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Do incentives still matter for the reform of irrigation management in the Yellow River Basin in China?

Jinxia Wang [a,*], Jikun Huang [a], Lijuan Zhang [a], Qiuqiong Huang [b]

[a] Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Jia, No. 11, Datun Rd, Anwai, Beijing 100101, China

[b] Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, United States

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SUMMARY

Under the pressure of increasing water shortages and the need to sustain the development of irrigated agriculture, since the middle of the 1990s, officials in the YRB have begun to push for the institutional reform of irrigation management. Based on a panel data set collected in 2001 and 2005 in the Yellow River Basin, the overall goal of this paper is to examine how the irrigation management reform has proceeded since the early 2000s and what the impacts are of the incentive mechanisms on water use and crop yields. The results show that after the early 2000s, irrigation management reform has accelerated. Different from contracting management, more Water User Associations (WUAs) chose not to establish incentive mechanisms. The econometric model results indicate that using incentive mechanisms to promote water savings is effective under the arrangement of contracting management and not effective under WUAs. However, if incentives are provided to the contracting managers, the wheat yield declines significantly. Our results imply that at the later stage of the reform, the cost of reducing water use by providing incentives to managers includes negative impacts on some crop yields. Therefore, how to design win–win supporting policies to ensure the healthy development of the irrigation management reform should be highly addressed by policy makers.

1. Introduction

Water is very scarce and is becoming more limited in the Yellow River Basin (YRB). The basin runoff, at 54 billion cubic meters per year on average, accounted for only 2 percent of the total national runoff in the past decade (Ministry of Water Resources, 2011). Since 1950s, precipitation in the YRB has been declining with obvious consequences for the available water supplies (Wang et al., 2013; Liu et al., 2008b). At the same period, the share of agricultural water use has decreased from over 97 percent to less than 70 percent, while the share of industry and domestic water use increased from less than 3 percent to over 30 percent (YRCC, 2012; Wang et al., 2011). Despite facing sharp competition, water use efficiency in the agricultural sector is very low, at only approximately 30–40 percent (Chang and Xiao, 2006; Deng et al., 2006).

Under the pressure of increasing water shortages and the need to sustain the development of irrigated agriculture, since the middle of the 1990s, officials in the YRB have begun to push for the institutional reform of irrigation management. The major purpose of irrigation management reform is to increase the agricultural water use efficiency and also to promote the continuing growth of agricultural production. To push the reform, local government has not only made detailed reform plans but has also issued relevant regulations and technical guidance (Wang et al., 2005). As a result, from the middle of the 1990s to 2001, the traditional collective irrigation management at the community level was replaced by Water Users Associations (WUAs) and contracting arrangements in many locations in the YRB (Wang et al., 2005; Zhou et al., 2009). In some regions, the reformed institutions (WUAs or contracting) have even become the dominant form of management.

However, not all irrigation management reforms in the YRB have been implemented successfully. Based on one large field survey in 2001, Wang et al. (2005, 2006) found that in most villages in the YRB, reform was only nominally implemented, and there are few apparent differences when comparing the reform institutions (WUAs or contracting) to the traditional collective management forms. These authors argued that only those institutions that provided incentives to the irrigation managers were successful in achieving large water savings and reduced the water use per hectare by 40 percent. In addition, the incentive mechanism had a

* Corresponding author. Tel.: +86 10 64889841; fax: +86 10 64856533.
E-mail address: jxwang.ccap@igsnrr.ac.cn (J. Wang).

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small or no effect on the crop yields. The incentives has been defined as offering the irrigation managers the rights to the earnings equal to the value of the water saved by irrigation management reform. In China, under collective management, managing water is only one of regular responsibilities for village committee. Village committee earn wages for all their responsibilities and they cannot claim any extra income from water saving. Therefore, the incentives only can be set up in WUAs or contracting management, not for traditional collective management. Other researchers also noted the institutional arrangement problems that arose when reforming the irrigation management in the YRB (Zhou et al., 2009).

In fact, not only in the YRB but also in other regions in China or in other countries, the record of irrigation management reform is also mixed. Under the guidance of the ''Five Principles'' promoted by World Bank, the irrigation management reforms in Hubei and Hunan Provinces in China have been generally considered to be success cases (Liu et al., 2008a,b; Wang et al., 2010). The ''Five Principles'' include adequate and reliable water supply, legal status and participation, WUAs organized within hydraulic boundaries, water deliveries that can be measured volumetrically, and the equitable collection of water charges from members by the WUA (Wang et al., 2010). However, visits to the field in rural China can easily uncover cases in which local irrigation management changes were implemented and failed (Ding et al., 2006). Mukherji et al. (2009) undertook a systematic review of 108 cases of irrigation management reform in large scale publicly owned irrigation systems in Asia and found that less than 40% of the documented cases were successful. The mixed performance of irrigation management reform has also been summarized by some other scholars, such as Mishra et al. (2011) and Yakubov (2012).

Facing with the mix record of irrigation management reform, evaluating the reform and identifying the factors influencing the successful implementation of the reform has attracted attention of many scholars. As expected, through establishing WUAs to transfer full or partial management responsibilities from the government to irrigators (or improve the collective action of farmers), the reform can obviously improve the performance of irrigation system (such as increasing irrigation efficiency, adequacy and equity of water delivery, cost recovery, agricultural productivity and farmer income) (Özerol, 2013; Bassi and Kumar, 2011; Vermillion and Sagardoy, 1999). However, most reforms have not realized the designed purpose due to many reasons. These reasons include such as lack of capacity building for farmers, lack of appropriate legal backup, unreliable water supply, lack of fund to meet the operation and maintenance cost, discrepancy among irrigators and nominally turning responsibilities and power to irrigators (Özerol, 2013; Bassi and Kumar, 2011; Mukherji et al., 2009; Parthasarathy, 2004; Meinzen-Dick et al., 2002).

Although many reasons have been identified for the failure of the reform, seldom literature has noticed the possible reason due to poor incentive mechanism facing by WUA managers. By a formal definition, WUAs are voluntary, non-governmental, nonprofit entities, established and managed by a group of irrigators located along one or several watercourse canals (Wuaconsult, 2008; Vermillion and Sagardoy, 1999). However, due to top-down fashion, in most cases, the ''WUA becomes a place in the strongly hierarchical structure that still is controlled by the government'' (Zavgorodnyaya, 2006; Veldwisch et al., 2012). Importantly, considering the nonprofit nature, establishing incentive mechanisms within WUAs has been much ignored. As Wang et al. (2005, 2006) pointed out that most irrigation reforms in the YRB are nominal due to lack of incentive mechanism. After evaluating the reform performance, Vandersypen et al. (2009) proposes to implement a mix of incentives and measures to resolve the conflict between farmers and the central management to their mutual benefit. In addition to these studies, seldom literature have examined or noticed the importance of incentives on the success of irrigation management reform. Internationally, most literatures focus on establishing incentives (such as using water price or water rights policy) for irrigators (instead of irrigation managers) to improve water use efficiency (Poddar et al., 2011; William and Liu, 2005 Dinar and Mody, 2004).

