WORKING PAPER 101/2015

TO CONSUME OR TO CONSERVE: EXAMINING WATER CONSERVATION MODEL FOR WHEAT CULTIVATION IN INDIA

Zareena Begum Irfan
Bina Gupta

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

April 2015

To Consume or to Conserve: Examining Water Conservation Model for Wheat Cultivation in India

Zareena Begum Irfan
Associate Professor, Madras School of Economics
zareena@mse.ac.in

and

Bina Gupta
Associate Professor
Department of Environmental Science, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand 247667

WORKING PAPER 101/2015

April 2015

Price : Rs. 35

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/2230 0307/2235 2157
Fax : 2235 4847/2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

To Consume or to Conserve: Examining Water Conservation Model for Wheat Cultivation in India

Zareena Begum Irfan and Bina Gupta

Abstract

Constitutionally in India, the individual states have responsibility for water, forests, and agriculture. Major canal irrigation accounts for over 80 percent of India's irrigation. The intensive wheat irrigated system in Haryana and Uttar Pradesh states of India is observed to analyze the impact of incentive mechanism favoring the crop yield and water use. The regions selected for the present study are built on a long tradition of canal irrigation. Findings from farm surveys are used to examine water management and water productivity in the Haryana and Uttar Pradesh state. Attributes of the irrigation sources help explain the widespread interest in groundwater use and the relative demise of canal water use. Sole consumption of groundwater as irrigation source was altered by the initiation of conjunctive water of both surface and ground through the incentive pathway by municipal level irrigation managers. A combination of technological, land use and market based approaches is likely to be most effective in achieving sustainable water management in these intensive cereal systems. Based on the data set for the Indo-Gangetic Plain, the overall goal of this paper was to examine how the irrigation management reform has proceeded since the early stages of implementation and what the impacts are of the incentive mechanisms on water use and crop yields. The results show that irrigation management reform has accelerated in the study sites. The econometric model results indicate that using incentive mechanisms to promote water savings is effective under the arrangement of contracting management. However, if incentives are provided to the irrigation managers, the wheat yield declines significantly. The 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 crop yields. Therefore, the design of win–win supporting policies is aimed to be achieved from the present study to ensure the healthy development of the irrigation management reform.

Keywords: *Canal Irrigation, Incentive, Water Use, Crop yield*
JEL Codes: *Q15; Q25; Q18*

ACKNOWLEDGMENT

The authors are grateful to their parent institutes, which provided them the infrastructural benefit of conducting the research work. The corresponding author is grateful to the financial support provided by the Council of Scientific and Industrial Research, India. The present paper is a part of the work titled "Implementation and policy level comparison of canal irrigation at the Dragon and Snake Land", which was presented in the International Conference on "Comparing Water Governance in China and India: Challenges and Policy Options", October 24-25th, 2014, Institute of Water Policy, Lee Kuan Yew School of Public Policy, National University of Singapore. The authors are thankful to the editorial comments provided for the same and being accepted for publication in the Water Policy Journal's special issue.

INTRODUCTION

The elixir of life, water is becoming a scarce resource, majorly in those economies, where the water dependent productive sectors contribute more to the development - with the share of agricultural water use decrease is mutually accompanied by the increase in the water consumption across the industrial and domestic segments. In the face of increasing competition for water from other sectors, concerns are being raised about agricultural water productivity (Hellegers *et. al.*, 2007; Kijne *et. al.*, 2003; Molden, 2007; Liu *et. al.*, 2008). Under the pressure of increasing water shortage and the need to sustain the development of irrigated agriculture, the country level organizations have begun to push for the major purpose of irrigation management. The local governments have not only made detailed reform plans but has also issued relevant regulations and technical guidance to push the irrigation management reform (Wang *et. al.*, 2005; Molden, 2007). 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. The guidance for the irrigation management reform was promoted based on the success cases of other regions. These guidelines are termed as by the World Bank entitled as 'Five Principles', which includes - adequate and reliable water supply, legal status and participation, committees enforced to monitor the reduction of water consumption within hydraulic boundaries, water deliveries that can be measured volumetrically, and the equitable collection of water charges from members of water saving committees (Wang *et. al.*, 2010).

Based on the guidelines from the World Bank, in the year 2006 an irrigation management reform was initiated along the villages of the Indo-Gangetic Plain (IGB) of Haryana and Uttar Pradesh states, India. The conventional individual irrigation management was replaced by the municipal level irrigation management with the motive of using water efficiently for agricultural productivity. The reformation is carried out

using incentive mechanism provision to the irrigation managers, which was successful model in achieving large water savings and reduced the water use per hectare. In addition, the incentive mechanism had a minimal effect on the crop yield. The incentives has been defined as offering the irrigation managers the rights to earnings equal to the value of the water saved by irrigation management reform.

