Does Participatory Water Management Contribute to Smallholder Incomes? – Evidence from Minle County, Gansu Province, P.R. China

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Abstract

Since the early 1990s, the Chinese water sector has undergone an important institutional reform that has shifted major responsibilities in irrigation management from the government toward water users, who are organized in so-called Water User Associations (WUAs). Such participatory water management is not only assumed to increase water use efficiency, but also to stimulate the incomes of member households. This study aims to provide empirical evidence of the impact of participatory water management on WUA performance and farmer incomes, using data collected for the year 2007 among 317 households and 35 WUAs in Minle County, Gansu Province. We find that having democratically elected leaders has a positive effect on WUA performance, by increasing investment levels and improving canal quality. Participation in decision making, however, has a significant negative impact on canal quality and does not affect other WUA performance indicators. Two aspects of WUA performance, investment levels and financial health, are found to have a positive impact on the farm income of member households. Water use per mu, on the other hand, has a significant negative impact on farm incomes. We also find evidence that households belonging to better performing WUAs increase their farm incomes at the expense of non-farm income. The resulting net impact of participatory water management on total household income is not significant for the households in our sample.

1. Introduction

As the world's population and average income level grows, so does its demand for food, and hence irrigation water. Questions are arising of whether the world can sustain this increased demand for water. Although 75% of the world's surface is covered with water, only a small portion of all this water is fresh water that is ready to use for agricultural, industrial or domestic purposes. Moreover, it is threatened by climate change and pollution, leading different scholars to state that water has become a scarce good. This is made all the more pressing by the fact that it is not only the demand for irrigation water that is increasing; a continued rise in living standards fuels a global increase in demand for domestic and industrial water as well.

Irrigation is vital to maintain global food supplies and thus to keep basic food affordable to the very poor (Carruthers et al. 1997). As the cost for creating new supplies – e.g. by building dams and other water infrastructure – are increasing, efforts are increasingly directed towards using the water that is currently available more efficiently. Policy makers in China, and in many other parts of the world, have sought to go beyond technical means of increasing water use efficiency in agriculture. The high costs of creating new and improving existing infrastructure has prompted the Chinese government to employ other methods to improve water management in regions, particularly in the North and Northwest, facing severe water shortages (Nickum 2005; Shalizi 2006). Since the early 1990s, the Chinese water sector has undergone an important institutional reform that has shifted major responsibilities in irrigation management from the government toward water users. Users of irrigation water have been organized in so-called Water User Associations (WUAs) in many projects (Lin 2003).

China's efforts to implement institutional reforms in order to combat water shortages fit in a wider, global trend, in which the issues surrounding water shortages are no longer stated purely as a technical problem. It is often realized that it is not just water that needs to be managed; to a very large extent, the success of irrigation depends on the management of people. Irrigation depends on people, staff, farmers, experts, engineers and other stakeholders, and the relationships among these groups to make it work. Subramanian et al. (1997) argue that inefficiencies in irrigation arise due to two inherent features: non-excludability and rivalry. Often, in the face of institutions lacking power and capabilities to enforce rules, actors appropriate an unfair amount of water at the expense of less privileged actors. The classic example of this is over-irrigation by farmers located close to the head works of an irrigation system, while farmers downstream are suffering water shortages. These factors are exacerbated by the complexities in water management, which means that planners have to make decisions on the basis of incomplete information. Local actors are assumed to have the most complete information. Including them explicitly in the decision making process ensures that issues such as poverty, food security, and public health problems, which are frequently used to motivate public intervention in water services, are addressed as effectively as possible (Subramanian et al. 1997).

WUAs are one of the most prominent types of institutional arrangements proposed to involve water users in the decision making and planning associated with irrigation. The discovery of farmer managed irrigation systems in the 1970s (such as the *Subaks* in Bali) led to the realization that irrigation was not necessarily a task for large scale bureaucracies run by the state. Becker & Ostrom (1995) propose to treat water as a common pool resource, best managed by the users themselves. Water users have a greater incentive than state bureaucracies to ensure that management is done in an adequate way. However, the large scale of many irrigation schemes makes some state involvement necessary. Sub-divisions of large-scale schemes are often turned over to farmers, while the government bureaucracy remains responsible for trunk infrastructure (Dinar et al. 1997).

The impact of the creation of WUAs on farmer incomes remains unclear. Participative institutions are expected to perform better in irrigation water management than state-run bureaucracies, and improved irrigation performance has been shown to increase farmer incomes (Rosegrant & Shetty 1994). But empirical evidence for the assumed positive impact of participatory water management on farmer incomes is hard to find. This is mainly due to the fact that water sector reform is often accompanied by other interventions, such as improvements in infrastructure, which makes it difficult to obtain estimates of their separate impacts.

This study aims to provide empirical evidence of the impact of participatory water management on farmer incomes. To this end, we will firstly examine to what extent participatory water management affects WUA performance, and secondly investigate the impact of WUA performance on the (farm and off-farm) incomes of households that participate in WUAs. The data for the analysis was obtained from of a survey performed among 317 households and 35 WUAs in Minle County, Gansu Province in Northwest China.

