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VARIABILITY IN WATER USE, CROP WATER PRODUCTIVITY AND PROFITABILITY OF RICE AND WHEAT IN RECHNA DOAB, PUNJAB, PAKISTAN

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ABSTRACT

Variation in water use, crop water productivity and profitability was studied across the sampled watercourses of the Lagar Distributary of Upper Gogera branch of Lower Chenab Canal. Stratified random sampling technique was used to identify and interview 120 farmers in total, ten each at head, middle and tail reaches of the four sampled watercourse using well-structured questionnaire. Surface as well as groundwater is being used in the study area, either separately or jointly, with groundwater as a major shareholder. The area underground water irrigation increased from 58 acres at head to 113.8 acres at tail. Groundwater productivity of wheat was found higher at head (0.97 kg m^{-3}) than middle (0.96 kg m^{-3}) and tail (0.89 kg m^{-3}). On the other hand, groundwater productivity of rice did not vary across the water channel. The main reason was that water demand of the crop was mainly met by groundwater at all locations. The % share of different inputs cost in total cost of production was determined. Fertilizer was found as the major contributor among land preparation, labor cost, chemicals, irrigation, seed and harvesting etc. Favourable soil conditions and more reliance on groundwater supplies resulted in greater gross value of product (GVP) and gross margins (GM) at the tail. At tail ends it is needed either to increase canal water allowance or government support to install electricity tubewells on sharing/collective basis. There is a need to promote resource conservation techniques like zero tillage, laser land leveling and watercourse lining to increase crop water productivity. This will also help to conserve groundwater.

Key words: Water use; Crop water productivity; Profitability.

INTRODUCTION

The Agriculture sector continues to play a central role in Pakistan's economy. It is the second largest sector, accounting for over 21 percent of GDP, and remains by far the largest employer, absorbing 45 percent of the country's total labour force (GOP, 2012). Punjab is ranked second biggest province, after Balochistan, having an area of 20.53 million hectare (M ha) which constitutes about 26 percent of the total area of Pakistan. The area of Rechna Doab is 3.52 M ha, while the area of selected district Sheikhupura for this study is 0.596 M ha. The area is famous for rice production and surface water is distributed through a system called warabandi (Singh, 1981; Malhotra, 1982) in which available water supply is given to each farmer according to fixed schedule specifying the time, day and duration of supply in proportion to his land holding. The allocated time of irrigation from canal is not sufficient for an individual farmer that is about 16-20 minutes per acre. Illegal use of canal water by head end farmers and substantial loss of water due to seepage create large variation in surface water supply. Because of this non-reliability and variation in surface water, the use of groundwater has become necessary. The importance of groundwater in crop production in the region can be judged by the fact that private tubewell density (number of private tubewells/1,000 ha) has increased to 32 in 2002 as compared to only 1 in 1960 (Qureshi and Akhtar, 2003). The groundwater pumpage has also increased from 10 Billion Cubic Meter (BCM) in 1965 to 68 BCM in 2002, and over 80 percent of groundwater is exploited by the private tubewell owners (Bhutta and Alam, 2005).

The overdependence on groundwater for water intensive cropping system and poor regulatory mechanisms have resulted in growing water scarcity and increasing threat to future of this valuable resource. The challenge for irrigated agriculture is to grow more food per drop of water available (Guerra *et al*., 1998). The old trend to use more inputs for getting more yields will have to be changed, and new paradigms of optimized resource use in sustainable ways need to be evolved (Chandra *et al*., 2008). This study investigated the groundwater productivity in a rice-wheat cropping system at field level in Lagar distributary of Lower Chenab Command (LCC). The study also tried to find out the variation in water use and profitability of farmers across the canal command.

MATERIALS AND METHODS

Description of the Study Area: The study area lies between 31° 5' to 32° 4' N and 73° 15' to 74° 41' E. Its shape is roughly that of trapezoid with a triangular off shoot to the west from the south west corner (Fig. 1).