Therefore, while there is a rich literature on the evaluation of irrigation management reform either inside or outside of the YRB, there are also research gaps that have limited our deep understanding of the reform. First, most research is either based on case studies or only qualitatively describes the possible experience and lessons of the irrigation management reform, particularly, seldom studies have examined the importance of incentives facing by irrigation managers (Ding et al., 2006; Zhao and Qiao, 2009; Mukherji et al., 2009; Liu and Li, 2011; Poddar et al., 2011). Second, although some researchers conducted the quantitative analysis based on large field surveys (such as Wang et al., 2005, 2006; Liu et al., 2008a,b), their studies were based on one period of data and could not reflect the performance changes from the reform over time. For example, based on field survey data collected in 2001 in the YRB, the early stage of the reform, Wang et al. (2006) applied an econometric model and assessed the performance of irrigation management reform in the YRB. However, after 2001, the reform has continued and spread widely to more villages in the YRB, but little information is available on how this reform has been implemented and what its impacts are on water use and crop productivity.

To gain a further understanding of the evolution of irrigation management reform and to contribute to more effective policy strategies in the YRB and other regions either inside or outside of China, it is urgent to answer the following important questions. After the early 2000s, how did the irrigation management reform continue to proceed? Has the reform seriously considered the incentive for irrigation managers? Have the effects of reform on water use and crop yields differed from those achieved in the early stage of reform? Does the effectiveness of the incentive mechanisms differ under different institutional arrangements? Understanding these issues is important because they have significant policy implications for designing more effective policy measures to improve the efficiency of water use and crop productivity.

The overall goal of this paper is to answer the questions mentioned above. To pursue this goal, we define the following three specific objectives. First, we trace the evolution of institutional reform and the incentives provided to managers in irrigation management in the YRB. Second, we identify the impacts of irrigation management reform on water use, focusing on the role of incentive mechanisms under various management patterns. Third, we analyze the impacts of the reform on crop yields.

The rest of this paper is arranged as follows. The second section discusses the sampling approach and the information collected. The third section provides the description on the reform of irrigation management and incentive mechanisms in two periods. Applying descriptive statistical analysis and econometric models, the fourth section is to assess the impacts of incentives of irrigation management on crop water use. In the fifth section, based on descriptive statistical analysis and established econometric model, the impacts of incentives on crop yield and the potential benefit-cost of the reform also has been discussed. The final section contains conclusions and policy implications.

2. Methods of data collection

The data for this study come from the two round surveys that we conducted in four irrigation districts (IDs) in Ningxia and Henan provinces in 2001 and 2005. In 2001, to represent as much diversity as possible in our data, we chose provinces located in the upper (Ningxia) and lower reaches (Henan) of the Yellow River Basin (YRB). From a number of IDs in each province, we chose two IDs, one upstream in the province and the other downstream. The villages were randomly chosen from a census of villages in the upper, middle and lower reaches of the canals within the IDs. We also randomly chose four households within each village. After obtaining the basic information about each household's plot, two plots from each household were selected for more careful investigation. In 2001, we surveyed 51 village leaders, 56 irrigation managers, and 204 farm households and gathered information on 408 plots. In 2005, we returned to the same sample sites to collect the same variables as collected in 2001. However, for various reasons (such as the combination of several villages), we were only able to collect information in 47 villages. Even so, our retention rate was still surprisingly high. Among the 204 households surveyed in 2001, we were able to interview 186 households (91 percent) in 2005. For each household, we also asked for information on the two plots that were surveyed in 2001. Thus, in total, we obtained balanced panel data with 186 households and 372 plots.

To meet the study's objectives to examine the evolution and impacts of irrigation management, we designed three separate survey instruments: one for farmers, one for irrigation managers and one for village leaders. During our survey, three types of irrigation management institutions were identified: collective management, Water User Associations (WUAs) and contracting management. In our questionnaires for the villages and the irrigation managers, we recorded the share of canals within the village that was controlled by each management type in 1990, 1995, 2001 and 2004 in two round surveys. The first round survey collected data in 3 years (1990, 1995 and 2001) and the second round survey collected data in 2004. In addition, enumerators also investigated the managers' compensation. Following the definition used in Wang et al. (2005), when the managers gain rights to the earnings of the irrigation management activities (that is, to the value of the water saved by irrigation management reform), we say that they face strong incentives (or *with incentives*). If the incomes from their irrigation management duties are not connected to water savings, they are said to be *without incentives*.

The survey also collected information to develop several measures for the effects of the incentives of irrigation management reform—the amount of water use and crop yields by plot. In our sample villages, more than 95% of irrigation comes from surface water resources. Therefore, water use in our analysis implies the application of surface water resources. Because measuring water use in villages that use surface water is always a difficult task, during the enumeration process we developed a methodology that was based on a strategy of eliciting information from more than one respondant in each community and asking about water use in a number of ways (Wang et al., 2005). To implement this strategy, we included special blocks on water use in both the village and irrigation manager forms. We also asked irrigation district officials in each area for information that could be used to check our survey-based estimates. We not only asked the respondants to provide estimates of water use per hectare on a cubic meter basis, but also recorded other information about the application process, such as the length of time that it took to apply water in the village, the depth to which the average field was flooded, the type of the soil and the area irrigated. We elicited these data for each irrigation for each crop during the season. With this information and with other information from the household, we were able to combine the various measures into a single measure from which we develop our final estimates of water use.

The rest of our survey collected data on a number of other variables that may affect the irrigation management institutions, the outcomes or both. For example, we asked the village leaders and the irrigation managers if the upper-level government officials took steps to encourage the extension of reform in their villages. A number of other questions were asked about the degree of water scarcity, the level of investment in the village's irrigation system over the past 20 years, as well as a number of other village, household and plot characteristics.

3. Reform of surface irrigation management and incentive mechanisms

Consistent with the findings of Wang et al. (2005), three primary irrigation management patterns coexist for surface water in the YRB. The traditional management pattern is *collective management*, one system that essentially allocated water in most of China's villages during the People's Republic period. If the village's irrigation system is said to be run by collective management, it implies that the village leadership through the village committee directly takes responsibility for water allocation, canal operation, maintenance (O&M) and fee collection. Two reformed institutions or non-collective institutions for water management are *WUAs* and *Contracting*. The WUA is theoretically a farmer-based, participatory organization that is established to manage the village's irrigation water. In the WUAs, a member-elected board should be assigned the control rights over the village's water. If the village leadership establishes a contract with an individual farmer to manage the village's water, this management has been defined as contracting. Therefore, if the collective management has been replaced by WUAs or contracting, water management responsibilities (such as water allocation, canal operation, maintenance (O&M) and fee collection) have been transferred from previous village committee to WUAs board or individual contracting farmers.

