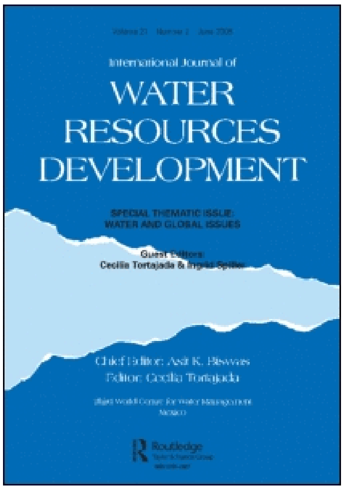


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# Understanding the Water Crisis in Northern China: What the Government and Farmers are Doing

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# Understanding the Water Crisis in Northern China: What the Government and Farmers are Doing

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ABSTRACT *The overall aim of this paper is to attempt to discover the true facts in order to ascertain whether or not there is a water crisis in China, and if there is, to identify the responses of the different stakeholders—government water officials, community leaders and farmers. In order to achieve this goal, several specific objectives are pursued. First, the paper evaluates the status of China's groundwater economy, examining whether or not the groundwater table is systematically falling. Second, in the parts of China that face a water crisis (or potential crisis), the paper documents the regulations and policies that the government—both local and regional—have implemented and discusses whether they have been successfully implemented. Third, it describes how farmers have responded to the water crisis and tries to assess whether or not their roles have helped alleviate the water scarcities or exacerbated the crisis. To meet these objectives, two large field surveys are used that cover seven provinces in northern China. The findings demonstrate that, although the water table is not falling everywhere in northern China, there are still a substantial number of communities that appear to be facing a water crisis. When there is a water crisis, the data show that the government in China has begun to make a number of policy responses, but the implementation is not always effective. Where water is becoming scarce, farmers and community leaders have also responded in numerous ways. However, farmers do not necessarily respond in ways that effectively save water, mostly because they do not always have incentives to do so. With good incentives, the research shows that they do save water. Hence, the government cannot ignore the way that farmers respond. Indeed, good policy needs to use this responsiveness to reduce the adverse effects of water scarcities and encourage conservation.*

## Introduction

Increasing evidence indicates that China is facing a serious water scarcity, particularly in northern China. The water scarcity is not only due to the falling supply of water, but also to the rising demand for water. On the supply side, one of the most obvious pieces of evidence is that surface water resources in some parts of China are diminishing. During the

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past two decades, the flow of rivers into several major river basins in northern China has declined significantly. For example, the runoff in the Hai River basin decreased by 41% (Ministry of Water Resources, 2007). The runoff in other river basins—the Liao, Yellow and Huai River basins—has also fallen by 9–15%. Because of this decline, some river basins (e.g. the Hai River basin and the Yellow River basin) have changed from being open to closed in some years; in other words, water does not flow into the lower reaches of the basin throughout the year (Wang & Huang, 2004).

With the decline of surface water resources, farmers in northern China have begun to turn more towards groundwater resources. Indeed, groundwater has become the dominant source of water supply for irrigation in northern China. In the early 1950s, there was almost no groundwater-based irrigation in northern China (Wang *et al.*, 2007a). However, by the 1970s groundwater use for irrigation increased, accounting for 30% of irrigation. By the mid-1990s, a decade or so after the launch of the economic reforms, groundwater irrigation continued to expand, reaching 58% in 1995. In 2004, most irrigation in northern China came from groundwater resources; the percentage of groundwater irrigated area increased to almost 70%.

Unfortunately, the development of groundwater may have resulted in a number of adverse environmental challenges. According to a report by the Ministry of Water Resources in 1996, the overdraft of groundwater was one of China's most serious resource problems (Ministry of Water Resources & Nanjing Water Institute, 2004). In the late 1990s the annual rate of overdraft exceeded 9 billion cubic metres. More than one-third of the overdraft was from deep wells, many of which were non-renewable (at least in the short to medium term). The drop in the deep groundwater table in some areas has exceeded 2 m per year. Based on the authors' previous research in Hebei Province, the shallow groundwater table is also falling, at least in some areas—approximately 1 m per year (Wang & Huang, 2004). In addition to the drop of the groundwater table, overdrafting of groundwater can cause land subsidence, the intrusion of seawater into fresh water aquifers and desertification (Wang *et al.*, 2007a).

Besides the declining water availability, demand is also playing a role in increasing pressure on the supply of irrigation water. China's rapidly growing industrial sector and an increasingly wealthy urban population compete with farmers for limited water resources. Between 1949 and 2004, total water use in China increased by 430%, a level of growth that is similar to the world's average increase of 400%, but greater than the average growth rate for developing countries (Wang *et al.*, 2005a). Industrialization and urbanization have caused China's water to be increasingly allocated to non-agricultural uses. From 1949 to 2004 the percentage of irrigation water use declined from 97% to 65% (Ministry of Water Resources, 2004). At the same time, the share of industrial water use increased from 2% to 22%; the percentage of domestic water use increased from 1% to 13%.