In India, the historic private ownership of farm lands accompanies water ownership. The traditional canal irrigation was characterized by the massive public investment. The public sector led scheme reflected their capital intensive nature and need for collective action, but their management has proven problematic including their inherent supply-led nature and cost recovery issues. The conventional canal irrigation was also proven to be difficult to equitable sharing of water, typically leading to the lower reaches having a reduced canal water supply, more water deficits and lower yields. Thereby, widespread interest in groundwater use and the relative demise of canal water as an irrigation source across Haryana and Uttar Pradesh was noticed. In each area groundwater now is the main irrigation source. This has led to the overexploitation of groundwater in the IGP region of Haryana and Uttar Pradesh. To avoid over exploitation of groundwater utility for irrigation purpose and the high investment led canal irrigation subsequently, a conjunctive use of canal and groundwater was initiated as an irrigation management reform at the municipality level across the IGP region of Haryana and Uttar Pradesh, India. The municipality level irrigation managers where provided with incentive to save water consumption efficiently by regulating the groundwater supply regulation to the individual farmers.

The irrigation management reform improves the performance of irrigation system – such as increasing irrigation efficiency, adequacy and equity of water delivery, cost recovery, agricultural productivity and

farmer income (Bassi and Kumar, 2011; Özerol, 2013). 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).

Thus, the objective of the present study is to examine the importance of incentives faced by irrigation managers and to analyse the performance changes from the reform over time. The reform has continued and spread widely to more zones of study site, 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 for India and other regions, it is urgent to answer the following important questions. After introduction, 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, the following three specific objectives are defined. First, to trace the evolution of institutional reform and the incentives provided to irrigation management in India. Second,

to identify the impacts of irrigation management reform on water use, focusing on the role of incentive mechanisms under various management patterns. And finally the impact of the reform on crop yields was targeted to be analysed.

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 irrigations 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 the descriptive statistical analysis and established econometric model, the impacts of incentives on crop yield has been discussed. The final section contains conclusions and policy implications.

METHODS OF DATA COLLECTION

The data for the present study was obtained from the two rounds of primary survey conducted in two wheat irrigation districts (IDs) in Yamunanagar and Bhagpat of the Indian state Haryana and Uttar Pradesh in 2006 and 2010. In 2006, to represent as much diversity as possible in the data, the district of Haryana located in the upper (Yamunanagar) and the district of Uttar Pradesh located in the lower reaches (Bhagpat) of the Yamuna River of Indo-Gangetic Plain (IGP). From a number of irrigation districts of Haryana and Uttar Pradesh, the two IDs, one upstream and the other downstream. The villages, Hathnikund and Khekra, from the Yamunanagar and Bhagpat districts of Haryana and Uttar Pradesh, respectively were randomly chosen from a census of villages in the upper 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 2006, we surveyed overall 51 village leaders, 56 irrigation managers, and

204 farm households and gathered information on 408 plots. In 2010, we returned to the same sample sites to collect the same variables as collected in 2006. Among the 204 households surveyed in 2006, we were able to interview 186 households (91 percent) in 2010. For each household, we also asked for information on the two plots that were surveyed in 2010. Thus, in total, we obtained balanced panel data with 186 households and 372 plots.

To meet the objectives of the present study so as to examine the evolution and impacts of irrigation management in India, three separate instruments: one for farmers, one for irrigation managers and one for village leaders were designed. The water share from various irrigation sources were utilized for the villages and the irrigation managers in two round data sets. The irrigation management reform process in India displayed that the municipal level irrigation management has provided with the incentive to regulate groundwater consumption during the initiated water source of conjunctive irrigation with surface water, they are termed as with incentives. If the incomes from their municipal level irrigation management duties are not provided for groundwater saving, they are said to be without incentives. Indian tubewells are typically of lower capacity, thereby helping explain the substantially longer pumping hours for groundwater use, but by the usage of the cheaper operation of the predominantly electric operated wells, the consumption of groundwater for irrigation increases and reduces the incentive to save groundwater. Hence, to cease this high usage of electric pumps, the municipal level irrigation managers of Haryana are provided with the incentive for the lower electricity consumption for irrigation too.