After the early 2000s, irrigation management reform has accelerated and more WUAs and Contracting have been established in place of collective management. From 1990 to 2001, the share of collective management declined from 91 percent to 64 percent, dropping by 30 percent (Wang et al., 2005). However, by 2004, the share of collective management further declined to 49 percent, dropping by 23 percent in only 4 years of reform (from 2001 to 2004) (Table 1, column 5). Obviously, the annual rate of decline for collective management from 2001 to 2004 (6 percent) was quicker than that from 1990 to 2001 (3 percent). With this accelerated decline rate for collective management, more villages established WUAs or contracting. Until 2004, 21 percent and 30 percent of villages set up WUAs or contracting management, respectively, to run their irrigation systems (rows 5 and 6, column 5).

Table 1
Irrigation management in the four selected irrigation districts, Ningxia and Henan Provinces, 2001–2004 (percentage of samples, %).

	Ningxia		Henan		Total
	WID-N[a]	QID-N[b]	PID-H[c]	LID-H[d]	
2001					
Collective	25	45	89	100	57
WUA[e]	50	17	0	0	17
Contracting[f]	25	38	11	0	26
2004					
Collective	25	29	89	100	49
WUA[e]	38	29	0	0	21
Contracting[f]	38	42	11	0	30

Data source: Authors' survey.
[a] WID-N: Weining Irrigation District in Ningxia Province.
[b] QID-N: Qingtongxia Irrigation District in Ningxia Province.
[c] PID-H: People's Victory Irrigation District in Henan Province.
[d] LID-H: Liuyuankou.
[e] WUA: Water User Associations.
[f] Contracting: Contracting management.

Similar to the early stage of reform, our survey data reveal that contracting has developed more rapidly than the WUAs. For example, the share of villages managed by contract reached 26 percent in 2001, 9 percent higher than the number of villages under the management of WUAs (Table 1, column 5). By the end of 2004, 30 percent of villages chose contracting, which is still 9 percent higher than those villages run by WUAs. As noted by Wang et al. (2005), the somewhat more rapid emergence of contracting may be due to the ease of establishing the system and the similarities of the reforms to the other reforms that have unfolded in rural China.

While there has been a shift from collective management to WUAs and contracting during the past 15 years, irrigation management reform still varies across the four sample IDs. WUAs and contracting have developed more rapidly in Ningxia than in Henan (Table 1). For example, in one of the Ningxia IDs (WID-N) and by 2004, the collective managed water was in only 25 percent of the sample villages (column 1). WUA managed water was in approximately 38 percent of the villages, with the same percentage for contracting managed water. In another Ningxia ID (QID-N), the share of villages under WUAs and contracting approached 71 percent in 2004, representing an increase of 16 percent from 2001 to 2004 (column 2). In contrast, significantly less reform was enacted in Henan. In fact, in two IDs in Henan province, from 2001 to 2004, almost no progress has been made on reform. Looking at either 2001 or 2004, only 11 percent of the villages in one of the sample IDs (PID-H) and none in the other (LID-H) have moved to contracting or to WUAs (columns 3 and 4).

3.1. Changes of incentive mechanism

As explained by Wang et al. (2005), the incentive mechanism of irrigation management reform is closely related to the payment system for irrigation fees. Irrigation fees collected from farmers include two parts: the *basic irrigation fees* associated with the fixed quantity of land in the village and the *volumetric irrigation fees* associated with the volume of water use. Prior to the farming year and based on historical use patterns and other criteria, the ID officials target the amount of water that a village should use (called the *target quantity*). The total value of the expected water use for the village is then divided by the village's total quantity of land, and this volumetric water fee is added to the basic water fee to create the farmer's total water fee. In implementing the irrigation management reform, the ID officials agree that the irrigation manager only has to pay the per cubic meter charge for the water that is actually used (*actual quantity*). If the actual quantity of water delivered to the village is less than the targeted quantity, the difference between the volumetric fee that is collected from the farmers and that which the manager pays for the water is his *excess profit*. In communities that provide the irrigation manager with a full incentive, the excess profit is earned by the manager.

The survey results show that after 2001, although showing some improvements, most of the irrigation management reforms are still nominal in terms of offering this type of incentives, regardless of whether they are WUAs or contracting. For example, until 2004, on average, the leaders in only 46 percent of the villages (only 1 percent higher than in 2001) offered WUA and contracting (or non-collective) managers with incentives that might induce the managers to exert an effort to save water to earn an excess profit (Table 2). In the remainder of the villages, although there was a nominal shift in the institution type (that is, the leaders claimed that they were implementing WUAs or contracting), in fact, from an incentives point of view, the WUA and contracting managers (irrigation managers under WUA and contracting arrangement) had not been provided with incentives. In these villages, the irrigation managers are similar to village leaders in a collectively managed system in that they do not have a financial incentive to save water. Hence, to the extent that the incentives are the most important part of the reform, these differences mean that it would not be surprising if in some villages, the WUAs and contracting were more effective at saving water than in other villages.

Table 2
Incentive mechanism of WUA and contract in the sample irrigation districts, Ningxia and Henan Provinces, 2001–2004.

	Percentage of samples (%)		
	With incentives	Without incentives	Total
2001			
WUA and contracting[a]	45	55	100
WUA[b]	25	75	100
Contracting[c]	58	42	100
2004			
WUA and contracting[a]	46	54	100
WUA[b]	20	80	100
Contracting[c]	64	36	100

Data source: Authors' survey.
[a] WUA and Contracting: Villages either managed by WUA or contracting.
[b] WUA: Water User Associations.
[c] Contracting: Contracting management.

Interestingly, the survey results indicate that over the 2001–2004 periods and for all samples, fewer WUA managers chose to establish incentive mechanisms, while more contracting managers preferred to establish incentive mechanisms. For example, in 2001, 25 percent of the WUAs established incentive mechanisms, but this number declined to 20 percent in 2004 (Table 2, column 1). On the contrary, the percentage of contracting management that established incentive mechanisms increased from 58 percent in 2001 to 64 percent in 2004.

However, a further analysis demonstrates that the change in incentives for both WUAs and contracting are not consistent over the various irrigation districts. For example, in one ID (WID-N) in Ningxia Province from 2001 to 2004, more WUAs chose not to establish incentives, and the share of WUAs with incentive mechanisms declined from 25 percent to zero (Table 3, column 1). However, for the WUAs in another ID (QID-N), we found the opposite story over the same period. In this ID, the share of WUAs that

Table 3
Incentive mechanism of WUA and contract by irrigation district in Ningxia Province, 2001–2004.

