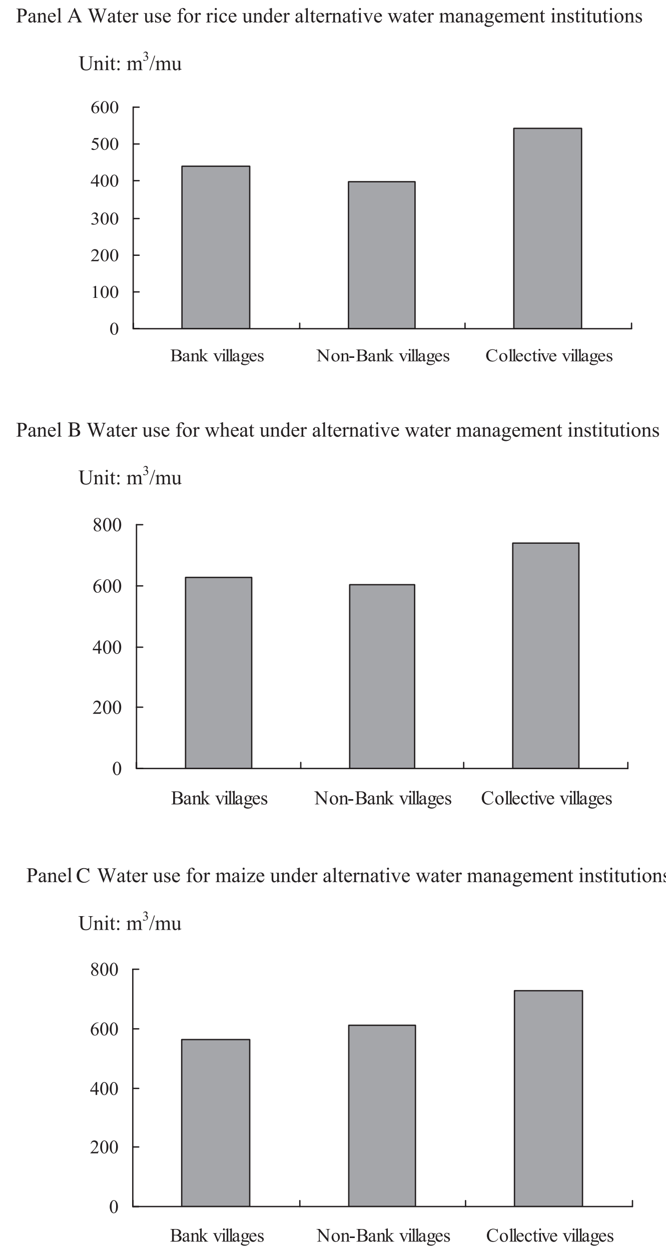
management activities (though not all). While fewer farmers in non-Bank villages told enumerators that most farmers participated in all management activities (only 29%), the number of villages in which farmers claimed to participate in all or all important activities was the same for non-Bank villages (65 = 29 + 36) as for Bank villages (63 = 52 + 11). Only 33% of farmers (in Bank villages) or less (21% in non-Bank villages) said that there was no participation in management. This number is very small relative to the findings in the Ningxia villages, in which more than 90% of villages reported little or no participation by farmers (Wang *et al.*, 2006).

Perhaps the most compelling evidence of the success that the Bank villages achieved is in improving water management—even relative to the non-Bank villages. The information was gathered during the survey when the enumerators asked the farmers if they believed that water management had improved relative to the traditional collectively managed form of water control after the adoption of their village’s

WUA. All (100%) Bank-villages (*vs*. only 50% of non-Bank villages) said that overall water was better managed by the WUA. Higher percentages of farmer focus groups also stated that there was more effort centered on saving water (93%); more timely delivery of water (96%); a reduction in water charges to farmers—in either an absolute or relative sense (89%); and less conflict when water fees were being collected (81%). The comparable percentage figures are much lower for the non-Bank villages. These data show that some combination of factors—the way the WUA was set up; governed; and/or managed—has greatly improved at least the perception of farmers about the way Bank WUAs are managing water. From this point of view, the Bank WUA projects can be considered a success.

In addition, there is a perception by farmers that WUAs—especially those in the Bank villages—were able to better resolve conflicts (Figure 5, panel B). To elicit the opinions of farmers on this, enumerators first asked the respondents whether or not before the establishment of WUAs there was any conflict within the village or between villages over water allocation (when water supply was scarce) or over the order in which water was delivered (to both farmers with the villages and among villages along the canal). In both cases (i.e., either regarding conflicts among farmers within villages; or among villages within the ID), the Bank WUAs were more effective in reducing conflict. In fact, while in 89% of Bank villages conflict among farmers within villages was reduced (*vs*. 71% in non-Bank villages), there were no Bank villages in which conflicts rose (while conflicts rose in 14% of non-Bank WUAs). While we do not know the exact reason, it likely has something to do with the participatory nature of WUAs and the way WUAs give farmers a platform from which they can address and resolve problems.

The relative success of Bank villages in resolving conflicts among villages within the ID was even greater. In 73% of Bank villages farmers told enumerators that conflicts among villages that shared the same canal reduced after initiating the WUA. Farmers did not report rises in conflicts in any of the Bank villages. Conflicts fell in non-Bank villages, also, but in a much lower share of villages (only 21%).