The data was used 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 the Indian data of irrigation management reform, the water source for irrigation comes from surface and

groundwater conjunctively. In the individual farming process of India, groundwater consumed as a single source of irrigation. The data of water use per hectare on a cubic meter basis, but also other information about the application process, such as the length of time that it takes to apply water in the village, the depth to which the average field was flooded, the type of the soil and the area irrigated for the present study. With this information and with other information from the household combined, a single measure was derived out from various measures to estimates the final water use. The rest of the data on a number of other variables that may affect the irrigation management institutions, the outcomes or both were also considered including, the degree of water scarcity, the level of investment in the village's irrigation system, as well as a number of other village, household and plot characteristics.

Reform of Irrigation Management and Incentive Mechanisms

Agricultural water management in India can be largely categorized as rainfed, canal irrigated and groundwater irrigated (Shah *et. al.*, 2009). The attractions of irrigation over rainfed agriculture are numerous and well documented, and include higher yields, reduced production risk, and incentives for farmers to intensify and commercialize. However, perhaps less obvious are the relative merits of the three prevailing irrigation categories. Tubewells are the prevailing groundwater source in India, although farmers use primarily diesel-powered pumps in some areas and electrical pumps in others. Irrigation from canals and diesel-operated wells can be stereotyped as differing in a number of attributes (Table 1). Most obvious perhaps is the marked difference in cost structure. Canal irrigation requires large initial investments with relatively low operation and maintenance (O and M) costs. In contrast, diesel operated wells are relatively cheap to install but relatively expensive to operate. The investment nature of canal irrigation also makes it typically large scale with limited flexibility in terms of command area or water use. Thus canal irrigation is inherently supply

driven and dominated by the public sector. In contrast, diesel operated wells are typically small scale with relatively large degrees of flexibility in terms of water use and even the command area—making them more widely accessible and more malleable to user needs. Electric operated wells typically take an intermediate position (Table 1). For farmers they are less expensive to operate than diesel-powered pumps, but a large public investment usually is required to extend the rural power grid across large areas serving many small-scale farmers (Shah *et. al.*, 2009).

Table 1: Irrigation Sources in India

Variables	Canal	Electric tubewell	Diesel Tubewell
Investment cost	High	Low	Low
Operation and maintenance cost	Low	High	High
Scale	Large	Low	Small
Flexibility	Low	High	High
Water use decision	Supply led	--	Demand led
Sphere	Public	--	Private

The electricity grid also can generate dependence on electricity supply, and that dependence can become an issue, particularly where power cuts ('load-shedding') are commonplace. Thus electrical wells often have less operational flexibility than comparable diesel-powered wells. Conjunctive water use of surface and ground water provision to the farmers of Haryana could lead to an attractive and viable option with

some of the shortcomings of canal irrigation, including rigid water delivery schedules and often unreliable and inadequate canal water supplies. Farmers were often willing to pay the higher O and M costs of groundwater irrigation because it is more responsive to their needs and flexible. Conjunctive use could also minimize adverse effects of using a single water source—e.g. when mixing or alternating water sources of different quality (Tyagi *et. al.*, 2005). The first (canal) irrigation development wave was primarily public sector led, whereas the second (groundwater) was primarily private. Access to groundwater irrigation is also typically more equitable than canal irrigation as access is determined less by topography, location and supply (Shah *et. al.*, 2007). In addition there are lower barriers to entry. Whether groundwater development became electricity or diesel dominated depended inter alia on the interplay of the public and private sector, particularly in terms of the degree and flexibility of rural electrification and the extent to which costs (investments and O and M) were passed on to the water user. The characteristics of groundwater irrigation and particularly diesel-operated wells also facilitate the development of water markets (e.g. Shah *et. al.*, 2009). Dependence on water markets reduces farmers' flexibility and can reduce crop yields, particularly in terms of unreliable water access when using electric-powered tubewells. Still, water markets make groundwater accessible to those who cannot afford to install their own tubewells and can alleviate water shortfalls in canal irrigated areas.

The wheat system in Haryana and Uttar Pradesh was dependent on irrigation. The annual potential evapotranspiration ($\geq$1400 mm) far exceeds the average annual precipitation (300–1100 mm yr^{-1} in Haryana; 896-1600 mm yr^{-1} in Uttar Pradesh). Conjunctive water use typically improves the overall availability and reliability of water, thus improving water use efficiency. In the IGP zone of Haryana and Uttar Pradesh, rainfall is variable and uncertain but free, while surface water is relatively cheap. However, farm-level surface irrigation supplies are

limited and rigid in canal irrigated areas, while groundwater can be fine-tuned to optimize water needs and returns after exploiting other sources (Hellegers *et. al.*, 2007). Indeed, farmers typically have very limited scope for decision making in respect of canal water, so that farmers' water management decisions are largely confined to tubewell operation (Tyagi *et. al.*, 2005). The reduced canal water supply at the lower reaches of canal irrigation systems forces farmers to pump more groundwater and incur higher irrigation costs. Groundwater provides the major share of total water supply at the farm gate in the study area of Haryana and Uttar Pradesh.