	Percentage of samples (%)		
	With incentives	Without incentives	Total
WID-N			
2001			
WUA and Contracting[a]	17	83	100
WUA[b]	25	75	100
Contracting[c]	0	100	100
2004			
WUA and Contracting[a]	33	37	100
WUA[b]	0	100	100
Contracting[c]	67	33	100
QID-N			
2001			
WUA and Contracting[a]	62	38	100
WUA[b]	25	75	100
Contracting[c]	78	22	100
2004			
WUA and Contracting[a]	53	47	100
WUA[b]	29	71	100
Contracting[c]	70	30	100

Data source: Authors' survey.
[a] WUA and Contracting: Villages either managed by WUA or contracting.
[b] WUA: Water User Associations.
[c] Contracting: Contracting management.

established incentives even slightly increased from 25 percent to 29 percent. For the contracting, we also found a different development trend for its incentives in two IDs. For example, in the WID-N, the share of contracting that established incentives approached 100 percent in 2004, but in the QID-N from 2001 to 2004, we observed a slight declining trend.

After understanding the trend in the change of incentives by various institutional arrangements, we are more interested in answering the following questions, which are related to the performance of the reform. First, over the reform period from 2001 to 2004, do the incentives still play a significant role in saving water? Second, if the incentives still play a significant role in saving water, will the financial benefit through saving water be at the cost of a negative impact on agricultural production? The following sections will further explore these issues by analyzing the impacts of incentives on crop water use and crop yields. As discussed in the above section, we did not observe any reform progress in two IDs in Henan province. Therefore, it is not rational to include the Henan samples in our analysis, which focuses on the reform performance assessment. In the following two sections, we will only use samples in Ningxia province to explore the impact of incentives on crop water use and crop yields.

4. Impacts of incentives on crop water use

Descriptive statistics using our data show that incentive mechanisms have possibly played a role in reducing water use for both wheat and maize. For example, regardless of whether managed by WUAs or contracting and also regardless of the WID-N or QID-N, the water use per hectare of wheat in the reformed villages with established incentives is lower than that in the villages without incentives or under the management of collectives. For example, in the WID-N (or QID-N), the water use per hectare of wheat was 7535 (5259) cubic meters, 0.07 (17) percent lower than for the reformed villages without incentives and 27 (15) percent lower than those villages under collective management (Table 4, column 1).

More importantly, further analysis finds that only under the management of contracting with an established incentive mechanism can the water use per hectare of wheat and maize be consistently reduced as is expected with irrigation management reform. For example, if the irrigation system of a village is managed by contracting with incentives for the manager to save water in the WID-N, wheat (or maize) water use per hectare is 6587 (or 7144) cubic meters, 10 (or 23) percent lower than in those villages under the contracting management without incentives and 37 (or 41) percent lower than those villages under collective management (Table 5, rows 3–5, columns 1 and 2). It is not hard to find a similar story in the QID-N, where contracting management with incentives also possibly plays a significant role in reducing water use for both wheat and maize (rows 8–10).

However, if checking this issue in those villages using WUAs, it is hard to find a consistent story for either wheat or maize, and the results can even conflict across two IDs. For example, in the WID-N, the results show that if the WUAs established incentive mechanisms, the per hectare water use for wheat (or maize) was 8719 (or 8250) cubic meters, 16 (or 32) percent lower than those villages under collective management (Table 5, rows 1, 2 and 5). However, in the QID-N, we found the opposite relationship between the use of incentives in the WUAs and the water use for wheat and maize. That is, in those villages that are under the management of WUAs and that have established incentives, the wheat or maize water use was even higher than in those villages run by collectives (rows 6, 7 and 10). These results imply that the incentive mechanism is possibly more effective in saving water under a contracting management arrangement than in a WUA. However, because many other factors affect water use, we cannot find a real relationship between the incentives and the water use. For example, the cropping structure and the canal system investment may affect the way that reforms are implemented and thereby affect water use. Therefore, multivariate analysis is required to analyze the relationship between irrigation management reform and water use.

Table 4
Incentives and water use in two irrigation districts in Ningxia Province, 2001–2004.

	Wheat	Maize
Water use (m^3/ha)		
WID-N		
Non-collective with incentives	7535	7587
Non-collective without incentives	7540	9899
Collective	10,378	12,184
QID-N		
Non-collective with incentives	5259	6065
Non-collective without incentives	6325	6990
Collective	6221	6875

Data source: Authors' survey.

Table 5
Incentives and water use of wheat and maize under various management patterns in two irrigation districts in Ningxia Province, 2001–2004.

	Wheat	Maize
Water use (m^3/ha)		
WID-N		
WUA[a]		
Non-collective with incentives	8719	8250
Non-collective without incentives	7651	10,255
Contracting[b]		
Non-collective with incentives	6587	7144
Non-collective without incentives	7340	9289
Collective[c]	10,378	12,184
QID-N		
WUA[a]		
Non-collective with incentives	7737	7358
Non-collective without incentives	6946	7350
Contracting[b]		
Non-collective with incentives	4834	5791
Non-collective without incentives	4826	6010
Collective[c]	6221	6875

Data source: Authors' survey.
[a] WUA: Water User Associations.
[b] Contracting: Contracting management.
[c] Collective: Collective management.

4.1. Econometric model

Based on the above discussions, the link between crop water use per hectare and its determinants, the incentive mechanisms of irrigation management institutions and other factors can be represented by the following equation, which applies plot level data in two IDs in Ningxia Province:

$$w_{ijk} = \alpha + \beta I_k + \delta Z_{ijk} + \phi Y_{ijk} + \gamma D_{ijk} + \varepsilon_{ijk} \quad (1)$$

where w_{ijk} represents the average water use per hectare of wheat or maize from the ith plot of household j in village k. The rest of the variables explain the water use. I_k, our variable of interest, measures the nature of the incentives faced by the irrigation managers in village k. To measure the incentives, we adopt two strategies. The first strategy is to classify irrigation management into three groups. The first and second group are both managed by non-collective institutions (WUAs or contracting), but the incentive mechanism is established in the first group and not in the second group. The third group is under the management of collectives and is treated as the basis for comparison (see the estimation results in Table 6). Because we are also interested in knowing if the contribution of incentive mechanisms to water use is different due to various management patterns (such as WUA or contracting), the second strategy is to create one set of interaction terms between the incentive and the management patterns. These interaction terms include the following: if with incentives and WUAs, if with incentives and contracting, if without incentives and WUAs, and if without incentives and contracting. The second strategy also treats the collective management as the basis for comparison (see the estimation results in Table 7). Based on our survey and previous studies (Wang et al., 2005), reform of irrigation management is mainly decided by upper level government and village leaders, Therefore, for farmers, it is one exogenous variable.

In Eq. (1), Z_{jk}, a matrix of control variables, is included to represent the other village, household and plot factors that affect water use. Specifically, we include a number of variables to hold constant the nature of the village's socio-economic characteristics, production environment and cropping structure. We include variables such as the number of households, the per capita annual income and the distance to the township to measure the socio-economic characteristics. The length share of the lined canals and the level of irrigation investment per hectare are used to measure the production environment, and the cropping structure is measured as the proportion of the village's sown area that is in rice. The household characteristics include age and the education level of the household head and the land endowment. We also add three plot characteristics: soil type, plot location (distance from the plot to the farmer's house), and whether the crop is planted in rotation with another crop (*single season* equals one, if not). Finally, our model also includes Y_{ijk}, a dummy variable representing the year 2004, and D_{ijk}, a dummy variable representing the ID that serves the household. The symbols α, β δ, ϕ and γ are parameters to be estimated, and ε_{ijk} is the error term, which is assumed to be uncorrelated with the other explanatory variables in our initial equations, an assumption that we subsequently relax.