The structure of the remainder of this paper is as follows. Section 2 provides the theoretical background. In section 3 the research setting and the dataset used for the econometric analysis are discussed. In section 4 the specification of the regression equations and the results of the empirical analysis are presented, while section 5 presents some concluding remarks.

2. Theoretical background

The institutional economics of irrigation

The 20th century has seen a huge increase in the size of irrigated land, from 48 million hectares in the year 1900 to 240 million hectares at the end of the century (Vermillion 2004). This increase has largely been made possible by government investments. Due to the sheer costs of investments in irrigation systems, most farmers are not able to finance such investments themselves. And even if they can, pervasive externalities (both positive and negative) associated with irrigation make claiming the benefits impossible. This has led to a situation where state-led bureaucracies have become responsible for the management of irrigation water. Gaining economic returns from these investments often was not a priority. Rather, irrigation was seen as a form of “social welfare” (Johnson 1995). However, the burdens associated with maintaining large-scale irrigation systems have led states facing increasing fiscal problems which led them to rethink their responsibilities in water management (Vermillion 2004).

A second impetus for institutional reform has been the realization that water users are in a better position to manage their water than large bureaucracies are. Farmers’ lack of a sense of ownership has caused a low willingness to pay for irrigation services. This in turn has led to poor service provision, further decreasing farmers’ willingness to pay. In many cases this vicious cycle has led to deteriorating infrastructure.

In order to address both financial problems and poor service provision, farmers have been given a greater role in irrigation management. It is realized that user organizations can be an effective way to manage common pool resources (Becker & Ostrom 1995). WUAs have therefore been implemented in an increasing number of countries.

WUAs provide a platform to co-ordinate the collective action required for successful irrigation, and hence lower the transaction costs as compared to state bureaucracies (Subramanian et al. 1997). Young (1986) defines transaction costs as “the resources required to establish, operate, and enforce a system to govern resource allocation.” Transaction costs therefore both include ex-ante and ex-post costs. Ex-ante, farmers have better information with respect to local water requirements than large bureaucracies have. So when setting rotation schedules, farmers can allocate the water to those areas that need water the most. Ex-post, it is easier for farmers to ensure that the actual allocation is done in the agreed way. While it is hard for farmers to monitor a large bureaucracy, the actions of their neighbours are relatively easy to observe. In order for this collective action to work at its best, solid conflict resolution mechanisms are essential (see e.g. Becker & Ostrom 1995; Dinar et al. 1997; Saleth & Dinar 1999a; Vermillion 2004).

Transferring responsibilities for irrigation management from the state to farmers entails more than a shift in the burdens associated with the operation and management of systems. It affects a greater sense of ownership by farmers. This sense of ownership is quite significant, due to the change in incentives it implies. State management has been characterized by an emphasis on creation of new projects, rather than the management of existing ones. Farmers, on the other hand care more for the existing schemes (which serve them) and will aim to improve infrastructure and service quality (Lin 2003; Nickum 2005; Johnson 1995).

While, theoretically, WUAs should both reduce government spending and increase efficiency, evidence of the performance impacts of WUAs is fragmentary (Meinzen-Dick 1997). Some authors point to perceived gains in service quality, area irrigated, equity and efficiency (Subramanian et al. 1997; Lin 2003). This generally comes at an increased price to farmers: the state retracts most subsidies, leaving farmers to pay for the provision of services (Meinzen-Dick 1997b; Vermillion 1997; Johnson 1995). The effect on equity is not automatically positive. It might well be the case that richer farmers have more leverage to influence decisions in WUAs to their advantage than poor farmers have (Van Koppen et al. 2002). It is unclear what the net effect of greater farmer participation is, but it may be expected that the benefits of improved performance outweigh increased costs to farmers.

Measuring WUA performance

In order to measure the performance of WUAs, it is first needed to define performance. A ready-to-use definition is proposed by Saleth & Dinar (1999). They distinguish between four kinds of performance:

- The **physical performance** of the water sector is evaluated in terms of the following aspects:
    a) Demand-supply gap,
    b) Physical health of water infrastructure,
    c) Conflict resolution efficiency (low-cost, including time), and
    d) Smoothness of water transfers across sectors/regions/users.

- The **financial performance** of the water sector is evaluated in terms of the following aspects:
    a) Investment gap (actual vs. required) and
    b) Financial gap (expenditure vs. cost recovery).

- The **economic efficiency** of the water sector is evaluated in terms of the following aspects:
    a) Pricing gap (water prices vs. supply cost) and
    b) Incentive gap (water prices vs. scarcity value of water).

- And, finally, the **equity performance** of the water sector is evaluated in terms of the following aspects:
    a) Equity between regions,
    b) Equity between sectors, and

c) Equity between groups.