Tubewells are the predominant irrigation source for the surveyed farmers in each area, although extensive canal irrigation systems were served in these zones of IGP. The reliance on tubewell water is particularly notable in winter reflecting the general scarcity of canal irrigation water at the time. Most striking is its positive association with farm size, reiterating the more equitable nature of groundwater irrigation. Cropland on surveyed farms in Haryana and Uttar Pradesh generally are well drained with loam or sandy loam soils prevailing. Irrigated double cropping prevails with high land use intensities, where many farmers reported some seasonal fallow and seasonal water scarcity, primarily during the monsoon season.

Table 2: Irrigation Management in the Selected Districts of India (2006-2010) for Wheat Cultivation (Percentage of Samples, Percent)

India	Hathnikund Village Yamunanagar District, Haryana	Khekra Village Bhagpat District, Uttar Pradesh
2006		
Individual	89	65
Municipal Level irrigation management	11	35
2010		
Individual	92	29
Municipal Level irrigation management	8	71

The data showed that the municipal level irrigation management was initiated and implemented at a pace of 11 and 35 percent, to provide conjunctive water supply to the farmers of Hathnikund and Khekra village of Yamunanagar district of Haryana and Bhagpat district of Uttar Pradesh, in the early stage of reform itself. As time progressed, at the end of 4 years it was observed that the Khekra village displayed almost 50 percent of more farmers adapting the conjunctive water supply for irrigation instead of individual management. Whereas, the pace in the Hathnikund village was reduced by 2 percent towards adapting municipal level irrigation management of conjunctive water supply, displays that farmers in this region solely utilized groundwater since the rural electricity being subsidized by the Haryana state electricity board and the electricity connection relatively is more attractive for cheap irrigation when compared to conjunctive mode. Although electric powered wells prevail in Haryana, conjunctive water use is more closely associated with diesel power –thereby decreasing the incentives to save groundwater. The farmers of the Khekra village of Uttar Pradesh were more satisfied with the regular water supply for irrigation through conjunctive process.

Changes of Incentive Mechanism

The incentive mechanism of irrigation management reform is closely related to the payment system for irrigation fees. From 2006 to 2010, the increase in the individual pattern of irrigation was observed in the Hathnikund village of Yamunanagar district, Haryana. It was owing to the wide interest of farmers towards the sole consumption of groundwater for irrigation and was not interested to adopt the conjunctive water of canal and tubewell. This observation is basically due to the sole ownership of both irrigation plots and tubewells and in addition the electricity connectivity provided to both domestic and agricultural utility together. Moreover, the subsidized electricity provision in the state attracted the farmers to extract more water from their own tubewells than to provide incentive to municipality and consume equitable conjunctive water supply. Even after subsidization of electricity to run tubewells, around 11 percent farmers at Hathnikund village initiated their farming pattern towards the municipality level management's in the year 2006. It was due to their economic status of not owning an electric tubewells or even worse of not being connected to electricity supply, which would benefit it cultivating wheat individually with diesel tubewells.

A rapid shift from individual farming mode to the municipal level irrigation pattern by more than 50 percent farmers of Khekra village, Bhagpat district of Uttar Pradesh was observed within four years (2006-2010) of irrigation management reform with incentive mechanism. The increase in the reform pattern is due to the farming environment prevailing in this region of wheat cultivation. The non-equitable utility of groundwater and biased electricity supply due to the affluent farmer groups were the stress-creators which forced the farmers to shift to a much more reliable, governed municipal level irrigation management with a minimal incentive to be paid as a maintenance amount to the municipality.

After understanding the trend in the change of incentives by various institutional arrangements, it would be more interesting to know the following questions, which are related to the performance of the reform. First, over the reform period in India, 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, it is observed that there is no reform progress in the Yamunanagar district of Haryana, India. Therefore, it is not rational to include the Haryana, India samples in the present analysis, which focuses on the reform performance assessment. In the following two sections, the details of samples in Khekra village, Bhagpat district, Uttar Pradesh to explore the impact of incentives on crop water use and crop yields.

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 wheat cultivation. For example, the water use per hectare of wheat cultivation in the reformed village with established incentive is lower than that in the villages the management of collectives. In the Indian context, the water use per hectare of wheat cultivation in the reformed village with established incentive mechanism is lower than those villages with individual management (Table 3). For example, in the case of Haryana state, Hathnikund village of Yamunanagar district, it was observed that when compared to those farmers who adopted the individual irrigation management mode cultivated 5 percent more than those farmers who cultivated under the conjunctive water use, in municipal level irrigation management of incentive mechanism. In the case of Uttar Pradesh state, Khekra village of Bhagpat district, it was observed that compared to those farmers under individual irrigation management cultivated around

25 percent more than the farmers who cultivated under the conjunctive water use in municipal level irrigation management of incentive mechanism.