Facing the simultaneous decline of water availability and increase of water demand, it is natural to believe that China is facing a severe water crisis. A reading of the literature and policy documents provides the same perception. For example, in 1999, Wen Jiabao, the Vice Premier in charge of agriculture at the time, and now the Chinese Prime Minister, warned of the dire situation that China's water crisis was creating (McAlister, 2005). Senior officials from the Ministry of Water Resources in China frequently point out that China is fighting for every drop of water and that the water crisis is threatening national grain production (Wang, 2008). Brown (2000) predicts that the falling water table in China may soon reduce the nation's output by so much that it will raise food prices internationally since China—a nation that can afford massive volumes of imports—will have to rely on food produced outside of China. Nankivell (2004) believes that China is now at a point when critical decisions must be made to resolve its severe water crisis. Although other observers have made more moderate predictions, they also forecast that many agricultural producers might have to forgo irrigation due to falling water supplies (e.g. Crook & Diao, 2000).

Despite these dire predictions concerning the severity of the water situation in China, the authors here believe that it is premature to claim that China is facing such a dire crisis. While conceding that many localities are facing water shortages, it is not thought that other studies and debates about China's water problems are based on compelling evidence. Most studies are anecdotal and rely on observations of producers or users in a single location. There is almost no work on China's water economy that is based on large-scale field level studies. When empirical work relies on the information from only a single location, it is hard to judge the seriousness of the overall water scarcity. Without systematic data across numerous locations, it is impossible to know definitively whether or not China really is facing a nationwide water crisis.

The overall goal of the research is to find the real facts, and in doing so to help make it clearer whether or not there is a water crisis in China. In order to achieve the overall goal, three specific objectives will be pursued. First, the paper evaluates the status of China's groundwater economy—examining whether or not the groundwater table is systematically falling. Second, the paper documents the way that the government has responded and identifies the effectiveness of their measures. Third, it describes how farmers have responded to the water crisis and an attempt is made to assess whether or not their roles have helped to alleviate the water scarcities or exacerbated the crisis.

Given the broad nature of the paper's objectives, the scope needs to be limited. Above all, the focus is only on northern China, and most attention is given to the rural economy. While there are many dimensions of the water problem that cannot be addressed (e.g. pollution of underground aquifers, land subsidence in urban areas created from overdrafting of groundwater), the level of groundwater in rural communities is used to illustrate one aspect of China's water challenge.

The rest of the paper is organized as follows. The next section describes the datasets that form the basis of this study. The following section reviews several of the key facts that illustrate China's water problems. There is then a discussion about the response of government to its perceived water problems. Both groundwater policy and the government's effort to reform surface water irrigation management are examined. The next section examines how farmers respond to the water scarcities in their areas, including how they invest in tubewells, how they manage groundwater resources, whether or not there has been an emergence of groundwater markets, and how farmers respond when the price of water rises. The final section concludes.

## Data

The analysis is based on the data collected in two field surveys that were designed to study China's water economy in general, and in particular it addresses questions about the effectiveness of irrigation practices and agricultural water management. The first survey, the China Water Institutions and Management survey (CWIM), was run in September 2004. Enumerators conducted surveys of community leaders, groundwater irrigation managers, surface water irrigation managers and households in 80 communities in Hebei, Henan and Ningxia Provinces. The communities were chosen according to geographic locations, which in the Hai River basin are correlated with water scarcity levels. In Hebei, communities were chosen from counties near the coast, near the mountains and in the central region between the mountains and the coast. In Henan and Ningxia Provinces, communities were chosen from counties bordering the Yellow River and from counties in irrigation districts (and sub-districts) situated at varying distances from the Yellow River. The 2004 CWIM survey was the second round of a panel survey, the first phase of which was conducted in 2001.

A second survey was conducted, the North China Water Resource Survey (NCWRS), in December 2004 and January 2005. The NCWRS survey interviewed community leaders from 400 communities in Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi Provinces. An extended version of the community leader instrument of the CWIM survey was used. A stratified random sampling strategy was used in order to generate a sample that was representative of northern China. First, counties in each of the regionally representative sample provinces were sorted into one of four water scarcity categories: very scarce, somewhat scarce, normal and mountain/desert. Two townships were then randomly selected within each county and four communities within each township. In total, combining the CWIM and NCWRS surveys, six provinces, 60 counties, 126 townships and 448 communities were visited.

The scope of the surveys was quite broad. Each of the survey questionnaires included more than 10 sections. Among the sections, there were those that focused on the nature of rural China's water resources, the most common types of well and pumping technology. There also were blocks that focused on understanding China's water problems, the response taken by the government (e.g. water policies and regulations) and the way that institutions emerged when water was scarce. Although the survey asked about both surface and groundwater resources, with two exceptions (a section on reliability of water resources and a section on water management), the focus is mostly on those communities that have groundwater resources. The survey collected data on many variables for two years, 2004 and 1995. By weighting the descriptive and multivariate analyses with a set of population-based weights (large communities in large townships in large counties were weighted more heavily in the analysis), it is possible to generate point estimates for all of northern China.



## Facts about China's Water Scarcity

Water scarcity is a difficult concept to measure. The authors believe that there are a number of different ways to measure the extent of the water scarcity in each locality. Therefore, this section examines the nature of northern China's water scarcity from three different viewpoints. First, there will be a report on the changes in the resource itself. This is done by recording shifts in the groundwater table over time. Although the fall in the groundwater table is an important indicator of rising water scarcity, it is not sufficient to fully explain the nature of the water crisis. Therefore, the second subsection reports on the seriousness of the water scarcity through the 'eyes' of local leaders and farmer-cum-respondents in the sample. Finally, there will be an examination of the seriousness of water scarcity by asking community leaders and well managers about the reliability of surface and groundwater supplies, according to their subjective judgement.