Source of Data: 2004 CWIM survey and 2006 Bank survey

FIGURE 6. Water Use for Rice, Wheat, and Maize Under Alternative Water Management Institutions.

Water Use and Yields in WUA and Non-WUA Villages

Figure 6 presents the initial results of analysis of the impact of the Bank's WUAs on performance. For analyzing the impact of the form of the water management institution on water use and yields, we necessarily must rely on a subsample of the villages. We are looking mainly at rice, wheat, and maize, because these are the only crops that were grown in more than 50% of all villages. They are also still China's three main crops in terms of sown area and output. In addition, when we asked each village leader about water use and yields, we only collected information on the three major grain crops grown in the village. If rice, wheat, and corn were not one of the three major grain crops, we did not collect information on them. This rule was chosen to avoid collecting information on a crop that was of minor importance in a village and on which the village leader/WUA manager may not have good information. Finally, we only could collect information on water use if the village actually had sown an area for the crop that was irrigated. For a subset of the villages, farmers cultivated wheat or maize on nonirrigated land. Although we have yield information for these crops, we did not use them in Table A1 because we wanted the sample coverage to be the same.

Relying on estimates by village leaders of water use per mu (1/15th of a hectare) on three major crops grown in the Bank survey villages, we find that water use in the Bank and non-Bank villages (which are all in Bank sites) on all major crops is far below water use in collectively managed villages. For example, in the case of rice, farmers in the Bank (non-Bank) villages used 439 (399) cubic meters per mu, while those in the collectively managed villages used 543 cubic meters per mu (1 ha equals 15 mu). This means that rice farmers in the Bank and non-Bank villages used around 20% less water. Although it might seem counterintuitive that the use of irrigation water on rice should be more than the use of irrigation water on wheat, it should be remembered that the crops (as well as other crops in the study) are grown at different times of the year. Therefore, these figures are plausible as rice is grown during the rainy season and, according to our data, requires less irrigation delivery. In the rest of the paper, although we only say "water use," we mean "use of irrigation water."

Although we do not systematically study the impact of water savings on ecosystem sustainability, the possible implications are worthy of discussion. In many cases, when there is water savings from the adoption of new management practices in the agricultural sector (as we have found in this case), it also can contribute to more effective integrated water resources management and ecosystem sustainability. Integrated water resources management is a set of systematic procedures that can contribute to the sustainable development, allocation, and monitoring of water resource use in the context of social, economic, and environmental objectives (http://waterwiki.net/index.php/IWRM). In its simplest incarnation, integrated water resources management is a logical and intuitively appealing concept. Its basis is that there are many different uses of finite water resources. Moreover, these different uses are interdependent. Therefore, faced with limited water resources, if water use efficiency in the agricultural sector is improved, it is possible that the saved water can be reallocated to other sectors, such as domestic, industry, and ecosystem. In many cases, the availability of new sources of water can reduce pressures in the system and can lead to greater stability. However, it is also possible that if water has been largely consumed in the agricultural sector and the saved water is discharged into a system that is not set up to capture the saved resource, there likely is not material impact on the sustainable development of other sectors.

The data also show that similar differences in water use appear for the other major crops (Figure 6, panels A and B). Wheat farmers in the Bank (non-Bank) villages used 628 (605) cubic meters per mu compared to more than 741 cubic meters per mu in the collective villages, a level about 15% lower. Maize farmers in Bank and non-Bank villages also used from 16 to 23% less water than those in collective villages.

So what can we infer from Figure 6? One interpretation based on Figure 6 might be that Bank and non-Bank WUAs are managed in such a way that they save water (as well as being managed better—as shown above) because when local WUAs are managed according to the Five Principles they can manage water more efficiently. In fact, interpreting these results requires caution and they need to be examined in conjunction with information on yields.

To illustrate one of the problems of coming to a conclusion about the efficiency of a single form of water management based on water use alone, we also present yields by water management type in Figure 7. According to our data, while water use is lowest in the non-Bank villages, yields are also lower. In fact, yields are lower in the non-Bank villages for all crops (rice, wheat, and maize) when comparing them to crops cultivated in both Bank and collective villages. Although the level of crop yields in non-Bank villages is lower than that in Bank villages in the descriptive statistics, remember that they are not statistically different using standard statistical tests. It is plausible that the distributions of the yields of farmers in these two types of villages are statistically the same—even when using multivariate analysis. In the case of the Bank results, it is only for maize that we are relatively more confident that WUAs are leading to more efficient use of water. While the yields of the crops in the Bank villages are highest for all crops, water use is only lowest in the case of maize (and it is only second lowest for rice and wheat—after non-Bank villages). In fact, there is an additional problem; it is possible that even in the case of maize there are other factors that are making maize yields rise in Bank villages while water use is falling. Therefore, it is important to also conduct more rigorous multivariate analysis. We also found that water productivity for the Bank WUAs is higher than that in both non-Bank WUAs and collective villages (Figure 8).