4.2. Estimation results on the impacts of incentives on crop water use

Our empirical estimation performs well for the water use model (Tables 5 and 6). The goodness of fit measure is good (most of the adjusted R^2 are approximately 0.40). Many of the coefficients for the control variables have the expected signs and are statistically significant. For example, we find that after holding other factors constant, in those villages with a larger number of households and a higher level of per capita annual net income, the farmers use more water per hectare for both wheat and maize (Table 5, rows 3 and 4; Table 6, rows 5 and 6). In addition, the farmers that are in villages with a high share of lining canals use less water per hectare for wheat and maize (Table 5, row 5; Table 6, row 7). We also find that those villages with a higher share of rice use less water for wheat and maize per hectare (Table 5, row 7; Table 6, row 9).

Importantly, our results show that when the officials provide the irrigation managers with incentives, without regard as to whether they shifted to a WUA or contracting management, the managers appear to reduce water deliveries for wheat and maize in the village (Table 6, row 1). The econometric results show that when compared to the villages without incentives under collective management (the omitted institutional type), the coefficient on the incentives indicator variable is negative and significant at the 1 percent level for both the wheat and the maize estimation results. In other words, without regard for the form of the irrigation management institution, if the managers are offered positive incentives, the water use per hectare of wheat can be reduced by 1345 cubic meters, or 21 percent of their typical water use. For maize, if the managers are offered an incentive to earn a financial benefit from saving water, the water use can be reduced by 1453 cubic meters, or 19 percent of their typical use. For either wheat or maize, the reduction in their water use per hectare is less than it was in the early stage of reform (40 percent, as revealed in Wang et al. (2005)). This finding implies that with the continuing push for irrigation management reform, the role of incentives on saving water still exists; however, its contribution is tending to decline. This decline is not hard to understand. The major reason is possibly due to a larger water saving opportunity than that seen in the early stage of the reform.

Is the effectiveness of the incentive mechanisms different under various management patterns? To answer this question, we examine our water use model results with interaction terms between incentives and reformed institutions (WUAs or contracting). The estimation results demonstrate that the incentive mechanisms for water saving are effective under the contracting management arrangement and not effective under WUAs (Table 7). For either the wheat or the maize water use model, the coefficients of the interaction term between the incentives and contract are all negative and statistically significant at the 1 percent level (row 2). Compared to the villages without incentives under collective management, the incentives established within contracting management can significantly reduce wheat and maize water use by 27 percent and 25 percent, respectively. However, unlike contracting, even when the WUA managers are provided with incentives, the crop water use did not tend to decrease (row 1).

Why are incentive mechanisms under the institutional arrangement of contracting more effective than those under the WUAs? This effectiveness could possibly be closely related to the different institutional arrangements of WUAs and contracting. As a farmers' organization, rather than increasing the water use efficiency, the major role of the WUAs' managers is to provide good irrigation service to its farmer members. If the role of the incentive mechanism on saving is at the cost of hurting agricultural production, the managers of the WUAs are more likely not to operate based on the incentives. In contrast, the contracting managers are individual farmers, and their major purpose in contracting to manage the canals is to earn some extra profit. If the incentive mechanism can play an effective role in saving water and at the same time bring more profit to their management activities, then it is not surprising that they will operate the incentives well. The next key question is then whether saving water through incentive mechanisms must be at the cost of generating a negative impact on crop yields. The following section will continue to examine this question.

5. Impacts of incentives on crop yields

Compared with those villages managed by collectives, those managed by contracting with incentives show a lower wheat yield but not maize yield. For example, the wheat yield per hectare in those villages providing incentives to the contracting managers was 3990 kg in the WID-N and 4191 kg in the QID-N, which are lower than those villages under the traditional collective management, at 4521 kg in the WID-N and 4501 kg in the QID-N (Table 8, row 1). If linking the water saving effect of the incentive mechanisms together, these results perhaps indicate that through improving management, the contracting managers have been able to save water and also to earn more money. However, at the same time, the wheat yield has likely been reduced due to the reduction in water use. Unlike wheat and despite the reduction of water use, the maize yield has not been reduced under the management of contracting with incentives; it has even increased (row 2). This result occurs because wheat grows in the dry season but maize grows in the rainy season; therefore, wheat is more sensitive to the reduction of irrigation water than maize.

Table 6
Regression analysis of the determinants of crop water use at the plot level in Ningxia Province.

	Water use per hectare	
	Wheat	Maize
Water management institutions		
If non-collective with incentives (1 = yes; 0 = no)	−1344.9	−1452.7
	(3.64)***	(2.78)***
If non-collective without incentives (1 = yes; 0 = no)	−417.3	−150.4
	(1.22)	(0.32)
Village characteristics		
Number of households (number)	4.072	5.202
	(4.09)***	(3.74)***
Per capita annual net income (yuan, log)	790.3	1482.7
	(1.73)*	(2.38)**
Length share of lining canals (%)	−22.4	−33.4
	(3.55)***	(3.91)***
Distance to township (km)	39.1	168.3
	(1.01)	(3.14)***
Value per hectare of accumulated investment into village irrigation infrastructure (yuan/ha)	0.057	0.003
	(2.00)**	(0.07)
Share of rice in sown area (%)	−29.9	−52.6
	(3.41)***	(4.20)***
Household characteristics		
Age of household head (years)	−28.2	−43.4
	(1.75)*	(1.91)*
Education of household head (years)	−93.2	−202.0
	(2.00)**	(3.08)***
Cultivated land areas per household (ha)	378.7	822.4
	(0.74)	(1.16)
Plot characteristics		
Conjunctive irrigation (1 = yes; 0 = no)	−221.3	1618.4
	(0.20)	(0.93)
Loam soil (1 = yes; 0 = no)	20.9	−118.6
	(0.06)	(0.24)
Clay soil (1 = yes; 0 = no)	−347.7	−641.4
	(1.07)	(1.40)
Distance to home (km)	−304.4	342.2
	(1.13)	(0.86)
Single crop (1 = yes; 0 = double cropping)	1061.4	513.5
	(2.24)**	(0.89)
Year dummy		
Year is 2004 (1 = yes; 0 = no)	−531.8	−92.5
	(1.37)	(0.17)
ID Dummy		
QID-N (1 = yes; 0 = no)	−2312.9	−3438.9
	(6.61)***	(7.14)***
Constant	3636.2	471.5
	(1.08)	(0.10)
Observations	310	310
Adjusted *R*-square	0.35	0.41

Absolute value of *t*-statistics in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Table 7
Regression analysis of the determinants of crop water use at the plot level in Ningxia Province (having interaction terms).