Table 3: Incentives and Water Use of Wheat Under Irrigation Management Patterns in Two Districts in India, 2006–2010

Irrigation Management Type	Water use (m^3/ha)
Hathnikund village	
Yamunanagar district, Haryana	
Municipal Level Irrigation Management with incentives	7737
Individual irrigation management	8221
Khedra village, Bhagpat district,	
Uttar Pradesh	
Municipal Level Irrigation Management with incentives	7340
Individual irrigation management	9899

Note: Estimates based on primary survey.

These results imply that the incentive mechanism is possibly more effective in saving water under reformed irrigation management arrangement than in a conventional mode across India. However, because many other factors affect water use in the 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.

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 Khekra village, Bhagpat district, Uttar Pradesh of India:

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

where W_{ijk} represents the average water use per hectare of wheat 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, two strategies were adopted. The first strategy is to classify irrigation management into two groups. The first group is managed by non-collective institutions (contracting) with the incentive mechanism established. The second group is under the management of collectives and is treated as the basis for comparison. Because to know if the contribution of incentive mechanisms to water use is different due to various management patterns, the strategy is to create one set of interaction terms between the incentive and the irrigation management pattern. This strategy also treats the conventional management as the basis for comparison (Table 4). Based on our survey and secondary data, 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, a number of variables to hold constant the nature of the village's socio-economic characteristics, production environment and cropping structure. The variables such as the number of households, the per capita annual income and the distance to the township to measure

the socio-economic characteristics are included. 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. The household characteristics include age and the education level of the household head and the land endowment. The 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, the model also includes Y_{ijk}, a dummy variable representing the year 2010 for India, and D_{ijk}, a dummy variable representing the irrigation districts 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.

Estimation Results on the Impacts of Incentives on Crop Water Use

The empirical estimation performs well for the water use model (Table 4). 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. The results show that when the officials provide the irrigation managers with incentives, (municipal level management, India) the managers appear to reduce water deliveries for wheat in the village (Table 4). The econometric results show that when compared to the village incentives under municipal level irrigation management, the coefficient on the incentives indicator variable is negative and significant at the 1 percent level for the wheat estimation results.

Is the effectiveness of the incentive mechanisms different under various management patterns? To answer this question, the water use model results with interaction terms between incentives and reformed

institutions (municipal level irrigation management, India). The estimation results demonstrate that the incentive mechanisms for water saving are effective under the institutional management reform (Tables 4). For the wheat 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. Compared to the villages the incentives established within reformed irrigation management can significantly reduce wheat water use more when compared to the collective management in India.

The major role of the irrigation managers is to provide good irrigation service to its farmer members rather than increasing the water use efficiency. If the role of the incentive mechanism on saving is at the cost of hurting agricultural production, the individual farmers in India is more likely not to operate based on the incentives. The irrigation managers, manage the water supply for irrigation 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 in India. The following section will continue to examine this question.

Table 4: Regression Analysis of the Determinants of Wheat Cultivation Water Use at the Plot Level for Haryana and Uttar Pradesh, India

Variables	Water use per Hectare	
	Haryana	Uttar Pradesh
Interaction term of incentives and municipal level irrigation management (1 = yes; 0 = no)	718.2	1854.9
	1.50)***	3.33)***
Interaction term of subsidized electricity and individual farming (1 = yes; 0 = no)	13.6	37.8
	0.04)	0.17)
Interaction term of subsidized electricity and municipal level irrigation management	1149.8	670.0
(1 = yes; 0 = no) *Village characteristics*	2.31)**	0.95)
Number of households (number)	1.349	1.495
	4.42)***	3.94)***
Per capita annual net income (US $, 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 (US $/ha)	0.010	0.047
	0.26)	0.90)
Share of wheat in sown area (%)	26.7	49.7
Household characteristics	2.98)***	3.79)***
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
Plot characteristics	0.92)	1.27)
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)

(Contd...4)

(Contd...4)

Variables	Water use per Hectare	
	Haryana	Uttar Pradesh
Distance to home (km)	282.7	60.8
	1.07)	0.90)
Single crop (1 = yes; 0 = double cropping)	.186.0	62.7
Year dummy	2.53)**	0.80)
Year is 2010 (1 = yes; 0 = no)	563.6	136.0
Irrigation District dummy	1.47)	0.26)
Uttar Pradesh (1 = yes; 0 = no)	2175.8	3331.5
	6.26)***	6.89)***
Constant	035.7	.120.7
	1.22)	0.24)
Observations	10	10
Adjusted R-square	.37	.41