3. Description of research area and data set

The information needed for this study was collected as part of a household and WUA survey on water resources, water policies, market development and institutional change, carried out in May 2008 in Minle County, Zhangye City, Gansu province. Zhangye City is located in the upper to middle reaches of the Heihe river basin. The Heihe river flows northwards from the Qilian mountains in Qinghai Province towards the Juyanhai lake in Inner Mongolia. The river has a relatively high runoff (Li et al. 2001). The water from the river turns the Hexi corridor –where the Silk Road passed between the Gobi desert and the Qilian Mountains– into a patchwork of fertile oases, allowing the cultivation of crops and turning an area that would otherwise be dry and barren into one of China’s major commodity grain producing (Zhang 2007). Major crops produced in the area are wheat, barley, maize and potatoes. However, due to water over-extraction in Zhangye City, the Heihe river failed to reach the Juyanhai lake in dry years such as 1992, leading to desertification (Zhang 2007).

In early 2002, the Ministry of Water Resources (MWR) initiated a pilot project called ‘Building a Water-saving Society in Zhangye City’, the first project of its kind in the country. The project aims to reduce the water use in Zhangye City through a combination of measures to stimulate non-agricultural sectors, investments in irrigation infrastructure, institutional innovations and an innovative system of water resources property rights allocation and trading. As a result of the measures that were taken, the water of the Heihe river more often reaches the Juyanhai lake in recent years. The lake is not drying up anymore since August 2004 and the ecosystem of the lake is recovering.

Minle County itself is spread between the foothills of the Qilian Mountains and the lower lying Hexi corridor. Its location results in different agro-ecological conditions: At the higher elevations, rainfall is relatively abundant, while at the lower altitudes it is almost zero. For water management, three zones are recognized, each with its own water requirements: Zone 3 is the highest zone and covers altitudes between 2,200 and 2,600 meters above sea level. Large parts of this zone are rainfed, while irrigated land mostly receives one flooding with a standard water allocation of 72 – 74 m^3/mu. Zones 2 and 1 consist almost entirely of irrigated land. Zone 2 is located between 2,000 and 2,200 meters and has a standard water allocation of 74 - 76 m^3/mu, with one or two floodings per year. Zone 1 is the lowest zone, between 1,600 and 2,000 meters. Irrigated land in this driest part of the county receives two or three floodings per year, with a standard allocation of 76 - 78 m^3/mu.

A Water Management Bureau (WMB) serves the entire Minle County. It is in charge of managing the reservoirs and providing water to its irrigation areas. The provision of water is carried out taking into account a sectoral priority: 1. Drinking water (requiring about 15% of the total water in Minle County), 2. Agriculture (75%) and 3. Industry (10%). There are 7 reservoirs, serving 5 irrigation areas. Each of the latter has its own exclusive reservoirs, and its Irrigation Area Bureau (IAB) is responsible for the provision of water to the villages within its own district. Irrigation is carried out by flooding groups of adjacent farmlands at a time, organized from lowest to highest altitudes Standard water quantities per mu are assigned for each flooding, but these quantities are only realized in years of abundant rainfall. Water is allocated according to a quota system based on the size of the so-called water use rights (WUR) land of the farmers. Not all the irrigated land is classified as WUR land. Its size depends on the labor provided by a village to the construction of the reservoir and other factors.

The household survey was undertaken in May 2008 by staff from the Gansu Academy of Social Sciences in Lanzhou and Nanjing Agricultural University. The collected data refer to the year 2007. To ensure that all townships and zones would be properly represented in the survey, the sample was stratified into its ten townships. Next, 10% of the villages in each stratum were randomly selected. Eight townships are entirely located inside one of the three zones. The other two townships were divided into two sub-stratums (one for each zone) and 10% of the villages were randomly selected in each. This ensures that the differences in water allocations and agricultural conditions between the three zones are also adequately reflected in the sample. Finally, in each of the 21 selected villages, 15 households were randomly selected to be interviewed.[1] The interviewee was the household head or another household member capable of giving the relevant information. If none of these persons was found, the household was dropped and replaced by the next one in the list of random numbers. For the purpose of this study, all households that had missing data on one or more variables used in the empirical analysis were excluded. This gave us a dataset containing 212 observations (households). WUA representatives were interviewed in the same 21 villages and in 14 additional, randomly selected, villages, giving a WUA sample size of 35.

4. Methods and results

The research consists of two steps. In the first step, we examine what factors determine WUA performance. To this end a regression analysis is performed. It is hypothesized that one of the main determinants of performance is the degree to which WUAs allow their members to participate in decision making. Some factors are not homogeneous across the research area: some villages are located further away from main canals than others, some villages have good political connections because high-level leaders were born there, and so on. We control for such factors in our regression analysis. The second step in the research is to examine the impact of WUA performance on rural incomes. Both on-farm and off-farm income is analyzed, as WUA management might affect labor requirements for irrigation and thus have an effect on both types of income. Apart from WUA performance (as discussed above), a set of “traditional” determinants of income, sub-divided into farm and village characteristics, will be used as explanatory variables. We will discuss the methods applied and the results obtained in each step in the next twosub-sections.