### *Decline of Groundwater Table*

Although the validity of the many bulletins that report severely falling water tables is not questioned here, when the study relies on the survey of a set of representative communities across northern China, it finds what may be to some observers a fairly surprising result. Specifically, the field survey reveals that not all regions in northern China are faced with falling groundwater tables (Wang *et al.*, 2007a).[1] Indeed, according to the data here, there was no fall in the groundwater table in 26% of communities in northern China using groundwater between 1995 and 2004. In another 9% of communities, respondents told the enumerators that the groundwater was in fact higher in 2004 than in 1995. Therefore, it is clear that such communities are not facing severe water scarcities and water is not being overused. Indeed, if another 16% of communities are added which experience an average annual fall in the groundwater table that was less than 0.25 m per year, it is found that in up to half of China's communities groundwater resources have shown little or no decline over the past decade.

Although up to half of the sample communities were nearly in balance between 1995 and 2004, it is not being argued here that groundwater problems do not exist. Indeed, there are still a large number of communities in which the water table is falling—and in some it is falling sharply. According to the data here, the groundwater table fell between 0.25 and 1 m annually between 1995 and 2004 in 38% of the sample communities. In 11% of the sample communities the groundwater table fell by more than 1.5 m per year. According to the Ministry of Water Resources' definition, this means groundwater is being 'seriously over-exploited' in these communities. Certainly, in most of these communities (and in many of those in which the water table is falling between 0.25 and 1 m per year) there is a water crisis.

So, is China facing a water crisis? According to the physical measure of the fall of the groundwater in the study, perhaps the most accurate answer is both 'yes' and 'no'. On the one hand, the groundwater table is falling rapidly in only a fraction of communities. In other communities the water table is falling, and while it might be a problem some time in the future, it certainly cannot be called a full-blown crisis. In addition, in a large number of communities there is little or no change. Therefore, an argument can be put forward that China is really not facing a crisis where the system is being destroyed. However, at the same time an argument can also be made that in an absolute sense the small proportion of communities that are in crisis still represents a large number. There are approximately 300 000 communities in northern China. According to the data in the study here, there are approximately 30 000 communities where the groundwater table is falling very rapidly. Since there are, on average, more than 1500 people in each of these communities (living in approximately 400 households), this means that there are still nearly 50 million people living in these communities.

### *Perception of Community Leaders and Farmers about Water Scarcities*

During the field survey, enumerators asked community leaders and farmers to describe the nature of water resources in their communities in 1995 and 2004. They were asked to choose from one of three options: (1) there is no water scarcity (at least currently); (2) there is a water scarcity but the scarcity is not severe; and (3) there is water scarcity and it frequently constrains agricultural production (or water scarcity is very severe). Based on the responses of community leaders and farmers, it is possible to have at least some insight into the status and the patterns of water scarcities in northern China.

**Table 1.** The opinions of community leaders and farmers regarding the nature of water scarcities in northern China's communities

| | Share of sample communities (%) | |
|---|---|---|
| The community's water environment | 1995 | 2004 |
| Not scarcity | 35 | 30 |
| Scarcity | 65 | 70 |
| When scarcity, severely short | 14 | 16 |

*Sources:* Authors' survey in 2004 (NCWRS dataset).



The responses of community leaders and farmers did not show an optimistic picture about the state of water resources in the future. Survey results show that respondents in 70% of the communities in the sample villages reported that they were facing water scarcity in 2004, or at the very least these communities felt they had serious water scarcity (Table 1). Among those communities that reported water scarcity, 16% were facing 'severe' water scarcities in 2004 (row 3, column 2). Only 30% of the respondents reported that they were not suffering any water scarcity problems (row 1, column 2).

More importantly, water scarcities have become more serious during the past decade. Survey results show that between 1995 and 2004, the percentage of communities with water shortages increased by 5% (Table 1, row 2). The percentage of communities that reported severe water scarcity problems also increased (row 3). It is clear that from the perception of the community leaders and farmers in those communities that they believed the locality's level of water scarcity was becoming a serious problem. Although not happening everywhere, most communities are facing such problems. In some communities, respondents stated that water scarcities were so serious that water had become the most limiting factor in agricultural production.

### *Changes in Surface and Groundwater Supply Reliability*

Looking at the problem from a different angle from that discussed above, the reliability of water supply is another indicator that can measure the degree of water scarcity. If surface water supplies are reliable in most cases, it can be assumed that water is not scarce. On the other hand, if the water supply is not reliable, water scarcities can frequently emerge even during times of the year (or during other years) when water resources are sufficient. To gain a sense of whether or not water resources in a community were reliable, farmers were asked the following question: "When considering the time period between 2001 and 2004, was there any part of any year (either one or more periods among a single year/or during either one or more years) that you were unable to have access to irrigation water (either surface or groundwater)?" Farmers were asked the same question about the time period between 1991 and 1995. If farmers said there was at least one part of a year when they were unable to access irrigation water, the community was said to have 'unreliable access'. If farmers never encountered such a situation, their surface or groundwater supplies were defined as reliable.

Survey results show that surface water is highly unreliable in northern China. The data suggest the farmers in many communities do not believe that they have a reliable supply of surface water (Table 2). During the period form 2001 to 2004, more than 60% of communities did not have access to reliable surface water resources.