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

Impacts of Incentives on Crop Yields

Compared with those villages managed by conventional irrigation management, those managed by reformed irrigation management with incentives show a lower wheat yield. For example, the wheat yield per hectare in those villages providing incentives to the irrigation management reform process was 4191 kg in the Uttar Pradesh study site, which is lower than those villages under the traditional collective management, at 4600 kg in the Uttar Pradesh study site, India (Table 5). If linking the water saving effect of the incentive mechanisms together, these results perhaps indicate that through improving management, the irrigation 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.

Table 5: Wheat Yield Under Various Management Patterns for Bhagpat District, Uttar Pradesh, India

Irrigation Management type	Crop Yields (kg/ha)
Khekra village, Bhagpat district, Uttar Pradesh, India	
Municipal Irrigation Management with incentives	4191
Individual farmer pattern	4600

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, the link between crop yield and its determinants by applying the plot level data in and Uttar Pradesh, India was analysed:

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

where Q_{ijk} represents the yields of wheat 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, the predicted water use from Table 5 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").

Estimation Results on the Impacts of Incentives on Crop Yields

Almost all of the models specified on wheat yields perform well and produce robust results that largely confirm our a priori expectations (Table 6). The goodness of fit measure for wheat yield for India, the adjusted R^2 is 0.12. 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. Compared with the multiple planting systems, if farmers only plant one single crop in one season, the wheat yield would be significantly higher. The production shock negatively influences the wheat yield in India.

Table 6: Regression Analysis of the Determinants of Wheat Yield at the Plot Level

Variables	Wheat Yield (log)
Production inputs	0.085[b]
Water use per hectare (log)	(1.55)
Labor use per hectare (log)	0.028
	(0.84)
Fertilizer use per hectare (log)	0.061
	(1.61)
Value of other inputs per hectare (log)	0.008
	(0.23)
Production environment Value per hectare of accumulated	0.00001
investment in village irrigation infrastructure (US$/ha)	(1.33)
Household characteristics	0.001
Age of household head (years)	(0.45)
Education of household head (years)	0.004
	(0.53)
Plot characteristics	0.037
If conjunctive irrigation (1 = yes; 0 = no)	(0.21)
Loam soil (1 = yes; 0 = no)	0.034
	(0.68)
Clay soil (1 = yes; 0 = no)	0.016
	(0.34)
Distance to home (km)	0.010
	(0.26)
Single crop (1 = yes; 0 = double cropping)	0.147
	(2.47)**
Production shocks	0.005
Yield reduction due to production shocks (%)	(3.97)***
Year dummy	0.085
If year is 2010 (India) (1 = yes; 0 = no)	(1.98)***
ID dummy	0.017
If Khekra (U.P. India) (1 = yes; 0 = no)	(0.32)
Constant	7.270
	(12.75)***
Observations	310
Adjusted R-squared	0.12

Predicted water use by the determinants of water use model
* significant at 10%; ** significant at 5%; *** significant at 1%

The results show that the wheat yield is not statistically significant to water use, implying that there are positive impacts from incentives on wheat yield. This result indicates that after holding other factors constant and increasing water use 23 percent, the wheat yield will increase by 4.8 percent. Checking this issue from the opposite perspective, the result demonstrates that a 23 percent reduction in water use will result in the reduction of the wheat yield by 4.3 percent. If the plot level analysis of the incentives of irrigation management and crop yields are correct, then the results would mean that in the sample areas, the trade-off between the water savings from establishing the incentive mechanisms for irrigation management reform pattern and crop yields occurs for wheat cultivation in is less severe. The conclusion is plausible and, although its validity may only hold for the sample region, it is consistent with many of the observations that were 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. The irrigation managers that have an incentive to save water may be able to time their use of irrigation water, while those that have no interest in saving water might adhere to a predetermined water delivery schedule, regardless of the weather.

Concluding Remarks

In this paper, it was aimed to understand that how the irrigation management reform of for conjunctive water use in the IGB region, India. In particular, the incentive mechanism still plays a role in saving water and benefiting agricultural production, the major purpose of the reform. Based on the panel data, the research results show that irrigation management reform with incentive was accelerated at the lower stream Khekra village of Bhagpat district, Uttar Pradesh than at the upper stream Hathnikund village, Yamunanaagar district, Haryana - due to administrative subsidization provided in Haryana. Although some

improvement on management mechanism was observed, most irrigation management reforms are still nominal. More importantly, over the past several years, more contracting managers preferred to establish incentive mechanisms. However, this trend differs by irrigation district within India. Applying both descriptive statistics and an econometric model approach and based on data from two irrigation districts of India, results demonstrate that the use of incentive mechanisms to promote water saving is effective under the reformed irrigation management arrangement. Specifically, providing incentives to municipal irrigation managers (India) will significantly lead to the reduction of water use for wheat. However, with a decrease in water use, the wheat yield will present a significant decline. 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.