Multivariate Analysis: Report of Findings

For the interested reader, we have included a more detailed description of the approach and full report of

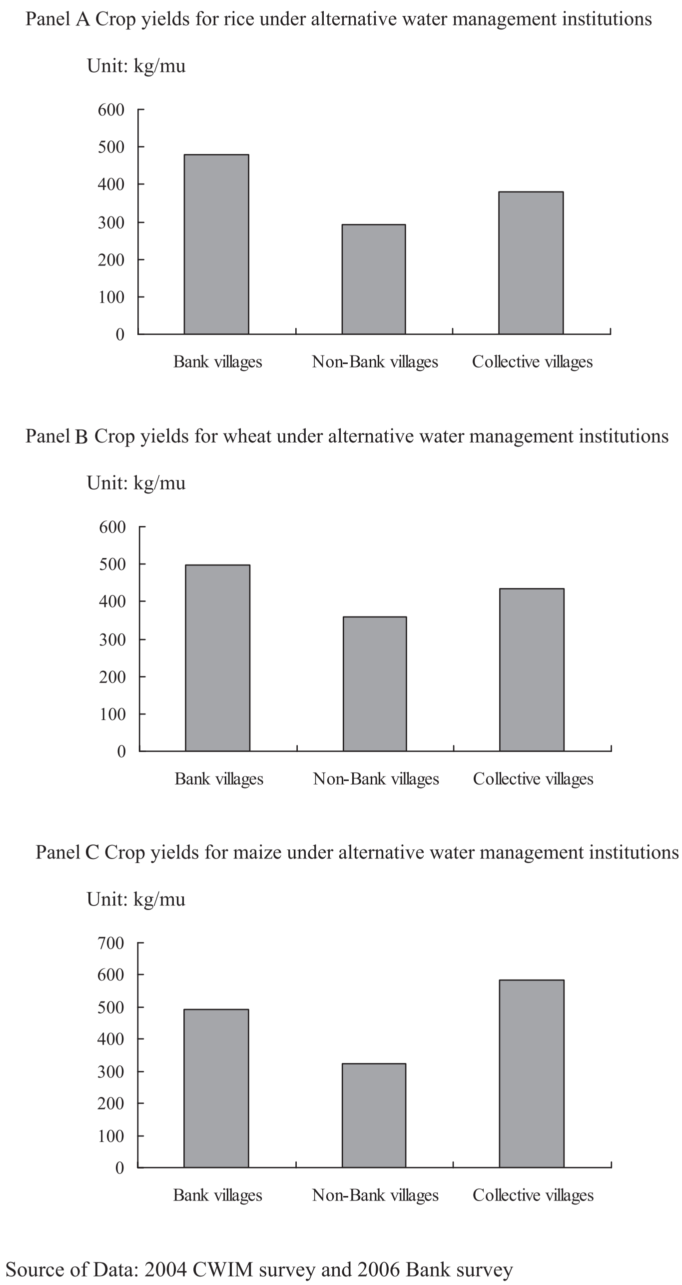


FIGURE 7. Crop Yields for Rice, Wheat, and Maize Under Alternative Water Management Institutions.

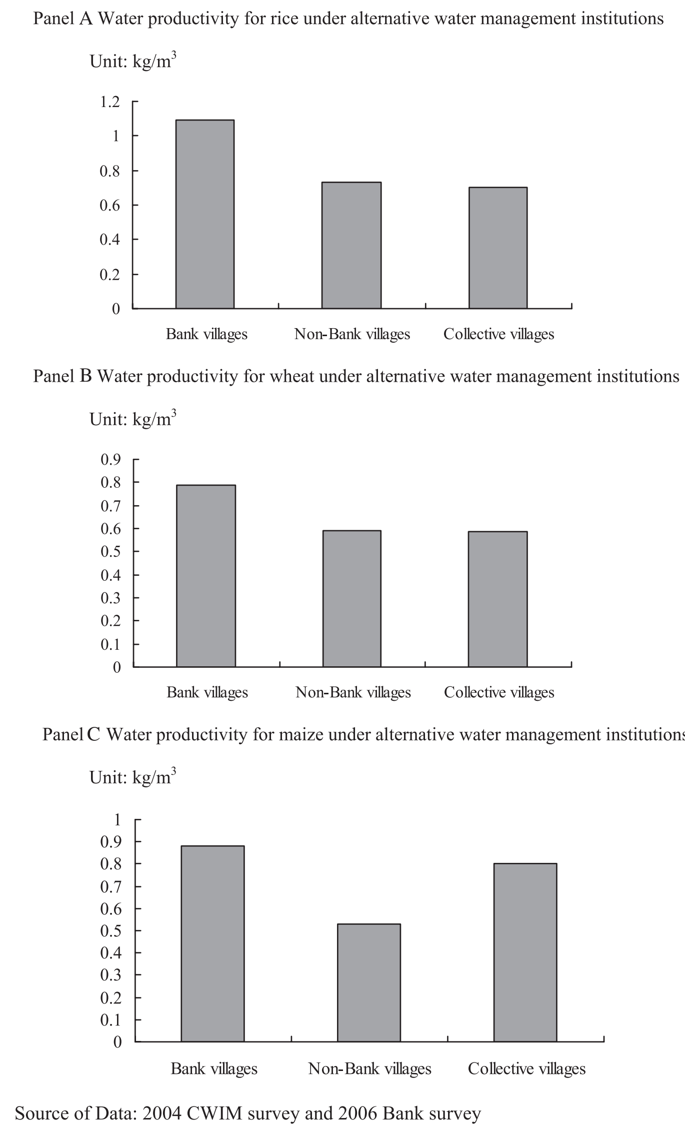


FIGURE 8. Water Productivity for Rice, Wheat, and Maize Under Alternative Water Management Institutions.

the findings in Appendix B and Table A1. In the main body of the text, we merely report the results.