	Water use per hectare	
	Wheat	Maize
Water management institutions		
Interaction term of incentives and WUA (1 = yes; 0 = no)	728.6	180.4
	(0.79)	(0.16)
Interaction term of incentives and contracting (1 = yes; 0 = no)	−1718.2	−1854.9
	(4.50)***	(3.33)***
Interaction term of non-incentives and WUA (1 = yes; 0 = no)	−13.6	87.8
	(0.04)	(0.17)
Interaction term of non-incentives and contracting (1 = yes; 0 = no)	−1149.8	−670.0
	(2.31)**	(0.95)
Village characteristics		
Number of households (number)	4.349	5.495
	(4.42)***	(3.94)***
Per capita annual net income (yuan, log)	785.2	1440.9
	(1.75)*	(2.32)**
Length share of lining canals (%)	−17.5	−30.2
	(2.73)***	(3.47)***
Distance to township (km)	56.0	185.6
	(1.46)	(3.42)***
Value per hectare of accumulated investment into village irrigation infrastructure (yuan/ha)	−0.010	−0.047
	(0.26)	(0.90)
Share of rice in sown area (%)	−26.7	−49.7
	(2.98)***	(3.79)***
Household characteristics		
Age of household head (years)	−37.3	−51.8
	(2.32)**	(2.25)**
Education of household head (years)	−121.5	−221.9
	(2.61)***	(3.35)***
Cultivated land areas per household (ha)	464.8	900.5
	(0.92)	(1.27)
Plot characteristics		
If conjunctive irrigation (1 = yes; 0 = no)	−278.9	1575.7
	(0.25)	(0.91)
Loam soil (1 = yes; 0 = no)	−257.2	−379.1
	(0.69)	(0.73)
Clay soil (1 = yes; 0 = no)	−378.7	−665.3
	(1.18)	(1.46)
Distance to home (km)	−282.7	360.8
	(1.07)	(0.90)
Single crop (1 = yes; 0 = double cropping)	1186.0	462.7
	(2.53)**	(0.80)
Year dummy		
Year is 2004 (1 = yes; 0 = no)	−563.6	−136.0
	(1.47)	(0.26)
ID dummy		
QID-N (1 = yes; 0 = no)	−2175.8	−3331.5
	(6.26)***	(6.89)***
Constant	4035.7	1120.7
	(1.22)	(0.24)
Observations	310	310
Adjusted *R*-square	0.37	0.41

Absolute value of *t*-statistics in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

However, the analysis results show that under the management of WUAs, the relationship between the incentives and the crop yields is not consistent in the two IDs. For example, in one ID (WID-N), compared with the villages under collective management (4521 kg/ha), in the villages that provide incentives to WUA managers, the wheat yield is lower (4256 kg/ha) (Table 8, row 1). However, in the other ID (QID-N), the results are the opposite. That is, if the WUA managers are provided with incentives to earn money by saving water, the wheat yield in their villages (5154 kg/ha) was even higher than in those villages managed by collectives (4501 kg/ha). Similar contrary results can also be found for maize. These results are not surprising and are consistent with our above analysis. Based on our analysis of the impacts of incentives within WUAs on crop water use, we found that the incentives did not significantly reduce the water use of wheat and maize.

5.1. Econometric model

In addition to the incentives from irrigation management reform, other socio-economic factors also influence crop yields. To answer the question of whether incentives affect outcomes, it is necessary to control for these other factors. To do so, we specify the link between crop yield and its determinants by applying the plot level data in two IDs in Ningxia province:

Table 8
Incentives, wheat and maize yields under various management patterns in two irrigation districts in Ningxia Province, 2001–2004.

	Wheat	Maize
Crop yields (kg/ha)		
WID-N		
WUA[a]		
Non-collective with incentives	4256	5606
Non-collective without incentives	4745	6014
Contracting[b]		
Non-collective with incentives	3990	7063
Non-collective without incentives	4592	5418
Collective[c]	4521	6196
QID-N		
WUA[a]		
Non-collective with incentives	5154	7311
Non-collective without incentives	4784	6379
Contracting[b]		
Non-collective with incentives	4191	6020
Non-collective without incentives	4595	5824
Collective[c]	4501	5481

Data source: Authors' survey.
[a] WUA: Water User Associations.
[b] Contracting: Contracting management.
[c] Collective: Collective management.

$$Q_{ijk} = \alpha + \beta W_{ijk} + \gamma X_{ijk} + \delta Z_{ijk} + \theta Y_{ijk} + \eta D_{ijk} + \varepsilon_{ijk} \quad (2)$$

where Q_{ijk} represents the yields of wheat and maize from the ith plot of household j in village k in terms of the natural log form. In Eq. (2), the yields are explained by the variable of interest, W_{ijk}, which measures the nature of incentives. Because the impact of incentives on crop yields is primarily observed through its influence on crop water use, we use the predicted water use from Table 7 to measure the impacts of incentives on crop yields.

Eq. (2) also includes some control variables. First, X_{ijk}, which measures other inputs to the production process, is included, and these inputs are also converted into natural log terms. The agricultural production inputs cover the measures of per hectare use of labor (measured in man days), fertilizer (measured in aggregated physical units) and expenditures on other inputs, such as fees paid for custom services. The second type of control variable, Z_{ijk}, which holds other factors constant, includes characteristics of the production environment of the village, household and plot, the year and the irrigation district dummy, Y_{ijk} and D_{ijk}, respectively. The control variable for the village production environment is measured by the level of irrigation investment per hectare. The household and plot characteristics are almost the same as for Eq. (1), except we do not include the variable for household land area. In addition, we add a variable that reflects production shocks (measured as the yield reduction on a plot due to floods, droughts or other "disasters").

5.2. Estimation results on the impacts of incentives on crop yields

Almost all of the models specified on wheat and maize yields perform well and produce robust results that largely confirm our a priori expectations (Table 9). The goodness of fit measure for wheat and maize yields, the adjusted R^2, is 0.09 and 0.12, respectively. Many coefficients for our control variables in these models are of the expected sign and statistically significant. For example, after holding other factors constant, if wheat production has been operated by older and more highly educated farmers, the wheat yield can be significantly increased (rows 6 and 7, column 1). Compared with the multiple planting system, if farmers only plant one single crop in one season, the maize yields are significantly higher (row 11, column 2). The production shock not only negatively influences the wheat yield but also reduces the maize yield (row 11).

Table 9
Regression analysis of the determinants of crop yields at the plot level.