Further analysis indicates that even when the irrigation managers with incentives can earn money by saving water, this result does not necessarily benefit the entire village. The results show that in India's study site, 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, the money lost per hectare for farmers was lower than the amount earned by the irrigation managers. Therefore, the overall villages are the losers.

Based on the analysis results, in the future, as the local governments in the IGB region 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 using 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 irrigation districts or even larger regions. The policy makers in the IGB region must find ways to balance the trade-off between saving water and increasing agricultural productivity and economic benefit over the long term.

A combination of technological, land use, and market based approaches is likely to be most effective in responding to increasing water scarcity and improving the sustainability of intensive cropping systems of the IGP region. For instance, increased water prices can induce farmers to shift to more water efficient crops and increase their incentives to use more water conserving technologies. A combined approach is also more likely to allow conjunctive water use to evolve into conjunctive water management in these water-scarce regions—whereby ground and surface water are managed in an integrated way to avoid overexploitation. Technological intervention thus needs to be

complemented with institutional reform to create an enabling environment for sustainable irrigated agriculture that promotes the economic use of water and other resources. Ultimately the root cause of land degradation in the post-Green Revolution era is not agricultural intensification per se, but rather the policy environment and associated incentives that encouraged inappropriate land use and injudicious use of water and other resources.

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 of 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.

REFERENCES

Bassi, N., M.D. Kumar (2011), "Can Sector Reforms Improve Efficiency? Insight from Irrigation Management Transfer in Central India", Water Resource Development, 27 (4), 709– 721.

Hellegers, P., C. Perry, J. Berkoff (2007), "Water Pricing in Haryana, India", In: Molle, F., Berkoff, J. (Eds.), Irrigation Water Pricing: The Gap Between Theory and Practice, CABI Publication, Wallingford, pp. 192–207.

Kijne, J.W., R. Barker, D. Molden (Eds.) (2003), "Water Productivity in Agriculture: Limits and Opportunities for Improvement", CABI Publication, Wallingford, UK.

Liu, L., Z. Liu, , Z. Xu (2008), "Trend Analysis of Climate Change in the Midstream of the Yellow River Basin in the 21st Century", Research Programme in Climate Change 3, 167–172 (in Chinese).

Meinzen-Dick, R., K.V. Raju, A. Gulati (2002), "What Affects Organization and Collective Action for Managing Resources? Evidence from Canal Irrigation Systems in India", World Development 30 (4), 649–666.

Molden, D. (2007), "Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture", Earthscan/IWMI, London.

Mukherji, A., T.Facon, J. Burke, C. de Fraiture, J.M. Faures, B.Fuleki, M. Giordano, D. Molden, T.Shah (2009), "Revitalizing Asia's Irrigation: To Suschangtainably Meet Tomorrow's Food Needs", International Water Management Institute, Colombo, Sri Lankam, Food and Agriculture Organization of the United Nations, Rome, Italy.

Özerol, G. (2013), "Institutions of Farmer Participation and Environmental Sustainability: A Multi-Level Analysis from Irrigation Management in Harran Plain, Turkey", International Journal of Commons 7 (1), 73–91.

Parthasarathy, R. (2004), "Objects and Accomplishments of Participatory Irrigation Management Programme in India: An Open Pair of Scissors", Gujarat Institute of Development Research, Working Paper 146.

Shah, T., M. Ul Hassan, M.Z. Khattak, , P.S. Banerjee, O.P. Singh, S.U. Rehman (2009), "Is irrigation Water Free? A Reality Check in the Indo-Gangetic Basin", World Development, 37 (2), 422–434.

Shah, T., C. Scott, A. Kishore, A. Sharma, (2007), "Energy-Irrigation Nexus in South Asia: Improving Groundwater CVonservation and Power Sector Viability", In: M. Giordano, K.G. Vilholth, (Eds.), The Agricultural Groundwater Revolution: Opportunities and Threats to Development, CABI Publication, Wallingford, UK, pp. 211–242.

Tyagi, N.K., A. Agrawal, R. Sakthivadivel, S.K. Ambast (2005), "Water Management Decisions on Small Farms Under Scarce Canal Water Supply: A Case Study from NW India", Agricultural Water Management, 77 (1–3), 180–195.