4.1 WUA performance

No indicators of economic efficiency and equity performance (see section 2 above) are available in the data set. The variation in these indicators within Minle County, however, is likely to be small. Economic efficiency depends on the allocation vis-à-vis other sectors. This can reasonably assumed to be equal across the county as the policies defining this type of efficiency are set at county-level by the water management bureau. For similar reasons conflict resolution and smoothness of transfers have been left out of the analysis. As for equity, the main concern in irrigation in this respect is the distribution of water over head-enders and tail-enders. In Minle County most farmers have plots both at the head-end of the canal and at the tail-end. So at WUA level, equity is not a major concern. This leaves two measures for physical performance, and two for financial performance.

The following equation is used for estimating the impact of WUA characteristics on its performance:

$$WP = c + \beta_{wc}'WC + \beta_{vc}'VC$$

[1] In the first two villages, 16 households were interviewed.

Where:
WP is a vector of WUA performance indicators;
WC and VC are matrices of WUA and Village Characteristics respectively;
β_{wc} and β_{vc} are vectors of the coefficients to be estimated.

Below we discuss in more detail the indicators of WUA performance and the variables representing WUA characteristics and village characteristics that are included in the analysis.

WUA performance indicators

In order to measure WUA performance, five indicators have been used. These include both physical (the amount of water supplied per mu, and the quality of secondary canals and tertiary canals) and financial indicators (investments density, and financial ratio).

Demand-supply gap: Water supply-demand ratio
Our data set has information on the amount of water that was supplied to the WUA in 2007. We use the standard water allocation for the agro-ecological zone in which the WUA is located as the indicator of water demand. A gap between supply and demand would imply that the value for the indicator can assume both positive and negative values. However, as will be discussed below, the household level analysis requires natural logs to be taken of all indicators. As this is impossible for negative values, a ratio has been chosen, where the supply (in cubic meters per mu) has been divided by the demand. One complicating factor in this is that there are multiple rounds of irrigation, up to four in the research year, but not all these rounds were used by the WUAs. This depends on local conditions, and crop choices. Therefore an average over all the cycles used by the WUA has been used. There are also rounds of irrigation after the growing season, but as the effects of these rounds on crop production are much smaller than those of the regular rounds, these have been left out.

Physical health: Secondary and tertiary canal quality
A canal system consists of several levels of canals. Primary canals feed water from the reservoir to secondary canals, which branch off these main canals. Secondary canals feed to their branches, which are tertiary canals, and so on. Farmers' fields are often located at small, quaternary canals. WUAs have responsibility for the quality the secondary and tertiary canals in their village, the quaternary canals are the responsibility of the farmer group with land at that canal. So only the secondary and tertiary canals will be examined here. They will be examined separately, as the health of the canals at different levels may not have the same impact: the water to multiple tertiary canals flow through the same secondary canal. Four indicators of quality can be distinguished: canals with no lining, canals lined with stones, canals lined with stones and concrete, and canals lined entirely with concrete. Concrete canals are the smoothest, and so deliver the water quickest from one end of the canal to the other, resulting in the smallest conveyance losses. In order to quantify quality for the purposes of this research, the ratio of canals treated with concrete is used. The data on this has been provided by WUA representatives.

Investment gap: Investment Density
As the amount of money invested in canal maintenance and improvement depends on the length of the canals in a WUA, the amount of investment in canals in 2007 is divided by the total length of the canals in a village. Investments include farmer's labour contribution as well as financial contributions by the WUA. Farmers' labour has been valued at the average wage in the county.

Financial gap: Financial ratio
The financial gap is obtained by subtracting the total expenditures of the WUA in 2007 from the

total revenues in the same year. Some WUAs have larger budgets than others, simply because they have more members to contribute water fees. In order to correct for this, the resulting gap has been expressed as a share of the total WUA revenues.

Table 1: *Descriptive statistics of WUA performance indicators*

Indicator	**Mean**	**Std. Dev.**	**Min**	**Max**
Investment Density	103	224	0.00	907
Secondary Canal Quality	0.73	0.34	0.00	1.00
Tertiary Canal Quality	0.40	0.44	0.00	1
Water supply-demand ratio	2.33	1.12	0.71	5.56
Finance Ratio	1.66	2.43	-0.15	10

Descriptive statistics of the performance indicators are presented in Table 1. One of the striking features is that the WUAs provided more than twice the standard amount of water (average water supply-demand ratio equals 2.33). This is because 2007 was characterized by abundant rainfall, and hence there was sufficient water to supply more than the standard amounts. Still, some WUAs did not achieve this, resulting in a minimum value smaller than one (i.e. 0.71). WUA revenues on average exceeded expenditures in 2007, as can be seen from the positive average value for the finance ratio, but some WUAs did make a loss (minimum value is -0.15). The finding that secondary canal quality is higher than tertiary canal quality makes sense, as larger amounts of water flow through the secondary level.