**Table 2.** The reliability of the water supply in northern China's communities

| | Share of sample communities (%) | | | |
|---|---|---|---|---|
| | Surface water reliability | | Groundwater reliability | |
| Nature of the water supply in terms of reliability | 1991–95 | 2001–04 | 1991–95 | 2001–04 |
| Reliable | 64 | 39 | 91 | 85 |
| Unreliable | 36 | 61 | 9 | 15 |
| Total | 100 | 100 | 100 | 100 |

*Source:* Authors' survey in 2004 (NCWRS dataset).



During the past decade the extent of water reliability has declined. In the early 1990s (1991–95), surface water supplies in most communities were fairly reliable. Approximately 64% of the communities reported that they had access to reliable supplies of water at that time (Table 2). However, in the early 2000s (2001–04), the percentage of communities with reliable supplies of surface water resources declined to 39%, a drop of 25 percentage points. According to the data (and an assumption about the relationship between water scarcity and reliability), as water resources have become less reliable in the sample communities, this is clearly exacerbating the already scarce water resources.

At the same time that surface water supply became less reliable, the reliability of the groundwater supply also declined, although to a much lesser extent than the surface water (Table 2). Groundwater resources have always been valued for their reliability since groundwater can frequently serve as a buffer against the uncertainties associated with surface water resources (Tsur & Graham-Tomasi, 1991). The data indicate that the groundwater supply is generally much more reliable than the supply of surface water. More than 90% of the communities had reliable supplies of groundwater between 1991 and 1995, a proportion that was 27 percentage points higher than communities that relied on surface water (Table 2). However, over time, even groundwater has become an unreliable source of water supply for some farmers. For example, in the early 1990s (1991–95), 9% of the communities reported that their groundwater supplies were unreliable. The percentage of communities without reliable groundwater resources rose to 15% in the early 2000s (2001–04). Therefore, in both groundwater-reliant and surface water-reliant communities, the reliability of the supply of water has deteriorated. This will no doubt intensify the water scarcity in northern China.

## Responses from the Government

Faced with increasing water scarcities in at least some areas, the government has responded in a number of ways in an attempt to tackle the problem. Local (township and county), regional (prefetural and provincial) and the central government have not only created and issued a number of laws, regulations and policies, but they have also tried to encourage local officials to reform water management. This section focuses on two major responses that the government has made. One response is the efforts that have gone into creating groundwater policies. The other is the time spent in developing and promoting the irrigation management reform of surface water resources. The next section seeks to understand what types of responses government has made. An attempt will also be made to examine their success in implementing their initiatives.

*Issuing Groundwater Policies*

Although limited in scope, government officials in China have made efforts to issue laws, regulations and policies to manage groundwater resources (Wang *et al.*, 2007b). For example, according to China's National Water Law, which was revised in 2002, all property rights to groundwater resources belong to the state. This means that the right to use, sell and/or charge for water ultimately rests with the government. The law also does not allow groundwater extraction if pumping is harmful to the long-term sustainability of groundwater use.

Beyond the formal laws, officials have also launched a number of policy measures in order to rationally manage the use of the nation's groundwater resources. There have been policies promulgated to control the right to drill tubewells, manage the spacing of tubewells and regulation of the fees for the collection of water resources. While there initially appears to be numerous policy measures managing China's groundwater, when compared with the number of regulations concerning other issues, such as flood control and the construction of water-related infrastructure projects, in fact, there are not many regulations relevant to groundwater management. Importantly at the national level, there is not one water regulation that specifically focuses on groundwater management issues.

If the effort to build up a regulatory framework is weak, there has been an even greater deficiency in the implementation of official laws and policy measures on groundwater management (Wang *et al.*, 2007b). For example, according to the survey data, less than 10% of well owners obtained a well drilling permit before drilling, despite the nearly universal regulation requiring a permit. Only 5% of the community leaders believed that well drilling decisions required consideration of well spacing. Even more noticeable is the fact that water extraction charges were not imposed in any community and there were no quantity limits put on well owners. Indeed, in most communities in China, groundwater resources are almost completely unregulated.

Why is this so? Certainly, part of the problem is historic neglect. At the ministerial level, in terms of employees, the size of the division of groundwater management is still relatively small. There are far fewer officials working in this division than in other divisions, such as flood control, surface water system management and water transfer. Moreover, unlike the case of surface water management (Lohmar *et al.*, 2003), there has been no effort to bring the management of aquifers that span jurisdictional boundaries under the ultimate control of an authority with control over all the local governments and private entities that use water extracted from different parts of the aquifer. Without a single body controlling the entire resource, it is difficult to implement policies that attempt to manage the resource in a manner that is sustainable in the long-term. However, either due to lack of personnel or other implementation-related difficulties, few regulations have had any effects inside China's communities (Wang *et al.*, 2007).

*Reforming Irrigation Management of Surface Water Resources*

Looming water scarcities also have pushed Chinese leaders to consider community-level irrigation management reform as a key part of their strategy to combat China's water problems. According to the survey in Ningxia Province, since the early 1990s, and especially after 1995, reform has successively established Water User Associations (WUAs) and contracting as a replacement for collective management (see Figure 1; also

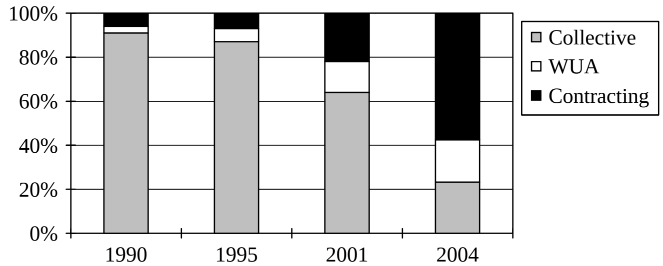


**Figure 1.** Evolution of an irrigation management in Ningxia Province. *Sources:* authors' survey in 2001 and 2004 (CWIM dataset).