In fact, the multivariate analysis—that is, when we hold the effects of a number of other covariates and nonvarying ID effects constant—we have evidence that farmers in Bank WUAs are producing more efficiently than those in collective IDs (and in the case of rice, non-Bank IDs). According to a joint analysis of water use and yields, we find that when compared with the use of water in collectively managed villages (the base set of villages), farmers in Bank WUAs use less water. The coefficient on the Bank WUA variable is negative and statistically significant. In the rice yield regression, however, there is no statistical difference in rice yields in the Bank WUAs and the rice yields in the base collectively managed villages. Based on these results (and a joint statistical test of the two coefficients), we can conclude the rice farmers in the Bank WUAs are more efficient as they use less water and get the same yields. In short, it can be concluded from the analysis that the Bank WUAs, those that are using best practice in terms of implementing the Five Principles, are more efficiently managing their water resources. Interestingly, according to our results, there is no difference in rice-growing non-Bank WUAs and collectively managed villages (despite the fact that the

TABLE 3. Examination of Implementation of the Five Principles of Water User Associations (WUAs).

Principles	Bank WUAs	Non-Bank WUAs	Ningxia's WUAs	Summary
Adequate and reliable water supply	Best	Some yes/some no	Some yes/some no	Best Practice: Bank WUAs
Legal status and participation	Best	Good	Poor … Little participation	Best Practice: Bank WUAs
WUAs organized within hydraulic boundaries	Most	Only some	None	Best Practice: Bank WUAs
Water deliveries can be measured volumetrically	Less	Some	Most	NO (Ningxia is best)
Nature of way in which WUAs collect water charges from members	All/transparent	All/transparent	All/nontransparent	Best Practice: Bank WUAs

mean value of the water use in non-Bank villages was lower than that in collective villages—but not statistically so).

When looking at the results of all crops, the conclusion that Bank villages are more efficient in their water use stands up (relative to collectively managed villages) and we find that non-Bank WUAs are also more efficient than collectively managed villages. In both the cases of Bank WUAs and non-Bank WUAs, the coefficients on their variables show that water use on all crops is lower than that in collectively managed villages. There is also no statistical difference in yields. Hence, while providing more evidence that the Bank WUAs are more efficient than collectively managed villages, it also suggests that there may have been a positive effect of having Bank WUAs in the region (and the learning that came from Bank WUAs and non-Bank WUAs). The fact that there may be spillovers is supported by statistical tests that show there are no statistical differences between water use and/or yields between the Bank WUAs and non-Bank WUAs when using the aggregate crop measures.

SUMMARY AND CONCLUSIONS

In this paper we have made a number of findings. Using a northern China representative data set, we have found that WUAs are indeed spreading across China. According to our estimates, about 10% of villages have now adopted WUAs. Of course, this does not mean all work well and manage water more efficiently; indeed the nature of implementation and the impact on performance are what we address in the rest of the paper.

Perhaps most fundamentally we have found that the Bank WUAs have excelled in many dimensions, particularly in the implementation of the Five Principles of WUA management (Table 3). Using four sets of villages (Bank WUA villages, non-Bank WUA villages, collectively managed villages in Bank sites, and Ningxia WUA villages) with data from the CWIM and Bank data sets to examine the implementation and performance, we find evidence that many of the management practices of the Bank WUAs are improved over other villages. In the case of Principle 1, Bank WUA villages had a number of characteristics that showed that they were endowed with more reliable water supply. In the case of Principle 2, Bank WUAs have been set up and are operating with a relatively high degree of farmer participation. The leaders are more consultative. The procedures are clearer and the processes more formal. Bank WUA villages are also set up in a way that makes them consistent with Principle 3; WUAs are organized largely within their hydraulic boundaries. Finally, the Bank WUA villages are successful in implementing Principles 4 and 5. For example, most of the Bank WUA villages can deliver water volumetrically (Principle 4); and all Bank WUA villages collect water fees from farmers (Principle 5). Hence, from this analysis, WUAs in the Bank villages can really be thought of as operating according to the best practices in terms of the Five Principles.

While the positive record is true in Bank villages—relative to all of the comparison cases—non-Bank villages in the Bank survey sites; collectively managed villages in the Bank survey sites; and in the Ningxia (and other) villages outside of the Bank survey sites; it is also true that there is evidence that the Bank's effort to promote WUAs is extending beyond their own project villages. The openness, consultative nature, and transparency that are found in the Bank WUAs are nearly matched by the non-Bank WUAs. Non-Bank WUAs are clearly following more formal procedures and adopting better practices than the other two comparison groups (collectively managed villages and Ningxia WUAs). That good practices can spill over into adjacent areas is an important finding. We do not know why this diffusion is occurring (and do not have the data to show it), but we suggest that this be studied in order to draw lessons. If there are activities that are promoting this learning they should be adopted in other projects; they may also want to be intensified to make the diffusion effect even more effective and widespread.