The soil condition in the Rechna Doab is generally basic in nature with pH value ranging from 8 to 8.5. The soil is moderately fine (silty clay loam, sandy clay loam, clay loam) in the selected area, with more heterogeneity in the top 15cm soil strata representing the top root zone.

The area falls in rice-wheat agro-ecological zones. Rice and forage crops dominate the summer (Kharif) season and wheat, sugarcane and forage are the major crops in the winter (Rabi) season (Arshad *et al*., 2009). The climate in the rice-wheat zone is semi arid, summers are very long and hot, lasting from April through September, with maximum temperature ranging from 21°C to 49 °C. Winter lasts from December through February, with maximum day time temperature of up to 27 °C and sometimes falling below zero at night. The average annual precipitation varies from 290 mm in the South (Shorkot) to 1046 mm in the North (Sialkot) of the Doab. The highest rainfall occurs during the monsoon period in July and August months and accounts for about 60% of average annual rainfall, about 75% of which falls during June to September monsoon. In Sheikhupura district, the hottest months with day temperatures are May and June with temperature ranging from 39 to 41 °C and January is the coldest month with a mean minimum temperature of 5 °C. Rainfall in the district is about 635 mm (PMD, 1998).

The study was conducted in Rechna Doab sub-basin (Land between the river Ravi and the Chenab) of Indus Basin Irrigation System. A multistage stratified random-cum purposive sampling technique was adopted to draw the sample. There are 28 irrigation sub-divisions in Rechna sub-basin. Keeping in view intensive cropping and heavy dependence of farmers on diesel & electric tube-wells as well as accessibility in terms of logistics and financial limitations Chuharkana sub-division was selected for the present study. Of the three major canal distributaries supplying water to this sub-division, Lagar distributary was chosen. At the third stage of sampling four sample villages were selected located at head of the distributary namely, Padianwala, Bhandoor, Sacha Soda and Mailian of district Sheikhupura. The selected area was mainly characterized by rice-wheat cropping system of the Punjab

The watercourses were selected keeping in mind the command area of each watercourse so that the required sample (number of farmers) could easily be chosen. A sample of 30 farmers (10 each at head, middle and tail of the distributary) was randomly selected from each watercourse. Primary data for this study were collected for the cropping season 2006-07, including Rabi 2006-07 and Kharif 2007. Information on source of income, irrigation source, cropping pattern, crop production, water use, water productivity, input use level and cost of production were collected.

Discharges of four selected water channels were measured at the head of each outlet off-takes from Lagar distributary using a cup type current meter (price type, Model 1205). The pipe trajectory method was used to estimate the flow rate from tubewells.

RESULTS AND DISCUSSION

Major crop yield: The yields of wheat and rice were found higher at tail as compared to head. For wheat and rice crops, it was 7.2 and 16% higher than at the head. Average wheat yield varied between 3.2 to 3.5 t ha^{-1} and that of rice varied between 3.6 to 3.75 t ha^{-1} from head to tail. Hussain *et al*. (2003) reported 4.11 t ha^{-1} of wheat yield in Lower Chenab Canal System in Chaj-Sub-basin of Punjab, however overall average wheat yield is 2.5 t ha^{-1} in Pakistan. Better soil conditions and reliable, timely water supply for irrigation through tubewells besides better agronomic practices could be the reasons for better yields at tail.

However, for sugarcane, the trend was found opposite to wheat and rice. Farmers located at head got maximum yield of 63.3 t ha^{-1} which might be due to higher doses of nitrogen (185.82 kg ha^{-1} at head as compared to 163.09 kg ha^{-1} at tail) and phosphorus (85.25 kg ha^{-1} at head as compared to 68.20 kg ha^{-1} at tail) and better management practices. Overall average sugarcane yield was 58.3 t ha^{-1}.