Wang *et al.*, 2007c).[2] In Ningxia Province the percentage of villages that manage their water under the system of collective management declined from 91% in 1990 to 23% in 2004. Contracting has developed more rapidly than WUAs. By 2004, 57% of the communities managed their water under contracting and 19% through WUAs. The survey here in six provinces also found a similar reform trend of irrigation management (see Figure 2; also Huang *et al.*, 2007). From 1995 to 2004 collective management declined from 90% to 73%. At the same time, WUAs increased from 3% to 10% and contracting management increased from 5% to 13%. If these figures are true reflections of northern China's averages, this means that nearly 100 000 communities in northern China are managed, at least nominally, under new types of surface water management institutions.

Although reforming the institutions in name might seem important, the nature of the incentives (and other features of the institutions) that motivate participants in the institutions might be more important (Wang *et al.*, 2005b).[3] According to the data here, not all reformed management institutions (WUA or contracting management) have been developed in such a

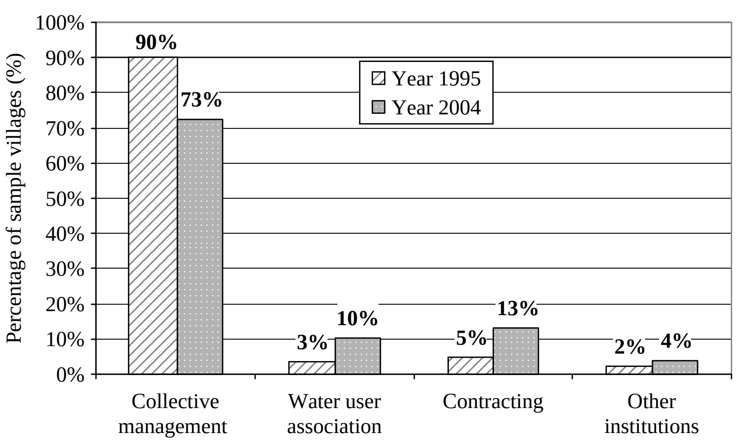


**Figure 2.** Changes in water management institutions from 1995 to 2004. *Sources:* Authors' surveys in 2001 and 2004 (CWIM and NCWRS datasets). *Notes:* Other institutions includes the four types of mixed institutions: (1) water user association combined with collective management; (2) water user association combined with contracting; (3) contracting combined with collective management; (4) water user association, contracting and collective management.

way that their members have an incentive to save water (or be efficient). For example, in 2001, on average, leaders in only 41% of communities offered WUA and contracting (i.e. *non-collective*) managers incentives that could be expected to induce them to increase efforts to save water in order to earn an excess profit. In the remainder of the communities, 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 incentive point of view, the WUA and contracting managers were operating without incentives. Indeed, in these communities non-collective managers are operating in a way that is similar to leaders in a collectively-managed community; neither have an incentive to save water.

It is perhaps for this reason that China is still facing water crises in some areas. According to the research here, nominally reforming irrigation management has no significant impact on water use (Wang *et al.*, 2005b). It is only when irrigation managers face effective incentives that they systematically begin to reduce water use. When either descriptive statistics or econometric analysis are used, the results all show that there is no significant relationship between water use in a community and whether or not it has reformed its irrigation management (according to a nominal definition). However, it was found that in communities that provided water managers with strong incentives, water use fell sharply. Good incentives have also been shown to improve the efficiency of the irrigation systems. Although communities with strong incentives have reduced their water uses, the output of their major crops, e.g. rice and maize, did not fall. Rural incomes (poverty) also did not fall (rise), remaining statistically unchanged.[4] Although the study here needs to be undertaken in other areas in the future before the results can be generalized for the rest of China, at least in the sample sites that provided their managers with incentives, water management reform has been almost a win-win policy in resolving water scarcity problems.



## Responses of Farmers

Although the government response has not been effective in solving China's water shortages, it does not mean that farmers have not responded. Indeed, faced with increasingly scarce water supplies, farmers in the study areas have responded in many ways. This section examines the responses of farmers to increasing water scarcities. These include sinking tubewells, moves to shift the ownership (and operation) of tubewells to private hands, actions to establish groundwater markets and a number of other behavioural changes that could potentially occur (e.g. cutting down on water use; changing crops or adopting water-saving technologies) when the cost of water rises.

### *Sinking Tubewells*

The most obvious response of farmers to increasing water scarcity is to sink tubewells. According to national statistics, the installation of tubewells began in the late 1950s (Wang *et al.*, 2007a). Since the mid-1960s, the installation and expansion of tubewells across China has been nothing less than phenomenal. In 1965 it was reported that there were only 150 000 tubewells in the whole of China (Shi, 2000). Since then, the number has grown steadily. By the late 1970s there were more than 2.3 million tubewells. After a period of stagnation during the early 1980s, when the irrigated area fell, especially that serviced by surface water, the number of tubewells continued to rise. By 1997, there were more than 3.5 million tubewells; by 2003, the number rose to 4.7 million.