So what have been the results of these efforts to implement WUAs according to the Five Principles? In our analysis of water efficiency use, we actually find that there is fairly convincing results that water is being used more efficiently in Bank WUA villages. This is true in rice-growing villages and in all villages that cultivate rice, wheat, and maize. To a lesser extent (but still significant), the same is true for non-Bank WUAs. According to this criterion of improving the efficiency of water use, Bank WUAs and the other WUAs in the same regions are successful.

It also is true that the paper has found almost unambiguous evidence that the procedures that have been put in place have resulted in a system that is operating in a way that is close to what it is designed for. Farmers are actually involved in management—or perceive they are so. The perception that things are getting better is overwhelming. There is a real perception that the new institutional form is making real differences in particular aspects of water management. There is a perception that water management is improving in general. There is a perception that there is less conflict—both within the village and among villages. In general, WUAs in a real sense are contributing to China's "New Harmonious Society." It can be concluded from this analysis that there is a direct causal link between WUA water management reform with World Bank characteristics and the positive feeling the farmers have about their village's water management activities. This is an important contribution and a success to be proud of.

Despite the great number of strengths, there are still puzzles in our results and potential weaknesses in the ways that the setting up and implementations of WUAs are being approached. Beyond water efficiency, the impact on actual economic performance (income and cropping structure) is more difficult to document. The point estimates of yields in Bank WUA villages are lower. The point estimates of the effect of WUAs on yields are negative (though insignificant). There is no measured absolute rise in income due to WUAs in the Bank villages. In other words, using the strictest statistical methods, it is possible to reject the hypothesis that WUAs increase yields or increase incomes. Somewhat surprisingly, grain area is higher in Bank WUA villages. If it is a policy to promote cash crops and specialization into nongrain crops, there is no evidence that it is happening in Bank WUA villages. According to this strict interpretation, while the Bank WUAs have brought nominal/surface changes, they have not generated more fundamental changes that lead to improved economic welfare or structural change.

APPENDIX A

A Note on Data Collection

Good empirical analysis relies on high quality data. In order to ensure the quality of our survey data was high and to reduce as much survey bias as possible, in organizing the data collection activities, we took two approaches. One key step was to ensure that the design of the questionnaires was carefully done, that the questionnaires contained as few ambiguities as possible, and that they were understandable by farmers. The other key step was to control the quality of the survey data during the data collection process itself. In the case of the questionnaire design, in fact, we have more than 10 years of experience in using the basic instrument that was used during the survey that produced most of the data for this study. Our first water field survey was organized in 1998. During that time we began to create a series of survey blocks that systematically enumerated the different aspects of village irrigation systems. The first set, asked when enumerating the village leader, contains nine blocks: (1) the characteristics of the village's water infrastructure (surface water); (2) the characteristics of the village's groundwater; (3) the form of surface management (with three subparts—one for collectively managed systems; one for contracting; one for WUAs); (4) the form of groundwater management (with three subparts—one for collectively managed tubewells; one for shareholding tubewells; one for individual tubewells); (5) crop water use; (6) the adoption of various water-saving technologies for irrigation; (7) investment by the village into the village's irrigation infrastructure; (8) agricultural production (crop-sown areas and crop yield); and (9) the socioeconomic characteristics of the villages (such as population, land, and income). We also have a similar set of instruments for farm households. Since 1998, we have updated and reused the survey instruments in 2001, 2004, and 2007 (twice). These are well tested instruments. The data from these survey instruments have been used in at least 15 papers that have been published in refereed academic journals, including water resource journals, water management journals, and social science journals. In the case of enumeration quality management, we went to extreme lengths to try to collect the highest quality of data. For example, we conducted the data collection effort ourselves (i.e., it is not contracted out). We hired the enumerators; we trained the enumerators in the classroom; we trained the enumerators in the field (in pretesting situations); and we supervised the data collection from start to finish. In addition, we used high-quality enumerators.

In fact, nearly all of the enumerators were Ph.D. students either from our institute or from agricultural universities. They all had grown up in rural areas. They were all interested in agriculture. And, during our rigorous in-the-classroom and in-the-field training we made sure that all of the enumerators asked the questions in a consistent way. We also trained them in how to interact with farmers and village leaders. It has been our experience for more than 10 years of work on water management issues, that with high-quality enumerators who have received high-quality training and who are being closely supervised, the data that they collect will be able to closely reflect the actual in-the-village situation.

APPENDIX B

Multivariate Analysis of WUAs and Water Use

In this appendix we report the findings of two sets of multivariate exercises. Specifically, we want to answer one main set of questions: holding other factors constant, does having a WUA affect water use? Does it affect yields?