WUA Characteristics

It has been discussed above that participative institutions are widely believed to perform better than non-participative ones. This hypothesis will be tested in this research by including variables in the WUA-level regression that reflect how participative the WUA is.

Democratic elections

The first such variable is whether or not the WUA leader was elected democratically. In the majority of the cases, the village leader acts as the WUA leader. Only in two villages this is not the case. Remarkably, these two WUA leaders were among those not appointed in democratic ways (i.e. not elected by member households or their representatives). Of the total sample of 35 WUAs, 12 leaders were appointed by democratic means.

Decision making participation

The process by which the association leader is elected is important, but there are many decisions to be taken after a leader is elected. These operational decisions can be made in a participative way, or not. Most studies seem content with a view of participation as a dichotomous variable: irrigation is done either participative or not. From there these studies go on to assess the advantages and disadvantages of participation (Lin 2002; Subramanian et al. 1997; Vermillion 1997). In Minle County, this dichotomous distinction is inappropriate: some WUAs devolve many decisions to their members, some only give them indirect control over a number of decisions, while still others might not give their members any say. The data set used for this research contains information on how seven types of decisions – ranging from irrigation order, to the assigning of guards to oversee water allocation – are taken. Nine ways of taking decisions were identified in the research. Decisions can be taken by:

1. WUA director;
2. WUA director, approval of general meeting of all WUA households needed;
3. WUA director, approval of meeting of representatives of WUA households needed;
4. General meeting of all WUA households;
5. Meeting of representatives of WUA households;
6. User groups in the WUA;
7. Individual households;
8. Water Management Bureau;
9. Party of the village.

Any of these that give at least some voice to water users have been considered participative for the purposes of this study. These include numbers 2 – 7 in the list above. The non-participation category also includes non-response by the WUA.

Table 1: *Number of WUAs that take participatorydecisions*

Decision	**Participatory**	**Non-participatory**
Irrigation order	27	8
Water price	11	24
Volunteer labor	15	20
Tertiary canal maintenance	27	8
Rules regarding groundwater use	24	11
Assignment of guards overseeing water the water allocation process	8	27
Sanctions against members breaking the rules	26	9

Table 2 provides the number of WUAs that take participatory decisions for each type of decision considered in the research. Participation by WUA members is highest for decisions on irrigation order, canal maintenance, groundwater use and sanctions against members. Member households have much less impact on water pricing, ‘voluntary’ labor contributions and the assignments of guards.

The indicator for participation that is used in the regression is a count measure indicating for each WUA how many decisions are taken participatory. It is expected that high values for this indicator lead to a better performance of WUAs.

Other characteristics

Other WUA characteristics that serve as explanatory variables of WUA performance in the regression analysis include characteristics of the leader (e.g. age and education), the number of farmer groups in a WUA and the number of years that have passed since the establishment of the association.

Village Characteristics

In order to control for factors that lie outside WUA control, a number of variables are included. Regional leaders might pass extra resources to the village in which they were born. In order to account for this a dummy variable indicating whether a leader was born in the village is included. Also, a village close to the county capital might be advantaged, because it is more visible to high officials from the water management bureau. The agro-ecological zone (dry, medium, or wet) in which the village is located might affect water management, as might the distance between the village and the main canal. Table 3 lists all these variables and the ones discussed above, provides brief summaries of how they are measured, and shows the expected affects for each of the explanatory variables.

Table 3: *Variables included in WUA performance regression*

Variable	**Type**	**Definition**	**Expected Effect**
Dependent Variables			
Investment Density	Continuous	Money spent maintenance, construction, and upgrading of canals by farmers and government divided by total length of secondary canals plus tertiary canals	
Secondary canal quality	Continuous	Ratio of improved canals	
Tertiary canal quality	Continuous	See secondary canal quality	
Amount of water per Mu	Continuous	The amount of water delivered per mu of agricultural land, per rotation, divided by the standard amount of the agro-ecological zone	
Financial Ratio	Continuous	(Total income – total expenditure)/total income (All in RMB)	
WUA Characteristics			
Leader Age	Continuous	Age in years of the WUA leader	+
Leader Education	Continuous	Years of education of the leader	+
Decision-making Participation	Discrete	Number of decisions taken in a participative way	+
Democratically elected leader	Dummy	Democratically elected leader=1, otherwise 0	+
WUA age	Continuous	Number of years since the establishment of the WUA	+

WUA size	Continuous	Number of farmer groups in the WUA	?
Village Characteristics			
Leader born	Dummy	1 = Important regional leader was born in the village	+
Distance from main canal	Continuous	Number of meters from main canal to village	-
Distance from county capital	Continuous	Number of km from village to the county capital, Hongshui	-
Zone 2	Dummy	1 = The village is located in the middle zone	?
Zone3	Dummy	1 = The village is located in the highest (and wettest) zone	?