While the growth of tubewells reported by the official statistical system is impressive, there is reason to believe the numbers are far understated (Wang *et al.*, 2007a). According to the data from the NCWRS, in 1995, on average, each community in northern China contained 35 wells. When extrapolated regionally, this means that there were more than 3.5 million tubewells in the 14 provinces in northern China by 1995. In addition, the data in the current study also found there had been a rapid increase in the number of wells. By 2004, the average community in northern China contained 70 wells, suggesting that the rise in tubewell construction since the mid-1990s has risen even faster than indicated by official statistics. By 2004, it was estimated that there were more than 7.6 million tubewells in northern China. At least in the sample communities, the number of tubewells increased by more than 12% annually between 1995 and 2004.

Therefore, is sinking new tubewells part of the problem or solution? In fact, it is probably rightly counted as both. Many of the tubewells are being sunk because old wells have become inoperable. These types of wells are not increasing consumption of water; they are mainly a means to maintain farm output and rural incomes. However, at the same time, a significant proportion of the new wells are being located in areas that still have room for the expansion of the cropping area, increased intensity of cropping and rising yields. Of course, this part of the rise in tubewells will result in increased consumption of water. From this point of view, the response of farmers is part of increasing water scarcity.

### *Privatization of Tubewells*

Farmers not only respond by sinking new tubewells that can sustain their production, they are also part of a movement that is changing the nature of groundwater management—one that has the potential for improving water management. In particular, the privatization of tubewells is perhaps the most prominent institutional change that farmers are a part of. According to the survey here, since the early 1980s the ownership of tubewells in northern China has begun to shift sharply. For example, in Hebei Province collective ownership of tubewells diminished from 93% in the early 1980s to 56% in the late 1990s (Wang *et al.*, 2006). At the same time, the percentage of private tubewells increased from 7% to 64%. Data from the NCWRS largely support these findings (Wang *et al.*, 2006). In 1995, collective ownership accounted for 58% of tubewells in the average groundwater-using community. However, from 1995 to 2004, collective ownership diminished and accounted for only 30% of tubewells in 2004. In contrast, during the same period the share of private tubewells increased from 42% to 70%.

Analysis based on the data here also demonstrates that privatization of the tubewells has increased the efficiency of farming in rural China. Specifically, the privatization of tubewells has promoted the adjustment of cropping patterns while having no adverse impact on crop yields. Econometric results show that since privatization, farmers have expanded the sown area of water sensitive crops (such as wheat) and high-value crops (such as horticulture crops, see Wang *et al.*, 2006a). It is perhaps because of the rising demand for horticulture crops that some private individuals have become interested in investing in tubewells. Such results are consistent with the hypothesis that when tubewell ownership shifts from collective to private and water is more efficiently managed (shown in Wang & Huang, 2002), producers are able to cultivate relatively high-value crops, which in some cases demand greater attention of tubewell owners. In addition, the research indicates that the shift from collective tubewell to private tubewell management did not accelerate the drop in the groundwater table.

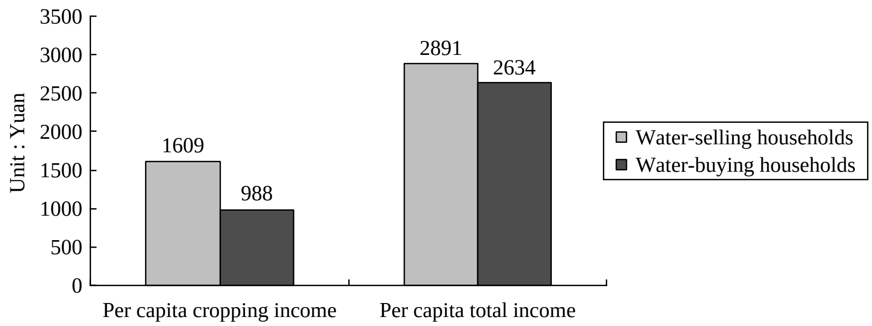


**Figure 3.** Differences in per capita cropping income and total income between water-selling households and water-buying households in 2004. *Sources:* Authors' surveys in 2004 (CWIM dataset).

*The Growing Importance of Groundwater Markets*

One possible adverse consequence of privatization—the difficulty for those without wells to access groundwater—has been addressed by another response from farmers. As tubewells have been privatized, groundwater markets have begun to emerge in recent years as a method for many farming families in rural China to gain access1to groundwater (Zhang *et al.*, 2008a). This emergence, while new in China, in fact appears to be following a pattern similar to that observed in parts of South Asia (Shah, 1993). During the 1980s groundwater markets were almost non-existent in China and, even by the mid-1990s, according to the NCWRS data, only a small proportion of communities (21%) had groundwater markets. However, by 2004 tubewell operators in 44% of communities were selling water. Across all communities approximately 15% of private tubewell owners sold water. Although groundwater markets exist in less than half of northern China's communities, the numbers are still significant: extrapolation from the estimates here indicates that farmers in more than 100 000 communities are accessing water through groundwater markets. Moreover, in communities that have groundwater markets, these markets play an important role in transferring large volumes of water to a large proportion of households.

In addition to helping farmers gain access to water resources for irrigation, the data here demonstrate that groundwater markets have also improved the efficiency and equity of water use in northern China. Specifically, groundwater markets have provided groundwater access opportunities to poorer farmers and reduced potential income gaps by enhancing the access to groundwater (Zhang *et al.*, 2008a). According to the data, households in the sample who buy water from groundwater markets are poorer than water-selling households (Figure 3). In addition, when farmers buy water from groundwater markets, they use less water than those who have their own tubewells or that use collective wells (Zhang *et al.*, 2008b). However, crop yields of water buyers do not fall (or are not lower than water sellers). Overall, the results show that groundwater markets in northern China do not have a negative effect on income—meaning that poorer farmers are getting access to water and increasing productivity.