	Wheat yield (log)	Maize yield (log)
Production inputs		
Water use per hectare (log)	0.177[a]	0.085[b]
	(3.07)***	(1.55)
Labor use per hectare (log)	−0.025	0.028
	(1.22)	(0.84)
Fertilizer use per hectare (log)	−0.026	0.061
	(0.69)	(1.61)
Value of other inputs per hectare (log)	−0.040	0.008
	(1.11)	(0.23)
Production environment		
Value per hectare of accumulated investment in village irrigation infrastructure (yuan/ha)	−0.000001	0.00001
	(0.19)	(1.33)
Household characteristics		
Age of household head (years)	0.003	−0.001
	(1.98)**	(0.45)
Education of household head (years)	0.008	0.004
	(1.74)*	(0.53)
Plot characteristics		
If conjunctive irrigation (1 = yes; 0 = no)	−0.162	−0.037
	(1.40)	(0.21)
Loam soil (1 = yes; 0 = no)	0.049	0.034
	(1.30)	(0.68)
Clay soil (1 = yes; 0 = no)	0.014	0.016
	(0.41)	(0.34)
Distance to home (km)	0.015	0.010
	(0.53)	(0.26)
Single crop (1 = yes; 0 = double cropping)	0.014	0.147
	(0.29)	(2.47)**
Production shocks		
Yield reduction due to production shocks (%)	−0.006	−0.005
	(4.45)***	(3.97)***
Year dummy		
If year is 2004 (1 = yes; 0 = no)	0.015	0.085
	(0.42)	(1.98)***
ID dummy		
If QID-N (1 = yes; 0 = no)	0.027	−0.017
	(0.68)	(0.32)
Constant	7.207	7.270
	(11.72)***	(12.75)***
Observations	310	310
Adjusted *R*-squared	0.09	0.12

[a] Predicted water use by the determinants of water use model (Column 1 of Table 7).
[b] Predicted water use by the determinants of water use model (Column 2 of Table 7).
* significant at 10%.
** significant at 5%.
*** significant at 1%.

Our results show that the wheat yield is significantly sensitive to water use, implying that there are negative impacts from incentives on wheat yield. However, the same is not true for maize. Based on the estimation results, the coefficient of the predicted water use variable in the wheat model is positive (0.177) and statistically significant at 1 percent (Table 9, row 1 and column 1). However, in the maize model, the same variable is not statistically significant (row 1 and column 2). This result indicates that after holding other factors constant and increasing water use 10 percent, the wheat yield will increase by 1.77 percent. Checking this issue from the opposite perspective, the result demonstrates that a 10 percent reduction in water use will result in the reduction of the wheat yield by 1.77 percent. Combining these results with the analysis in the last section, we know that if incentives are provided to contracting managers, the water use for wheat will be reduced

Table 10
Benefit and cost estimation of the wheat water saving due to establishing incentives within contracting management in two IDs in Ningxia Province, 2001–2004.

		WID-N	QID-N
Average irrigation water supply price (yuan/m^3)[a]	1	0.058	0.058
Average industry water supply price (yuan/m^3)[a]	2	1.4	1.4
Wheat yield (kg/ha)[a]	3	4568	4498
Average water use (m^3/ha)[a]	4	8338	5916
Wheat price (yuan/kg)[a]	5	0.702	0.702
Wheat water use elasticity for crop yield[b]	6	0.177	0.177
Marginal value of water productivity at the average value for wheat production (MPV, yuan/ha)	7 = 6 * (3/4)	0.097	0.135
Wheat water use when MPV is equal to irrigation water price (m^3/ha)[c]	8	14,062	13,847
Wheat water use under the management of collectives[a]	9	10,378	6221
Reduction percentage of wheat water use for contract with incentives when compared with collectives (%)[d]	10	27	27
Reduced wheat water use by incentives in contracting when compared with collectives (m^3/ha)	11 = 9 * 10/100	2802	1680
Wheat water use under contracting with incentives	12 = 9–11	7576	4541
Money lost per hectare for farmers due to reduction of wheat water use (yuan/ha)[c]	13	256	312
Earned money by managers due to reduction of wheat water use (yuan/ha)	14 = 11 * 1	163	97
Net cost for the village due to reduction of wheat water use (yuan/ha)	15 = 13–14	93	215
If selling the reduced water per hectare to industrial sectors, the total water charges collected from industrial sectors (yuan)	16 = 11 * 2	3923	2352

[a] Data come from the field survey.
[b] Data come from the regression results in Table 9 (row 1, column 1).
[c] Data in rows 8 and 13 represent the accumulated marginal value of wheat from two analyzed points.
[d] Data come from the calculation results based on the regression coefficient of the interaction term of incentives and contract (Table 7, row 2, column 1) and wheat water use under collective.

by 27 percent. After linking these issues together, it is not hard to estimate that with a reduction in water use by 27 percent, the wheat yield will be reduced by 4.8 percent.

If our plot level analysis of the incentives of irrigation management and crop yields are correct, then the results would mean that in our sample areas, the main tradeoff between the water savings from establishing the incentive mechanisms for contracting and crop yields occurs for wheat; this tradeoff is less severe or even absent for maize. The conclusion is plausible and, although its validity may only hold for our sample region, it is consistent with many of the observations that we made in the field. Wheat is the crop that depends, more than any other, on irrigation because its growth period occurs almost entirely during the dry season. Water cutbacks should be expected to reduce yields. Maize, in contrast, is grown during the wet season, and the irrigation managers that have an incentive to save water may be able to time their use of irrigation water with the rains, while those that have no interest in saving water might adhere to a predetermined water delivery schedule, regardless of the weather.

When the water use has been decreased, how much money do the farmers lose? Because contracting managers can earn a certain benefit from saving water, when examining the welfare issue for the overall village, will the village gain a net benefit or a net loss? To answer these questions, we have further analyzed the marginal value of water use for wheat production. Based on our calculation, the marginal value of wheat water productivity at the average value (MPV) reached 0.097 yuan per hectare in the WID-N (Table 10, row 7). In other words, for each hectare of wheat production, the application of one additional cubic meter of irrigation water produces the economic value of 0.097 yuan. In the QID-N, this number was 0.135, which is higher than that in the WID-N. QID-N is located downstream and uses less water (by 29 percent) than that in the QID-N (row 4); under an almost identical wheat yield level condition (differing by 2 percent in two IDs, row 3), it is not surprising that the MPV in the QID-N is higher.

The results show that under the low level of irrigation water price, the farmers will lose some money due to the reduction of water use. In the two IDs, the price of the irrigation water supply was only 0.058 yuan per cubic meter during the 2001–2004 period, much lower than the MPV in the WID-N (40 percent less) and in the QID-N (57 percent less) (rows 1 and 7). This result implies that in these two IDs, under the low level of irrigation water price, the farmers did not obtain the optimal use of water for maximizing their benefit. When their wheat MPV is equal to the irrigation water price, in the WID-N, the farmers need to use at least 14,062 cubic meters of water per hectare, approximately 1.7 times the actual water use (rows 4 and 9). In the QID-N, we also found a large difference between the optimal water use and the actual water use. Further analyses indicate that if the water use per hectare was reduced by 27 percent due to the implementation of incentive mechanisms within contracting management, the farmers lost 256 yuan per hectare in the WID-N or 312 yuan per hectare in the QID-N (rows 9–13).