Results

The results of the regression analysis are summarized in Table 4. The variables listed in the top row are the independent variables, i.e. the WUA performance indicators.

Table 2: *Results of village level regression analysis*

	Investment Density	Secondary Canal Quality	Tertiary Canal Quality	Water Per mu	Finance Ratio
WUA Characteristics					
Decision Participation	-3,02	-0,11 **	0,00	-0,04	-0,11
	-(,1)	*-(2,73)*	*(,14)*	*-(,26)*	*-(,54)*
Democratic Elections	277,18 **	0,23 *	0,08	-0,61	-1,06
	(2,19)	*(1,84)*	*(,42)*	*-(,89)*	*-(1,61)*
Leader Age	3,94	0,00	0,00	-0,02	0,02
	(,74)	*-(,54)*	*-(,04)*	*-(,49)*	*(,26)*
Leader Education	7,13	0,03	0,04 *	-0,02	-0,14
	(,51)	*(1,36)*	*(1,8)*	*-(,23)*	*-(,87)*
WUA Age	12,94	0,01	0,08 **	0,11	-0,10
	(,92)	*(,57)*	*(2,26)*	*(,88)*	*-(,5)*
WUA Size	-6,35	0,00	0,01	0,02	0,01
	-(,79)	*(,44)*	*(,36)*	*(,5)*	*(,11)*
Village Characteristics					
Leader Born	170,64	0,43 ***	0,09	0,84	-1,56
	(1,38)	*(4,2)*	*(,37)*	*(1,15)*	*-(1,13)*
Distance Main Canal	-2,13	0,00 **	0,00	0,03 ***	0,02 **
	-(1,66)	*-(2,8)*	*(,59)*	*(3,94)*	*(2,72)*
Distance County Capital	-2,11	0,00	0,00	0,00	-0,06
	-(,56)	*-(1,01)*	*(,24)*	*-(,11)*	*-(1,44)*
Zone 2	39,53	-0,16	-0,11	0,93	0,39
	(,4)	*-(1,28)*	*-(,42)*	*(1,67)*	*(,4)*
Zone 3	-58,94	-0,61 ***	-0,38	1,43	0,48
	-(,55)	*-(3,51)*	*-(1,25)*	*(1,55)*	*(,29)*
Regression Statistics					
R^2	0,37	0,63	0,44	0,50	0,26
n	35	30	33	35	35

Note: t-values are in parentheses. * indicates significance at 10%-level, ** at the 5%-level, *** at the 1%-level

The two variables chosen to represent participation – democratically elected leaders and decision-making participation – indeed seem to have a significant impact on WUA performance. However, this impact is not uniformly positive. While democratically elected leaders seem to have a positive impact on performance (in terms of secondary canal quality and investment density), this is not true for increased decision making participation (which has a negative correlation with secondary canal quality). Two explanations for this last effect can be put forward: firstly, farmers are unwilling to invest in secondary canals, because benefits of good-quality canals cannot be fully captured by the individual farmers. This would lead participative institutions to under-invest, as each farmer would rather have the others invest. A second explanation would be more positive about the attitudes of the farmers towards collective action: in villages with poor quality canals, farmers are in a stronger position to demand more say in the decisions taken. We would be seeing reversed causality here. The fact that decision making participation does not have a significant negative impact on investment might support this position. However, this argument does reveal one problematic aspect of canal quality as an indicator for WUA performance. Canals predate the establishment of water user associations in the research area. As such, canal quality depends to a large extent on past investments. This would suggest that WUA characteristics are of limited importance to the physical health of the infrastructure.

Of the WUA characteristics not directly related to participation, both leader education and WUA age have an effect on tertiary canal quality. Especially the fact that WUA age positively affects performance is an indication that the reforms initiated in Minle are beneficial, and that some of the benefits take some time to materialize.

When considering the village characteristics – which were added to the regressions as controls – three variables are found to have a significant effect on performance. A regional leader being born in the village has a positive effect on secondary canal quality. This is a possible indication for nepotism. Secondly, the distance from the main canal matters for the secondary canal quality, amount of water delivered and the financial situation of the WUA. That secondary canal quality is lower, which can be explained by the fact that the canals are longer, and thus more costly to upgrade. The fact that villages located far away from the main canal are able to supply more water than those close to the canals is explained by the way the variables are defined. The amount of water supplied is the amount the WUA obtains from the WMB, at the branch of the secondary canal from the primary canal. As the WMB compensates the WUA for conveyance losses in the stretch between the primary canal and the village, villages located far from the canal receive more water without having to closely manage their water. The effect on financial situation is more mysterious. One would expect such an effect to be negative, if anything, due to the extra expenses more canals bring with them. Finally the zone in which the village is located matters for canal quality.

4.2 Farmers' income

Three reduced form equations will be estimated in order to examine the importance of WUA performance relative to the other determinants of farm income, off-farm income and total income. The variables for WUA performance used in the equations are the same as the dependent variables in the first stage. However, for the set of regressions that make up the second stage of the research, they will serve as independent variables. Added to this are three other types of variables thought to have an impact on household income: household characteristics – covering aspects of the household members, such as age and education, farm characteristics – which cover aspects such as land holdings and soil fertility, and village characteristics – as defined above.