Water use for major crops: Rice is the most frequently irrigated crop with average number of total irrigations ranging between 32.8-37.8 irrigations. This is followed by sugarcane and wheat with their respective ranges of average number of total irrigations as 25.1-32.5 and 4.0-4.4. Generally in Punjab 15-25 irrigations are applied for rice from its transplantation till maturity (Ahmad *et al*., 2007). Due to prevalence of light texture soils in the study area rice is irrigated even more frequently, therefore, number of total irrigations for rice is higher in the area. This can also be observed through the decrease in total number of irrigations from head to tail, where percent of heavy texture soil is more than head. Total number of irrigations applied for wheat almost remained constant across the water channel reaches. Total number of irrigations for sugarcane was higher in the middle of the channel, this might be due to the fact that sugarcane is only cultivated by a few farmers with marked difference in their cultivated area and distribution across the canal reaches. Number of canal irrigations for all the crops were decreased from head to tail, except sugarcane where it had maximum value at middle, while the number of tubewell irrigations increased from head to tail again with the exception of sugarcane.

Overall contribution of canal water in total irrigation was very small. It showed increased dependence on groundwater when we move down from head to tail due to decreasing canal water availability resulting from different losses. According to Ahmad (2002) about 40% of the total crop water requirements are partially met from groundwater and rainfall. Heavy reliance on groundwater for crop husbandry could also be judged from Table 1, which shows the amount of groundwater applied to mature major crops in the study area. According to the results, average amount of groundwater applied for the wheat ranged between 3390 m^3 ha^{-1} to 4002 m^3 ha^{-1} with overall average value of 3625 m^3 ha^{-1}. Rice was the major consumer of the groundwater because kharif crops have more crop water requirements (Sarwar, 1999). Its average consumption per hectare ranged between 25504 m^3 to 26658 m^3. Annual water requirement of wheat and rice to meet evapotranspiration requirements in Rechna Doab is 330 mm (33000 m^3 ha^{-1}) and 640 mm (64000 m^3 ha^{-1}), respectively by Ullah *et al*. (2001). It shows that water applied through groundwater alone was in excess of the requirement and if canal water was also taken in to account then both wheat and rice were over irrigated.

Groundwater productivity: Table 2 shows the groundwater productivity of major crops in the area. The groundwater productivity of all crops decreased from head to tail except rice, which had slightly higher productivity at tail. Soil and higher input use level could be the reasons. Wheat productivity varied from 0.97 to 0.89 kg m^{-3} with an average value of 0.94 kg m^{-3} which is lower than 1.37 kg m^{-3} reported by Hussain *et al.* (2003) for Chaj sub-basin of Pakistan, as productivity varies from region to region that might be the cause of difference. Crop yields of wheat and rice were higher at tail as compared to head yet groundwater productivity of wheat was less at tail. Its main cause was less number of tube well irrigation at head than tail. While in case of rice yield was higher at tail but the numbers of groundwater irrigations were same at head and tail. Sugarcane cultivated area at head was three times higher than at tail and size of the plot cultivated by respondent farmers at head was also larger than at tail. Sugarcane productivity was highest at head; its major cause was more groundwater irrigation at tail. Moreover, higher investment for cultivating larger farm size might have compelled the farmers to use better inputs and adopt better management practices to get better output.

Input use level: The share of various cost components in total cost of production by major crops is shown in Table 3. Cost for land preparation was found to be the major contributor in total crop production. Table 3 shows that ploughing and planking were applied higher in number at head, while less at tail. For sugarcane, the use of ploughs and planks was high for preparing land as compared to wheat and rice. Puddling practice was higher at head than middle and tail. Light texture soil could be the reason. Application of seed increased from head to tail. Two major fertilizers in the area were di-ammonium phosphate (DAP) and urea. The use of nitrogen and phosphorous showed increasing trend from head to tail for the major crops. The use of both nitrogen and phosphorus was least for sugarcane at the middle of the channel. The highest dose of nitrogen (237.36 kg ha^{-1}) was applied to wheat at tail; while of phosphorus (85.25 kg ha^{-1}) was applied to sugarcane at head. Combined use of both the nutrients (nitrogen and phosphorus) was higher for wheat and rice at tail, while for sugarcane, it was highest at head. In-case of wheat, number for labor employment days for different practices was highest at middle, for rice it was higher at head and for sugarcane it was maximum at middle. Overall, farmers hired less number of laborers for different agricultural practices.