To do so, we begin to specify the following model for the impact of water management on water use in our sample villages in 2005:

$$\begin{aligned}\text{Water Use, crop}(i) = {} & a_0 + a_{11} \times \text{Bank WUA} + a_{12} \\ & \times \text{non-Bank WUA} + a_2 \\ & \times \text{Village characteristics} \\ & + a_3 \times \text{Location dummies} + e \quad (A1)\end{aligned}$$

where Water Use is measured as the amount of water applied to each crop i, where $i = 1$ for rice; and for $i = 2$ for an aggregate of rice + wheat + maize. In our analysis, we would have liked to run a separate regression for rice, wheat, and maize; however, there were not enough observations in the World Bank Study sites for wheat and maize to run them separately. Instead, we combined rice, wheat, and maize, and included a set of interaction variables by interacting the wheat and maize dummies with the Bank WUA and non-Bank WUA variables to control for the specific crop effects. The variable WUA is measured as a set of dummy variables, which measures whether or not a village is managed by a Bank WUA, a non-Bank WUA (and in the regressions the omitted category are collective villages in the Bank survey site). We include a number of village characteristics as control variables, including Water Scarcity (which is measured as a dummy variable that equals 1 if the respondent said the village's water was scarce); Education of Labor Force (which is measured as the share of the labor force with an educational attainment above high school); Cultivated Land per capita (measured in mu); Share of Irrigated Area (which is measured as the percent of cultivated area that is irrigated); Distance to Township (which is measured in kilometers by the shortest route by road); Downstream (which is a dummy variable that indicates if a village is located in the lower reaches of the ID); age of the Party Secretary (in years); education of the Party Secretary (in years of educational attainment); Water Management Experience of the Party Secretary (which is measured in the number of years during which the current party secretary at some point in his life was in charge of managing the village's canal system); and the Main Job of Party Secretary (which is a dummy variable that is equal to 1 if the party secretary relies primarily on farming for his income; and 0 if it is from a wage earning job or nonfarm self-employment). In addition and importantly, in the regression model we also include a set of county level dummies. These will hold constant all nontime-varying county wide effects, including factors such as climate, soil, and varieties.

In addition, we also specify three other equations for analyzing the impact on yields (kg/mu), income (measured in per capita terms in yuan), and cropping structure (share of total sown area in grain). As above, all of the explanatory variables are the same, including the variables used to measure the effect of WUAs (the two dummy variables) and the control variables. We also estimate this model for our village sample in 2005.

$$\begin{aligned}\text{Yields, crop}(i) = {} & a_0 + a_{11} \times \text{Bank WUA} + a_{12} \\ & \times \text{non-Bank WUA} + a_2 \\ & \times \text{Village characteristics} + a_3 \\ & \times \text{Location dummies} + e, \\ & \text{for } i = 1 \text{ for rice and } i = 2 \text{ for rice} \\ & + \text{wheat} + \text{maize} \qquad (A2)\end{aligned}$$

Results

In terms of goodness of fit, when we use an Ordinary Least Squares (OLS) estimator to estimate the parameters of Equations (A1) and (A2), the results are strong (Table A1). In the rice water use and yield equations the adjusted R^2 is 0.48 (in both columns 1 and 2). In the grain regressions, the R^2 in the water use equation is 0.70 and the R^2 in the

TABLE A1. Results of Regression Analysis on Impact of WUAs on Water Use and Yield in World Bank Survey Sites, 2005.

	Rice		Rice, Wheat, and Maize	
	Water Use (m^3/mu)	**Yield (kg/mu)**	**Water Use (m^3/mu)**	**Yield (kg/mu)**
WUA				
Whether or not a village is managed by a Bank WUA (1 = yes; 0 = no)	−292.0 (1.92)*	−60.4 (1.07)	−173.3 (1.86)*	11.2 (0.18)
Whether or not a village is managed by a non-Bank village (1 = yes; 0 = no)	−129.7 (0.56)	−127.4 (1.50)	10.7 (0.08)	−38.4 (0.40)
Crop choice				
Wheat dummy × Bank WUA dummy (1 = yes; 0 = no)			−296.2 (2.00)**	−316.0 (3.17)***
Wheat dummy × Non-Bank WUA dummy (1 = yes; 0 = no)			−487.0 (2.93)***	−52.8 (0.47)
Maize dummy × Bank WUA dummy (1 = yes; 0 = no)			−341.0 (2.63)***	−92.8 (1.06)
Maize dummy × Non-Bank WUA dummy (1 = yes; 0 = no)			−326.0 (2.20)***	45.3 (0.45)
Village characteristics				
Whether water scarcity was scarce in a village (1 = yes; 0 = no)	−258.3 (2.18)**	25.6 (0.58)	−195.2 (2.64)**	11.1 (0.22)
Share of the labor force with an educational attainment above high school (%)	−508.0 (1.48)	42.0 (0.33)	−359.1 (1.98)**	15.5 (0.13)
Cultivated land per capita (mu)	−16.1 (0.58)	−10.3 (1.01)	−21.9 (1.05)	−9.9 (0.71)
Percent of cultivated area that is irrigated (%)	25.0 (0.08)	7.3 (0.06)	145.9 (0.67)	−96.4 (0.66)
Distance to township by the shortest route by road (km)	−1.4 (0.12)	0.7 (0.16)	−1.04 (0.14)	−5.0 (1.01)
If a village is located in the lower reaches of the ID (1 = yes; 0 = no)	44.7 (0.36)	−52.3 (1.14)	33.6 (0.48)	−71.6 (1.53)
Age of the Party Secretary (years)	−2.1 (0.19)	−3.0 (0.75)	−3.0 (0.55)	−7.1 (1.99)*
Education of the Party Secretary (years of educational attainment)	21.9 (0.57)	0.1 (0.00)	12.2 (0.65)	−18.0 (1.44)
Water management experience of the Party Secretary (years)	1.2 (0.08)	−3.0 (0.57)	−5.2 (0.56)	−12.2 (1.94)*
Main job of the Party Secretary (dummy) (1 = he/she relies primarily on farming for his income; 0 = he/she relies primarily on a wage-earning job or nonfarm self-employment)	63.0 (0.38)	−59.7 (0.98)	47.5 (0.50)	42.2 (0.67)
Location dummies				
County dummies	—[1]	—[1]	—[1]	—[1]
Constant	1,100.6 (1.23)	796.3 (2.39)**	1,999.1 (4.10)***	1,003.1 (3.06)***
Observations	40	40	75	75
R^2	0.48	0.48	0.70	0.52