The resulting set of equations is:

$$Y = c + \beta_{hc}'HC + \beta_{fc}'FC + \beta_{vc}'VC + \beta_{wp}'WP$$

Where:
Y is a vector of income: On-farm, off-farm and total.
HC, FC and VC are matrices of household, farm and village characteristics respectively;
WP is a matrix of WUA performance indicators;
β-terms are matrices of the parameters to be estimated.

Income consists of two components: on-farm and off-farm income. The number of household in the sample that have no or negative income from farming is so small as to be negligible (n=16). Things are different for off-farm income. Not every household in the sample is engaged in the off-farm labor market. And no household make a loss at their off-farm activities. Only for the households that do engage in the labor market have effects been estimated, using a truncated regression.

To both make regression estimations consistent with a Cobb-Douglas production function and mitigate the effects of potential outliers, the natural logs of the variables on both sides of the equation will be taken.

Income measures

Even though most of the households in the research area can be typified as farm households, many also engage in income generating activities that are not directly related to farming activities in the region. As Table 5 indicates, a significant portion of the income in Minle County is derived from off-farm sources. While irrigation management is likely to affect farming income, it could also indirectly affect off-farm income. Improved irrigation canals could, for example, lead to lower labor requirements for irrigation, and thus free up labor for off-farm activities. These two forms of income are therefore both analyzed.

Table 3: *Mean Incomes in Minle County*

	Mean	**Std. Dev.**	**Min**	**Max**
Cropping Income	9018	11138	-5804	96904
Off-farm Income	8310	15739	0	210000

For farm income, only cropping income has been considered. While there is some livestock raising, this is likely to be affected differently by irrigation than cropping. Livestock is more dependent on large areas of unirrigated land, and thus of less interest here. The produce used for own consumption has been valued at market prices and added to income.

Off-farm income comprises three sources: labor or business outside the farm (but in the region), income from migrant labor – many women go to Xinjiang in the far west of China to pick cotton every year – and remittances from family members living elsewhere in China.

Table 4: *Variable specification for the household level regression*

Variable	**Type**	**Definition**	**Expected Effect**
Dependent Variables			
Farming Income	Natural log	Income generated from cropping	
Off-farm Income	Natural log	Income generated from off-farm activities	
Total Income	Natural log	Off-farm plus farm income	
Household Characteristics			
Labor	Natural log	Number of persons in the household	+
Gender	Ratio	Ratio of men in the household	+
Age1	Ratio	Ratio of household members between the age of 16-55	+
Age2	Ratio	Ratio of household members aged over 55	+
Education Head	Natural log	Years of education of the head of the household	+
Age head	Natural log	Age of the head of the household	+
Farm Characteristics			
Farm Size	Natural log	The area in mu planted with crops	+
Irrigation Status	Ratio	Ratio of land irrigated	+
Slope	Ratio	Ratio of land on slope	-
Fertility	Continuous	Average fertility of the land: 3 means bad quality, 1 means good.	+

Household Characteristics

The composition of the household matters greatly to the ability of the household to generate an income. Aspects that are included are: the total members in the family, the ratio of men to women, and the age of the household members. To account for the farming ability of the household, the age and education of the household head have been included.

Table 5: *Results of household level regression analysis*

	Farm Income	Off-Farm Income	Total Income
Household Charactheristics			
Labour	-0,04	0,99 ***	0,35 **
	-(,29)	(2,84)	(2,1)
Gender	-0,09	-0,02	0,23
	-(,3)	-(,04)	(,6)
Age1	-0,02	0,91 **	0,26
	-(,06)	(2,)	(,9)
Age2	0,01	-0,02	0,04
	(,03)	-(,04)	(,12)
Age Head	0,00	0,00	0,00
	(,19)	-(,11)	(,47)
Education Head	0,01	0,02	0,02
	(,44)	(1,06)	(1,24)
Farm Characteristics			
Land	1,07 ***	-0,21	0,58 ***
	(12,78)	-(1,26)	(4,82)
Irrigation Status	0,12 **	-0,31	0,10
	(2,52)	-(,98)	(,93)
Slope	-0,14	-0,52	-0,15
	-(,88)	-(1,51)	-(1,)
Fertility	0,05	0,12	0,12
	(,59)	(,94)	(1,64)
Capital	0,05 **	0,05	0,03
	(2,21)	(,98)	(1,04)
Village Characteristics			
Distance county capital	-0,06 ***	0,00	-0,05
	-(2,91)	-(,06)	-(1,58)
Distance main canal	0,00	0,03	0,00
	-(,14)	(,81)	-(,13)
Zone2	0,15	0,66 ***	0,30 **
	(1,14)	(3,02)	(2,07)
Zone3	0,38 **	0,11	0,20
	(2,21)	(,36)	(1,06)
WUA Performance			
Water Per mu	-0,28 ***	0,34	-0,01
	-(2,77)	(1,49)	-(,07)
Investment Density	0,03 *	-0,08 **	0,00
	(1,95)	-(2,19)	-(,14)
Secondary Canal Quality	-0,18	-0,53 *	-0,23
	-(1,27)	-(1,87)	-(1,44)
Tertiary Canal Quality	0,11	-0,40	-0,09
	(,72)	-(1,34)	-(,46)
Finance Ratio	0,05 **	0,01	0,04 *
	(2,28)	(,24)	(1,81)
Constant Term	5,85 ***	6,55 ***	6,59 ***
	(12,22)	(6,37)	(8,89)
Regression Statistics			
R^2	0,54	0,10	0,31
n	301	258	312