Wang, J., Z. Xu, J. Huang, S. Rozelle (2005), "Incentives in Water Management Reform: Assessing the Effect on Water Use, Productivity and Poverty in the Yellow River Basin", Environment and Development Economics, 10, 769–799. http://dx.doi.org/10.1017/S1355770X 05002524.

Wang, J., J. Huang, L. Zhang, Q. Huang, S. Rozelle (2010), "Water Governance and Water Use Efficiency: The Five Principles of WUA Management and Performance in China", Journal of the American Water Resources Association, 46 (4), 665–685.

MSE Monographs

* Monograph 18/2012
  Performance of Flagship Programmes in Tamil Nadu
  K. R. Shanmugam, Swarna S Vepa and Savita Bhat
* Monograph 19/2012
  State Finances of Tamil Nadu: Review and Projections A Study for the Fourth State Finance Commission of Tamil Nadu
  D.K. Srivastava and K. R. Shanmugam
* Monograph 20/2012
  Globalization and India's Fiscal Federalism Finance Commission's Adaptation to New Challenges
  Baldev Raj Nayar
* Monograph 21/2012
  On the Relevance of the Wholesale Price Index as a Measure of Inflation in India
  D.K. Srivastava and K. R. Shanmugam
* Monograph 22/2012
  A Macro-Fiscal Modeling Framework for forecasting and Policy Simulations
  D.K. Srivastava, K. R. Shanmugam and C.Bhujanga Rao
* Monograph 23/2012
  Green Economy – Indian Perspective
  K.S. Kavikumar, Ramprasad Sengupta, Maria Saleth, K.R.Ashok and R.Balasubramanian
* Monograph 24/2013
  Estimation and Forecast of Wood Demand and Supply in Tamilandu
  K.S. Kavi Kumar, Brinda Viswanathan and Zareena Begum I
* Monograph 25/2013
  Enumeration of Crafts Persons in India
  Brinda Viswanathan
* Monograph 26/2013
  Medical Tourism in India: Progress, Opportunities and Challenges
  K.R.Shanmugam
* Monograph 27/2014
  Appraisal of Priority Sector Lending by Commercial Banks in India
  C. Bhujanga Rao
* Monograph 28/2014
  Fiscal Instruments for Climate Friendly Industrial Development in Tamil Nadu
  D.K. Srivastava, K.R. Shanmugam, K.S. Kavi Kumar and Madhuri Saripalle
* Monograph 29/2014
  Prevalence of Undernutrition and Evidence on Interventions: Challenges for India
  Brinda Viswanathan.
* Monograph 30/2014
  Counting The Poor: Measurement And Other Issues
  C. Rangarajan and S. Mahendra Dev

MSE Working Papers

Recent Issues

* Working Paper 90/2014
  Analyzing the Pathway to Improve Tiger Conservation in India
  Zareena Begum. I and Amanat K. Gill

* Working Paper 91/2014
  A New Approach to Construct Core Inflation
  Sartaj Rasool Rather, S. Raja Sethu Durai and M. Ramachandran

* Working Paper 92/2014
  Energy Use Patterns And Firm Performance: Evidence From Indian Industries
  Santosh Kumar Sahu

* Working Paper 93/2014
  Women's Malnutrition In India: The Role Of Economic And Social Status
  Shikha Dahiya and Brinda Viswanathan

* Working Paper 94/2014
  Asymmetric Price Adjustment - Evidence For India
  Sartaj Rasool Rather, S. Raja Sethu Durai and M. Ramachandran

* Working Paper 95/2014
  Volatility Spillover Between Oil And Stock Market Returns
  B. Anand , Sunil Paul and M. Ramachandran

* Working Paper 96/2015
  A Dynamic Economic Model of Soil Conservation Involving Genetically Modified Crop
  Amrita Chatterjee

* Working Paper 97/2015
  Entrepreneurial Choice of Investment Capital For House-Based Industries: A Case Study in West Bengal
  Shrabani Mukherjee

* Working Paper 98/2015
  Technology Import, R & D Spillover And Export: A Study of Automobile Sector in India
  Santosh K. Sahu and K. Narayanan

* Working Paper 99/2015
  Inflation Forecasting and the Distribution of Price Changes
  Sartaj Rasool Rather, Sunil Paul and S. Raja Sethu Durai

* Working Paper 100/2015
  An Inter-Country Analysis on Growth of Non-Bank Financial Intermediaries
  K. R. Shanmugam

---

* Working papers are downloadable from MSE website http://www.mse.ac.in

$ Restricted circulation