Table 1. Amount of groundwater use by major crops in the study area

Location	Groundwater use (m^3 ha^{-1})			
	Wheat	**Rice**	**Sugarcane**	**At farm level (for all crops)**
Head	3390	25504	7440	36334
Middle	3553	25526	12070	41149
Tail	4002	26658	28463	59123
Average	3625	25986	16609	46220

Table2. Groundwater productivity of major crops

Location	Wheat (kg m^{-3})	Rice (kg m^{-3})	Sugarcane (kg m^{-3})
Head	0.97	0.14	8.50
Middle	0.96	0.13	4.28
Tail	0.89	0.14	2.01
Average	0.94	0.14	3.51

Profitability of major crops: Gross value of product (GVP), cost of production (CoP) and gross margins (GM) were used to determine the profitability of major crops across the water channel command areas. Wheat and rice had higher value of GVP at tail. Overall CoP for wheat and rice was Rs. 20713 and 31723 per hectare. The CoP for wheat and rice ranged from Rs. 20287 to 21303 from Rs. 34260 to 37104 per hectare across water channel reaches, respectively. Cost of fertilizer application was major contributor in CoP for wheat followed by land preparation, harvesting and irrigation. Cost of Irrigation was the major component of CoP of rice; fertilizer application and land preparation were other major contributors. Overall CoP was less at tail. Tail had higher number of electric tubewells compared to other locations and per hour operational cost of electric tubewell was almost half of the diesel-operated tubewells. It could be the cause of lower CoP besides lower harvesting and land preparation costs at tail. Overall GM for wheat and rice was Rs. 14697 and Rs. 44373 and ratio of the gross margin to the CoP was double in case of rice. The profitability of wheat and rice is shown in Fig. 2.

Table3. Share of various cost components in total cost of production by major crops across canal reaches

Major crops by location	Total Cost of Production ($Rs.ha^{-1}$)	% Share of Cost Components								
		Land Preparation	Sowing	Seed	Irrigation	Fertilizer	FYM	Chemical	Harvesting	Labor
Wheat Head	21303	16.1	0.3	8.2	9.7	37.3	1.0	6.7	11.5	9.2
Wheat Middle	20287	17.3	0.5	8.2	12.5	32.7	0.7	5.5	8.3	14.3
Wheat Tail	20590	13.8	0.1	7.2	12.0	35.8	0.7	7.4	8.4	14.7
Rice Head	36235	11.5	4.7	0.0	41.9	16.2	2.1	8.4	9.6	5.4
Rice Middle	37104	10.6	3.9	0.0	49.5	15.3	0.6	4.2	8.3	7.5
Rice Tail	34260	11.3	4.1	0.0	43.8	18.1	1.9	5.1	7.8	7.8
S. cane Head	27156	17.7	1.0	25.9	11.9	20.7	0.0	7.8	0.0	15.0
S. cane Middle	26563	20.7	0.0	0.0	29.0	14.1	0.0	0.0	0.0	36.2
S. cane Tail	43132	8.4	0.0	26.8	39.7	12.1	0.0	1.9	0.0	11.0
Average										
Wheat	20713	15.8	0.3	7.9	11.4	35.2	0.8	6.5	9.5	12.5
Rice	35723	11.2	4.3	0.0	44.8	16.6	1.6	6.0	8.6	6.9
Sugarcane	32350	15.6	0.6	22.4	22.1	17.4	0.0	5.0	0.0	16.9