[1]The regression results of county dummies variables are not given in detail; absolute value of *t* statistics in parentheses.
*Significant at 10%; **significant at 5%; ***significant at 1%.

yield equation is 0.52 (columns 3 and 4). The sign on the water scarcity variable (columns 1 and 3, row 5) is negative and significant. Although we do not report the coefficients for the county dummies, they are jointly significant in all of the regression models.

Interestingly, and importantly for our analysis, results of our joint analysis (using OLS) of water use and yields suggest that the Bank WUAs do affect the efficiency of water use in the rice-growing villages in our sample (Table A1, columns 1 and 2). When compared with the use of water in collectively managed villages (the base set of villages), farmers in Bank WUAs use less water (row 1). The coefficient on the Bank WUA variable is negative and statistically significant. In the rice yield regression, however, there is no statistical difference in rice yields in the Bank WUAs and the rice yields in the base collectively managed villages (column 2, row 1). Based on these results (and a joint statistical test of the two coefficients), we can conclude the rice farmers in the Bank WUAs are more efficient; they use less water and get the same yields. This is one of the most important findings of the report.

Interestingly, according to our results, there is no difference in rice-growing non-Bank WUAs and collectively managed villages (Table A1, columns 1 and 2, row 2). Although there is no difference in yields, there is also no statistical difference in water use. According to our statistical analysis in rice-growing villages, non-Bank WUAs are not any more efficient than collectively managed villages. Such findings, in fact, are consistent with some of the analysis in previous sections. In general, while non-Bank WUAs had somewhat better governance and incentives than collectively managed villages, the improvements were not as great (generally) as the case of Bank WUAs. This interpretation is supported by statistical tests that also suggest that Bank WUAs outperformed non-Bank WUAs (row 1 *vs*. row 2).

When looking at the results of all crops, the conclusion that Bank villages are more efficient in their water use is prominent and we find that non-Bank WUAs are also more efficient than collectively managed villages (Table A1, columns 3 and 4, rows 1 and 2). In both the cases of Bank WUAs and non-Bank WUAs, the coefficients on their variables show that water use on all crops is lower than that in collectively managed villages. There also is no statistical difference in yields. Hence, while providing more evidence that the Bank WUAs are more efficient than collectively managed villages, it also suggests that there may have been a positive effect of having Bank WUAs in the region (and the learning that came from Bank WUAs and non-Bank WUAs). The fact that there may be spillovers is supported by statistical tests that show there are no statistical differences between water use and/or yields between the Bank WUAs and non-Bank WUAs when using the aggregate crop measures.

These results differ strikingly from those in the Ningxia sample (Wang *et al*., 2005, 2006) in which having a WUA did not affect performance. The performance of all WUAs in the survey sites suggests that something is fundamentally different between the process that set up and implemented WUAs in Ningxia and those that set up and implemented WUAs in Hubei, Hunan, and Gansu sites.

APPENDIX C: CASE STUDIES ON WATER MANAGEMENT IN THE VILLAGES

Case Study 1: World Bank WUA Village

One of our Bank WUA villages is Gaojiayan village in Yiling County in Hubei Province. Gaojiayan village is located in the upstream of the Dongfeng Irrigation District (DID). The total population is 3,180 and total cultivated land is 3,090 mu (or 206 ha). In Gaojiayan village the share of irrigated land reached 68%. In the village 66% of canals were lined. In the DID the first Bank WUA was established in 1996. The number of WUAs in the DID gradually increased thereafter. The World Bank completed its first round of WUA projects in 2002. In 2004, the World Bank initiated another round of projects in order to further promote the development of WUAs. In 2005, Gaojiayan village was selected as one of the sites for pilot projects in the new round of the Bank projects.

During our separate discussions with village leaders, water managers, and farmers, we were unanimously told that the village did not have a serious water shortage problem even before WUAs were established in 2005. Farmers, however, told us that although they did not lack in the quantity of water, the supply of water was often highly unreliable. Further discussions with farmers revealed that the unreliable water supply was mainly due to poor canal maintenance and insufficient water fee collection when water was managed by the collective. It was difficult for village leaders to collect water fees from all farmers. As a result, the village could only pay the local ID a small proportion of the water fees it was supposed to receive for its irrigation services. The local ID, in turn, frequently did not supply water to the village in time. Importantly, there was almost never any punishment for farmers that forfeited their water fees. The lack of punishment discouraged more farmers from paying their water fees because they could get water anyway.