*The Response of Farmers to Water Price Increases*

As the water table falls, even without the imposition of water charges by government officials, the price paid by farmers for their groundwater (either from their own well or from a groundwater seller) naturally increases. For example, according to the CWIM data, comparing the prices paid for groundwater by farmers in the Hebei communities which had aquifers with a water depth of only 4.4 m against the prices paid by farmers in communities which had aquifers with a water depth of 77.5 m, the cost (or henceforth, the price) of groundwater for wheat-producing households increased from 0.08 Yuan/$m^3$ to 0.56 Yuan/$m^3$ (Wang *et al.*, 2007b). Since pumping costs rise as the water table declines, this indicates that, to some extent, trans-community differences in groundwater prices can mimic differences in the scarcity of water resources. Across the CWIM sample of Hebei wheat producers, it is estimated that pumping costs rise by 0.005 Yuan per cubic metre of groundwater extracted for each additional metre in pumping.

Importantly, in the search to understand the response of farmers to water scarcity, as groundwater prices rise, farmers respond by reducing water use and changing cropping patterns. The analysis of the behaviour of Hebei wheat farmers in the CWIM dataset indicates that, when the groundwater price increased from 0.08 Yuan/$m^3$ to 0.56 Yuan/$m^3$, water use per hectare decreased from 6433 $m^3$ to 2154 $m^3$ (Wang *et al.*, 2007b). In addition, it was found that as the water table has fallen, there has been an increase in the proportion of cash crops planted by farmers. In other words, as the cost of water rises, farmers in the sample shift from staple cereals to horticultural crops, cotton and peanuts. More precisely, when the depth of water in a community falls from 4.7 m to 79 m, the area percentage of cash crops increases from 13% to 41%. Therefore, the results imply that as water tables fall and the cost of acquisition rises, farmers not only adjust the quantity of water that they use, they also change the cropping decision.

Despite benefits in water conservation that accompany the price increase of water, there is an inevitable negative impact on farmers' income (Wang *et al.*, 2007b). In other work undertaken by the authors using the same dataset, it is estimated that doubling the price of groundwater in Hebei causes 75% of wheat-producing farmers to lose money on cropping activities, and it has a negative effect on agricultural output (Huang *et al.*, 2006). Therefore, given the government's interest in maintaining rural incomes, almost certainly any use of pricing policy must also be accompanied by complementary policies that can offset the negative effect of price increases. In Huang *et al.* (2006), it is shown that a large and growing subsidy is required (and it needs to be given in a non-distorting way) to keep the income level of farmers unchanged if the price of water were to be increased by policy makers.

### *Adopting Water Saving Technologies*

Another possible response to the water shortages is the adoption of water saving technologies (Blanke *et al.*, 2007). A block of the survey instrument covered three sets of water saving technologies: traditional, household-based and community-based technologies. Traditional technologies are agronomic-based, highly divisible and have been generally practised by farmers, even in pre-People's Republic of China. Traditional technologies include border irrigation, furrow irrigation and levelling technologies.

There are also a number of newer technologies. One type, household-based technologies, is highly divisible; it requires low fixed costs and little collective action. Common household-based technologies include surface hose technology, plastic film, conservation tillage and drought resistant varieties. The other type, community-based

**Table 3.** Adoption rate of water saving technologies over time in northern China's communities

| | Traditional water saving technologies (%) | Community-based water saving technologies (%) | Household-based water saving technologies (%) |
|---|---|---|---|
| Adoption rate (%) | | | |
| Percentage of communities | | | |
| 1950 | 35 | 0 | 4 |
| 1980 | 45 | 5 | 7 |
| 1995 | 49 | 15 | 27 |
| 2004 | 52 | 24 | 50 |
| Percentage of sown areas | | | |
| 1995 | 20 | 3 | 8 |
| 2004 | 25 | 7 | 21 |
| Growth rate of adoption (%) | | | |
| Percentage of communities (2004/1980) | 16 | 433 | 669 |
| Percentage of sown areas (2004/1995) | 25 | 133 | 163 |

*Source:* Authors' survey in 2004 (NCWRS dataset).



technologies, not only requires collective action for adoption and maintenance but also has relatively high fixed costs. Commonly observed community-based technologies include underground plastic piping networks, sprinkler systems and lined canals.

With the availability of an increasing number of new water-saving technologies, what do the data say about whether or not farmers have adopted them? Before examining the adoption of newer technologies, the data show that the percentage of farmers using traditional technologies is fairly high (approximately 52% in 2004). However, this may not be surprising since these are technologies that have been around for a long time. In fact, as early as the 1950s the level of adoption of traditional technologies was already at 35% (Table 3). Hence, in the case of traditional technologies, this means that the rate of growth has been slow. Between the 1950s and 2000s, this has only been 17 percentage points.

The record of new technologies is somewhat better, but their adoption is still not universal, especially in the case of community-level technologies. In particular, while starting at low rates of adoption in the 1980s, by 2004, approximately half of communities had adopted some type of household-based water saving technology. In contrast, only 24% of communities had adopted some type of community-based water saving technology. Using sown area measures, the adoption rates were even lower; the percentage of sown area adopting community-based water saving technologies was only 7% in 2004.