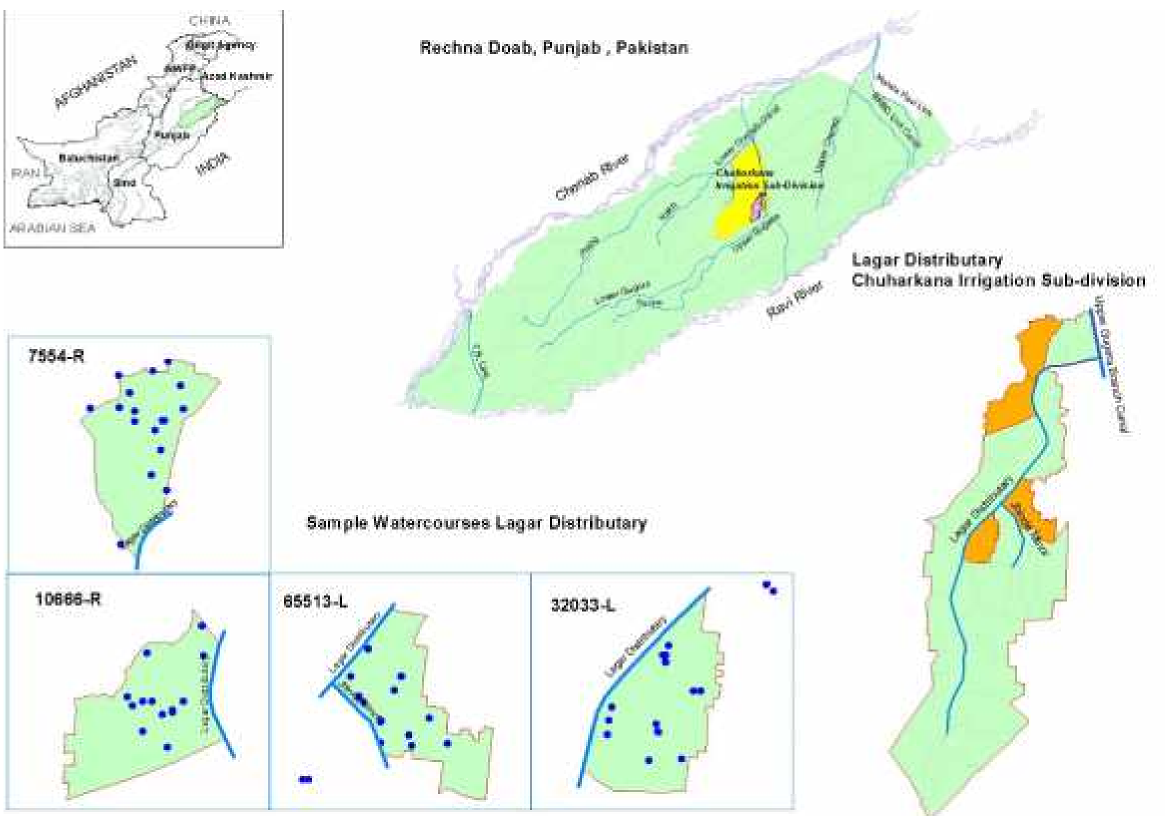

Fig. 1 Location Map of Study Area

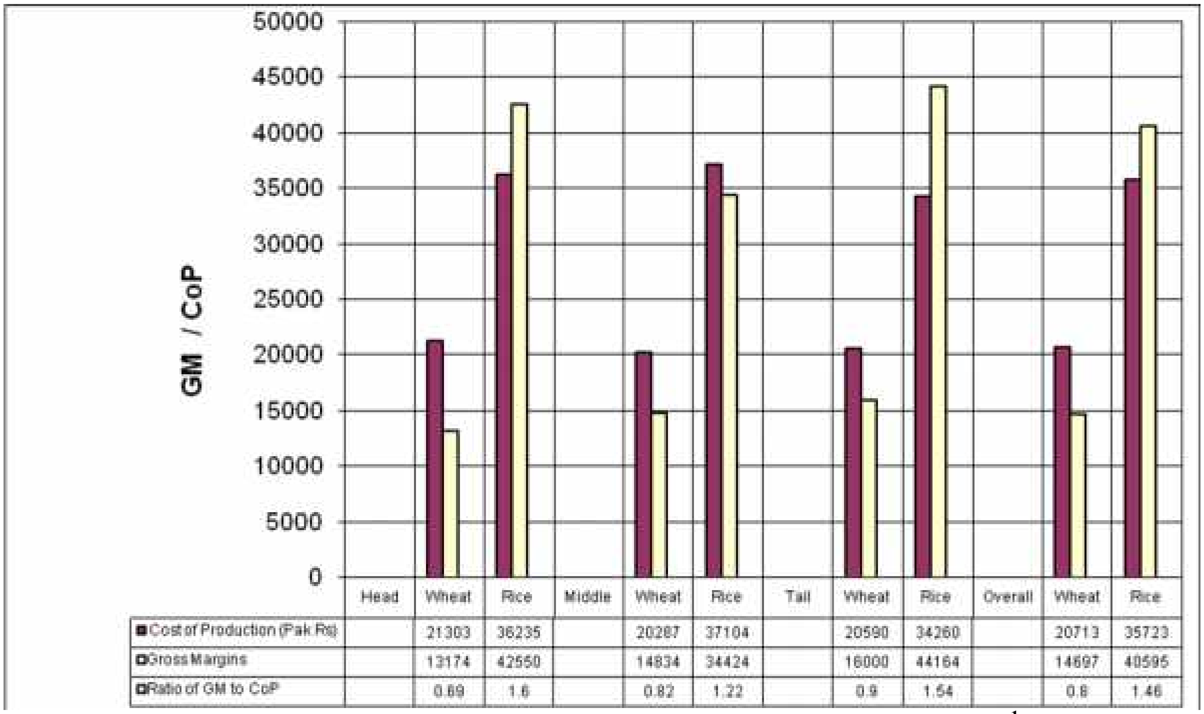

Fig. 2 Profitability of wheat and rice across canal reaches (Pakistan Rs ha^{-1}).

Conclusion: In the irrigated areas of Lagar distributary, on an overall basis, irrigated area by groundwater is highest followed by canal only. Irrigated areas under conjunctive water use decreased from 78 % at head to 46 % at tail while ground water use alone increased from 17 to 43 % across head to tail. Similarly irrigated area under canal water decreased from 1.7% at head to 0.95 % at middle and none of the farmers reported to irrigate from canal water only source. Average groundwater use was estimated higher at tail as compared to head. Wheat and rice yield per hectare were higher at tail as compared to head resulting in higher GVPs at tail. Among major crops, rice has the highest profitability followed by sugarcane and wheat. Average pumping cost was relatively less at tails as compared to middle & head mainly due to larger number of electric tubewells. Gross margin and cost benefit ratios were slightly higher at tail as compared to head and middle.

Recommendations: Although groundwater use/abstraction was higher at tail ends as compared to head but the share of irrigation cost in total CoP was less (resulting in higher GM) mainly due to shared electricity tubewells. This calls for installation of collective/shared electricity tubewells across locations particularly at tail ends that will not only reduce tubewell density but also the increasing pressure of pumping cost on the part of farmers.

1. In order to conserve the groundwater resource, there should be strong incentives to the farmers for establishing artificial groundwater recharge structures in the form of waiving electricity costs.
2. Water conservation techniques such as watercourse lining, laser land leveling and zero tillage need to be promoted by giving subsidy on prices to increase crop productivity. This will also help to conserve the groundwater.

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