Although the contracting managers earn some money through water savings, considering the relatively large loss of economic benefit for the farmers, the overall village will see a net loss instead of a net benefit. According to the design of the incentive mechanisms of irrigation management reform, the profit from the reduced water use will belong to the contracting managers. If so, the contracting managers in the WID-N earned 163 yuan per hectare, which is less than the amount of money lost by farmers (256 yuan per hectare). Similarly, in the QID-N, the contracting managers earn less money (97 yuan per hectare) than the money lost by farmers (312 yuan per hectare) (row 14). Putting these two results together, it is not hard to find that the overall net cost for the villages in the WID-N was 93 yuan per hectare and 215 yuan per hectare in the QID-N. These results mean that the contracting managers earn money at the cost of farmers' earnings. Even so, we found that the loss for the villages is not so high; it is approximately 3 percent of the net revenue of wheat per hectare in the WID-N. In the QID-N, this number is even higher, at approximately 6.8 percent (the net revenue of wheat per hectare in these two IDs was approximately 3150 yuan).

However, if we reallocate the saved water to the high value sectors such as the industrial sectors, the social benefit from saving water will be high. For example, from 2001 to 2004, the average industry water supply price was 1.4 yuan per cubic meters, 24 times that in the irrigation sector. If the IDs reallocate the saved water per hectare to the industrial sectors, they can collect a water fee of 3922 yuan in the WID-N (or 2352 yuan in the QID-N), approximately 42 times (or 10 times) the amount of lost money in the villages. Therefore, if the IDs can reallocate the saved water to high value sectors and examine the benefit of water savings at the larger scale regions (such as at the ID level), the total benefit of water savings through the reform of irrigation management will be high.

More importantly, the estimation results further confirm our previous question. The cost of reducing the water use by providing incentives to managers is the negative impacts on crop yields, particularly for those crops that are sensitive to irrigation water supplies, such as wheat. This cost likely explains why more WUA managers over the past several years give up the opportunity to earn more money by establishing incentives. On the contrary, given their individual motivations, the contracting managers do not necessarily consider the potential negative effects of incentives on crop production. Our results are different from Wang et al. (2005), who found no negative impacts on crop yields from providing incentives to WUAs or contracting managers. It is possible that the major reason for the difference is that at the early stage of reform, as analyzed by Wang et al. (2005), due to the relatively large opportunity for water saving, the crop yields are not negatively influenced by the reduction of water use. However, after several years' of reform, the water saving opportunity has become limited and crop production is more sensitive to the additional reduction of water use.

6. Concluding remarks

In this paper, we have sought to understand how the irrigation management reform of surface water in the YRB has proceeded since the early 2000s. In particular, we are interested in exploring whether the incentive mechanism still plays a role in saving water and benefiting agricultural production, the major purpose of the reform. The data used in the analysis come from large field surveys conducted in two rounds, 2001 and 2005, in four IDs in the YRB. Based on the panel data, the research results show that after the early 2000s, irrigation management reform has accelerated in Ningxia province, but no progress has been made in Henan Province. Until 2004, 21 percent and 30 percent of villages established WUAs or contracting management, respectively, to manage their irrigation systems for all samples. Although some improvement on management mechanism was observed, most irrigation management reforms are still nominal. More importantly, over the past several years, more WUA managers gave up the opportunity to establish incentive mechanisms, while more contracting managers preferred to establish incentive mechanisms. However, this trend differs by ID. The decline in the incentives established by the WUAs primarily occurred in WID-N and not in another ID.

Applying both descriptive statistics and an econometric model approach and based on data from two IDs in Ningxia Province, our results demonstrate that the use of incentive mechanisms to promote water saving is effective under the contracting management arrangement and not effective under WUAs. Specifically, providing incentives to contracting managers will significantly lead to the reduction of water use for both wheat and maize, but the same is not true for the incentives provided to WUA management. However, with a decrease in water use, although the maize yield will not be significantly influenced, the wheat yield will present a significant decline. Based on the assessment results for the early stage of reform by Wang et al. (2005), even when water use was reduced, the crop yields for both wheat and maize were not negatively influenced. These results imply that at the later stage of the reform, reducing water use by providing incentives to managers is at the cost of negative impacts on crop yields, particularly for those crops that are sensitive to the irrigation water supply, such as wheat. This relationship possibly explains why more WUA managers give up the opportunity to earn more money by establishing incentives.

Further analysis indicates that even when the contracting managers with incentives can earn money by saving water, this result does not necessarily benefit the entire village. The results show that in both WID-N and QID-N in Ningxia Province, the marginal value of water productivity was much lower than the irrigation water price. Under the low irrigation water price, the reduction of water use for wheat will result in lost money for the farmers. More importantly, in the same ID, the money lost per hectare for farmers was lower than the amount earned by the contracting mangers. Therefore, the overall villages are the losers. However, if the IDs reallocate water to high value sectors such as industrial sectors, the overall ID will obtain a higher benefit due to the high water supply price for the industrial sectors.

Based on the analysis results, in the future, as the local governments in the YRB continue to foster the reform of irrigation management, they must design win–win supporting policies to ensure the healthy development of the reform. On the one hand, to achieve the goal of water saving to resolve the increasing water shortage issues, establishing incentive mechanisms within the reformed institutions can still be treated as an important policy alternative. On the other hand, the policy makers also cannot omit the potential negative impacts of incentives on agricultural production and the economic benefits for farmers. To offset the potential money lost by farmers due to the reduction of water use, the policy makers should consider to use subsidy policies to offset farmers' economic losses due to reduction of water use. Of course, along with irrigation management reform, some effective measures for increasing the water productivity of agricultural production are urgently needed by farmers, such as new crop varieties (such as drought resistant varieties), new planting and cultivation systems (such as conservation agriculture, new patterns of crop rotation) and water saving technologies (such as wetting and drying irrigation approach, plastic film mulching, surface and groundwater pipe) that can help increase the utilization efficiency of agricultural inputs and offset the negative impacts of water use reduction on crop yields. In addition, to keep the reform sustainable, local governments also need to consider how to use water right policy to reallocate water to higher value sectors that will increase the overall benefit of the reform to the IDs or even larger regions. The policy makers in the YRB must find ways to balance the trade-off between saving water and increasing agricultural productivity and economic benefit over the long term. In addition, as results revealed that at the later stage of reform, the water saving effects have tend to decline. Therefore, when pushing the continuing reform if irrigation management, policy makers also can significantly increase the irrigation fee. When the irrigation fee is high enough and even higher than the average marginal water productivity of crop production, the farmers lose their incentive to use more water because a reduction in water use will make them better off. Of course, if we want to reduce water use through increasing irrigation fee policy, how to provide subsidy policies to offset farmers' economic losses is also necessary. Finally, setting up some education programs for farmers to improve their understanding on the necessary of improving water use efficiency and increasing their capacity to use some innovative practices or technologies are also necessary.

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