Although farmers did not always know whether their village was a Bank project site, they were clearly aware of the changes in water management brought about by the WUA establishment since 2005. Farmers noticed a difference from the previous situation. First, and foremost, villagers stated that they had been asked to vote for the WUA managers. After their election, WUA managers put more effort into maintaining the canal and allocating water among farmers. More importantly, they noticed changes in water fee collection. It was easier for WUA managers to collect water fees from farmers. Most farmers told us that the reason for the relative ease of water fee collection was because WUA managers were elected by and thus were trusted by farmers. In addition, if some farmers really had no money to pay for water fees before the irrigation season (but could pay later), WUA managers were able to secure alternative funds to make up for the shortage in water fees in order to pay the ID in time. With sufficient water fees from the village, the local ID was able to supply water to the village in time. These changes, according to our interviewees, have led to significant improvements in water supply reliability and also to the degree of satisfaction of farmers with current WUA water management arrangements.

In the new round of World Bank projects, it was emphasized that the WUAs would be established in conjunction with the Five Principles. The successful implementation of the Five Principles can be seen from the responses of the farmer-interviewees. Farmers reported that their WUA was a legal entity and registered with the local Civil Affairs Bureau. The WUA in Gaojiayan village also had a high degree of transparency. WUA managers regularly shared information with farmers on water fee collection, water use volume, and the area that was irrigated. Farmers were also involved in almost all of the meetings that made decisions on important management issues. Finally, all farmers told us that after implementing WUA management, water use efficiency in the village was improved and their crop water use was reduced.

Case Study 2: Non-Bank WUA Village

In another village in Yiling County, Hubei Province, Meidian village, irrigation was run under WUA management. This village's WUA was not funded by the World Bank. Meidian village is also located in the downstream of DID. The total population in the village is 2,435 and the total cultivated land is 8,397 mu (or 560 ha). In the village, 49% of land was irrigated and 35% of the canals were lined. Through interviews with the village leaders, WUA managers, and farmers, we learned that although water was available, water supply in the villages was not reliable. In some years farmers could not get water in time during irrigation seasons. Due to the unreliable water supply, farmers think that their was shortage of water.

In 2005, a WUA was established in Meidian village. Although the Meidian WUA was not directly funded by the World Bank, the local ID officials organized a trip for the village leaders and farmers to visit the Bank WUAs in 2004. After the visit, with the support of local county and township government water officials, the village leaders began to organize a WUA in their village. Similar to the WUAs in the Bank area, the Meidian WUA let farmers elect their own leaders. The WUA also was registered with the local Civil Affairs Bureau and had a formal constitution. The transparency of the management was also often a subject on which farmers had an opinion. Farmers told us that WUA managers shared information on water fee collection, water use volume, and irrigated areas. In addition, farmers also participated in most meetings that made important management decisions.

Farmers told us that the most significant change after their WUA was established was the improvement in the reliability of the supply of irrigation water. The improvement was mainly due to better canal maintenance and more adequate water fee collection. However, farmers in Meidian village did not think the WUA had played any major role in saving water. In addition, farmers told us that their WUA did not have enough power to coordinate water allocation or resolve water conflicts inside the village. If they encountered any difficulty in the management of water, they still needed help from the village leaders.

Case Study 3: Collectively Managed Village Within Bank Sites

Water resources in Jinxing village were managed by the village collective. Jinxing village is in Dangyang County in Hubei Province. The village is located in the downstream area of the DID. The total population of Jinxing village is 2,800. Among the 6,000 mu (400 ha) of cultivated land, 60% is irrigated. In this village, only 20% of the canals were lined. Farmers in the village reported that water shortages and an unreliable water supply were both serious problems in the village's management of water.

Discussions with farmers clearly revealed that they were not involved in water management in the village. Almost all farmers said that they were not clear about who actually managed the village's water. Although the village leaders were the de facto water managers, they often did not play any active role in managing water. For example, no individual was assigned to maintain canals. Farmers often found water in the canals overflowing the banks of the canals (into ditches and into fields) and wasted. In addition, there were no clear rules that governed water allocation. Villagers reported that from time to time there were water conflicts among the farmers. Under such a management system, farmers also had no incentive to pay water fees. If they did not pay, there were few consequences. Furthermore, farmers did not have information on the level of water fee, the volume of water used, or the size of area that was irrigated. Most farmers in Dangyang village had somewhat vague ideas about WUAs. They believed that if WUAs were established in their village, irrigation services in their village would be improved.

Case Study 4: WUA Village in Ningxia Province

Malutan village, located in Zhongwei County, Ningxia Province, obtains irrigation water from the Zhongwei Irrigation District. The total population in Malutan village is 1,210 and the total cultivated land is 1,360 mu. Nearly all of the cultivated land (99%) was irrigated. The share of lined canals in the village was 79%.

The WUA in Malutan village was established in 2001. Different from WUAs in the Bank sites, the WUA leaders in Malutan village were not elected by farmers, but appointed by village leaders. In fact, WUA leaders were also the village leaders. In addition, the Malutan WUA was not formally registered with the local Civil Affairs Bureau. Although the WUA shared information on water fee collection, water use volume, and irrigated areas with farmers,

farmers seldom participated in the meetings in which decisions were made about water management. During conversations with farmers, we found that some farmers did not even know that there was a WUA in their village. Most farmers told us that the water supply in the village had improved over the years. However, this was not necessarily due to the nature of water management, but, instead was due to the improvement in their canal maintenance and investment in canal lining. Farmers did not believe that the efficiency of water use in the village had improved.

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