Compared with community-based water saving technologies, the increase in the rate of adoption of household-based water saving technologies is much higher. Since the 1980s, the proportion of communities adopting household-based water saving technologies increased by more than six times (Table 3). The proportion of sown areas adopting household-based, water-saving technologies increased by 1.6 times from 1995 to 2004. Indeed, one interpretation of these figures is that the high growth rate of adoption of household-based water saving technologies implies that when they are faced with increasing water scarcity, farmers do respond. Since community-based technologies are beyond the reach of individual farmers, the lower rates of adoption may suggest a failure of local leaders to extend these water-saving approaches effectively.

Based on these descriptive contours, while it is unclear what is driving the adoption path (or holding back the adoption of) community-based technologies, work by Blanke *et al.* (2006) suggests that it is probable that there are two sets of forces that are both encouraging and holding back adoption (Wang *et al.*, 2007b). On the one hand, rising scarcity of water resources is almost certainly pushing up demand for community-based technologies. On the other hand, the predominance of household farming in China (Rozelle & Swinnen, 2004) and the weakening of the collective's financial resources and management authority (Lin, 1991) have made it more difficult to gather the resources and coordinate the effort required to adopt technologies that have high fixed costs and involve many households in the community. In contrast, household-based technologies may be more widely adopted due to relatively low fixed costs, divisibility and minimal coordination requirements.



## Conclusion

The primary goal of the paper was to understand better the nature of northern China's water scarcities and sketch a picture showing how different actors are responding. In doing so, mostly with the aid of several datasets, the findings show that there is a water crisis in northern China. However, the severity of the water crisis depends on which criteria are used to measure water scarcity. For example, based on the perception of community leaders and farmers (who were asked if there is a water scarcity or not), approximately 70% of communities are facing increasingly tight water supplies. According to the same measure, among the communities short of water agricultural production is severely constrained by water scarcity. Farmers in these communities state that in the case of either surface water or groundwater (or both), the water supply has become less reliable than in the past.

When using other measures of scarcity, a more nuanced picture emerges. According to data on the change in the groundwater table in communities over the past 10 years, there has been a decline in groundwater resources in approximately half of China's groundwater-using communities. In a small percentage of them (approximately 8%), the groundwater table was falling rapidly. Hence, according to this metric, there also is a problem in many communities. However, from another viewpoint, an alternative interpretation can be taken. There is no severe problem with the groundwater resources in up to half of China's communities in northern China. Specifically, in approximately 50% of communities, groundwater resources have shown little or no decline since the mid-1990s; in some the groundwater table has actually risen.

Therefore, it is thought that the best interpretation of northern China's water resources is that there *is* a water crisis in northern China. However, the crisis does not occur everywhere. There are many parts of China in which water resources have not deteriorated over time. Although not everywhere, half of northern China is suffering from falling groundwater tables. This area affects a large number of farm households—between 50 to 100 million. Hence, policies to address water scarcity problems should be implemented, but they should also be carefully targeted.

Perhaps a more important conclusion is that a more active role by the government—or the adoption of a new strategy—will be required in order for China to be able to begin to solve the problems in the groundwater sector. Although the government in China has begun to make a number of policy responses, to date implementation has not been very effective. In contrast, farmers have shown themselves to be much more responsive. However, since farmers often work on their own, their actions have both helped and damaged water resources. According to the data here, on occasions the actions of farmers have been helpful in alleviating the crisis (e.g. by adopting water-saving technologies and reducing water use as the cost of water rises). At other times, they are not (e.g. by continually drill wells, even in areas where the groundwater table is falling rapidly).

Therefore, one of the main messages of this paper is that it is possible to address China's water crisis. It is going to take more effective actions by the government to channel farmer behaviour in a productive, non-harmful way. Above all, it must be realized that nominal reform cannot realize the policy goals of increasing water use efficiency and water conservation. The government must create the institutions and infrastructure through which they can make an environment that will provide the incentives that will make farmers save water. If they can, it has been shown here that farmers will save water, make adjustments and adopt new technologies that are helpful to overcome the water crisis. It is thought that a sustainable environment needs to be built on effective water pricing and water rights policies. To make this work, a huge commitment is required to set up the institutions and infrastructure to implement them. Although this is a challenge, it is believed that it will be more effective and much cheaper than other technological solutions (such as, the South to North Water Transfer Project).



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## Notes

1. Although many authors, including those of this paper, often use the fall of the groundwater table as an indicator of overuse by users of groundwater resources, it is important to recognize that a community's water resources may not be over-exploited, even if the water table is falling. Given the fact that many of China's aquifers do not have natural sources of recharges, any extraction will result in a declining water level. Hence, even under a rationally planned groundwater utilization strategy, there will be a proportion of communities in which water tables would be falling.
2. *Collective management* implies that the community leadership through the community committee takes direct responsibility for water allocation, canal operation and maintenance (O&M) and fee collection. *WUA* is theoretically a farmer-based, participatory organization that is set up to manage the community's irrigation water. *Contracting* is a system in which the community leadership establishes a contract with an individual to manage the community's water.
3. When managers have partial or full claim on the earnings of the water management activities (for example, on the value of the water saved by reforming water management), it is said that they face strong incentives (or that the manager is managing *with incentives*). If the income from their water management duties is not linked to water savings, they are said to manage *without incentives*.
4. Results described in this paragraph are reported in detail in Wang *et al.* (2005b).

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