*Note: T-values are given in parentheses. * Indicates a variable significant at the 10% level, ** at the 5% and *** at the 1% level.*

Farm Characteristics

Not only the demographic characteristics of the household members matter, their assets also need to be taken into account, which are grouped under the header of farm characteristics here. The amount of land in mu, how much of their land is sloped, the fertility of the land, the irrigation status of the land, the amount of capital and livestock are all included.

Results

Judging from Table 7, the main determinants of income seem clear, and are as expected: more land, capital, and irrigation rights lead to more farm income, while labor is the main determinant of off-farm income.

As for WUA Performance: the indicators for investment and financial performance have a positive impact on income. However, not all indicators were found to have a positive effect: no impact of canal quality was observed. The amount of water provided per mu even carries a negative sign. It is possible that this effect is due to the fact that water allocation is often intended to compensate for adversarial circumstances. In drier, riskier areas, more water per mu is provided. In villages that are located farther from main canals, canal quality is often higher (see table 4).

As for off-farm income, the indicators for investment and secondary canal quality are associated with negative coefficients. This could indicate that farm households in better performing associations are willing to rely more on their farming activities, and thus seek less off-farm employment. In such a case one would expect farm income to be higher, after all, the household would only shift away labor from off-farm activities in favor of farm activities if it were compensated by means of extra income. As observed above there is some evidence for this effect of WUA performance on farm income.

As for the impact on total income (off-farm and on-farm combined), very little positive impact of the WUA performance indicator remains visible. This might be due to the fact that all data for the research comes from a wet year. The direct benefits from improved WUA performance, more water that is timed better, are not very large: after all there is more than enough water to make up for conveyance losses in poorly maintained canals.

5. Conclusion

This study provides empirical evidence of the impact of participatory water management on farmer incomes in Minle County, Gansu province, China. To this end, we will firstly examine to what extent participatory water management affects WUA performance. It is a widely held believe that the level of user participation is a key determinant of performance. Our results do not unambiguously support this position. We found that increasing participation by having democratically elected leaders has a positive effect on WUA performance, by increasing investments and improving canal quality. However, more direct decision making participation did not show a positive effect on WUA performance. Apart from participation, other important factors were identified as determinants of WUA performance, such as agro-ecological location or being the home village of an important regional leader. This might be taken to imply that increasing participation is not the panacea it is often claimed to be. However, the clear positive effect of democratic elections demonstrates the potential of holding management accountable to association members. The fact that apart from increasing participation, being a home village of a regional leader leads to better water management performance, does not demonstrate the limitations of participation. It demonstrates that leaders at higher levels of water management should also be made more accountable. The fact that older WUAs have better tertiary canals demonstrates that the reforms have not had their full effect in all villages yet, and that improvements are to be expected even without further reform.

Secondly, we investigated the impact of WUA performance on the (farm and off-farm) incomes of households that participate in WUAs. We found a positive impact of some indicators of WUA performance (financial health of the WUA and investment density) on household farm income, but also a negative impact of another: the amount of water supplied per mu. This negative impact probably has more to do with compensating for harsh circumstances than with overuse of water. Although WUA performance is found to have a positive impact on cropping income, its performance is found to be negatively affect off-farm income. This is explained by the fact that increased WUA performance leads to higher farm productivity, and thus forms a disincentive for engaging in off-farm employment. One the whole, one would then expect WUA performance to have a positive impact on the combination of off-farm and cropping income. This effect was not found. This is probably related to the fact that the data used for this study were collected for a year (2007) which happened to be characterized by abundant rainfall. In such circumstances a well functioning irrigation sector is of less importance. The more abundant the water, the less important it is to economize on it.

The results presented in this paper provide some limited evidence that increasing participation has a positive impact on WUA performance, which in turn has a positive impact on income from farming. This implies that increasing participation is a strategy to not only limit government outlays on water management and to conserve water resources; it also has value as a strategy to increase farm incomes. The small sample size at the WUA level (n=35), and the limited scope of this research (one growing season in one county in China), however, prevent grand conclusions from being drawn from this research. More empirical research, on a larger number of WUAs is a larger number of counties, is needed to check the robustness of our findings.

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