Research Report No.R-106

Farmers' Management Responses to the Gap Between Supply and Demand of Canal Water

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September 2000

International Water Management Institute
Lahore, Pakistan

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ABSTRACT

In the Indus Basin of Pakistan, the irrigation water demand is generally greater than entitlement for the canal water. This gap between the demand and supply of irrigation water is mainly due to the increase in cropping intensities and change in cropping patterns. Farmers try and minimize this gap by undertaking various water management activities. This paper looks at how farmers respond and manage the gap between irrigation water demand and canal water entitlement at the farm level. Specifically, the study investigates actions farmers undertake at times when this gap is negative, zero or positive and the outcomes of those actions.

The study was undertaken in the command of Chistian Sub-Division of the Fordwah Irrigation System in southeastern Punjab, Pakistan. The two tail distributaries, Mahmood and Fordwah, were selected based on their different physical features and delivery environments. Six watercourses were selected in the commands of these two distributaries for detailed monitoring of the data and field measurements. The criteria used for the selection of distributaries were also used for the selection of watercourses. However, an additional parameter, i.e., the tubewell density per 100 ha, was also considered while selecting the watercourses for monitoring. The data was collected for two crop seasons, Kharif 1997 and Rabi 1997-98. Relative water supply was used as an indicator to demonstrate farmers' management responses to meet the gap between demand and supply.

INTRODUCTION

In Punjab, canal water as per farmer's entitlement (CWFE) is not defined in terms of volume but in terms of the time a farmer gets for irrigation. The design discharge is fixed for each watercourse command area. This Watercourse Command Design discharge (WCDD) does not guarantee reliable actual discharge. In reality water received may or may not be equal to WCDD. Very often actual canal water supply (ACWS) is not adequate to fulfil irrigation water demand (IWD) of the existing cropping pattern and cropping intensity. Farmers have to manage this gap between irrigation water demand and canal water supply as per entitlement (CWSE). Canal water supply as per entitlement in this paper is referred to as the actual canal water supply at watercourse head without farmers' interventions. Farmers undertake a number of actions to reduce this gap. They try and acquire additional water for irrigation by intervening with the system and/or by exploiting groundwater resources

At the tertiary level, very often the Irrigation Department provides *warabandi* (water distribution schedule) that need to be followed by the farmers. However farmers often deviate from *warabandi* by swapping water turn, or by borrowing or lending full or part of water turn. Although the law forbids the sale of canal water, farmers do sell and buy full or part of water turn, based on their requirements. In case of surplus water supply, farmers have to get rid of the irrigation water to save their crops by over-irrigation. Although farmers do not compartmentalize these actions into systematic activities, their ultimate goal in undertaking these activities is to get more control over irrigation water at the farm level to match evaporative demand of the crops.

This research investigates all the water management actions that farmers undertake to manage the gap between the supply and demand.

The study was conducted for two crop seasons, Kharif 1997 and Rabi 1997-98 in the command of Chistian Sub-division of the Fordwah Irrigation System in the southeastern Punjab, Pakistan. The main question addressed is how do farmers manage the gap between demand and supply of irrigation water? Specifically, what actions do farmers undertake at the times this gap is negative, zero or positive and what are the outcomes of those actions?

METHODOLOGY

This study was undertaken in the command of Chistian Sub-Division of the Fordwah Irrigation System in southeastern Punjab, Pakistan. The two tail distributaries, Mahmood distributary and Fordwah distributary, were selected based on their different physical features and delivery environments. Among others two main features are size and actual discharge of the distributary. Fordwah is a big distributary with low Delivery Performance Ratio (DPR). DPR is the ratio of actual discharge to the design discharge. Mahmood distributary is small but its DPR is high.

Six watercourses were selected in the commands of these two distributaries for detailed monitoring of the data and field measurements (Figure 1). The criteria used for the selection of distributaries were also used for the selection of watercourses. However, one additional parameter, i.e., the tubewell density per 100 ha, was also considered for the selection of watercourses. During the selection process, care was taken that these watercourses were spread along the distributary to take into account variation in water supply in the first and second half of the distributary. The selected watercourses along Mahmood distributary were MD 1-R, and MD 11-TC, whereas FD 38-L, FD 67-L, FD 84-L, and FD 96-R were selected along Fordwah distributary.

The study was conducted for two crop seasons, Kharif 1997 and Rabi 1997-98. A total of 281 farmers were visited during the study period. Information related to land holdings was collected on seasonal basis. The crops, cropping intensities, and cropping patterns were observed by field monitoring. Irrigation water data were collected on daily basis. Irrigation water data covered information on canal water supply, purchase of canal and/or groundwater, installation of tubewells for groundwater extraction, exchange of canal water turn, use of orchard's entitlement for crops, acquiring higher discharge at the *mogha* through remodeling, siphoning of canal water, and excess water management practices.

AGRICULTURAL CHARACTERISTICS OF THE STUDY SITE

Land Holdings

The irrigation system in the study area was part of the settlement schemes of the Bahawalpur State in early 20th century. People from different parts of Eastern Punjab and some from other parts of the state "*Riasati*" shifted to this area. The average land holdings in the command of selected watercourses along Mahmood distributary is 4.26 and 4.97 acres for MD 1-R, and MD 11-TC, respectively. Along Fordwah distributary, the average land holdings size of owners in acres is 31.75, 8.89, 3.01 and 3.38 for FD 38-L, FD 67-L, FD 84-L, and FD 96-R, respectively.

Some landowners increase their cultivated land by renting more land in the command of selected watercourses. The average land holding size of the cultivators in the command of selected watercourses is 4.90, 5.28, 47.5, 8.08, 5.30, and 5.60 acres for MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L and FD 96-R respectively. For this study, farms are divided in three categories, farms less than 5 acres (small farms), farms between 5 and 12.5 acres (medium farms) and farms greater than 12.5 acres (big farms). All the watercourses except FD 67-L and FD 38-l have higher percentage of farmers cultivating land less than five acres.

Cropping Patterns

The cropping patterns of the two selected distributaries as a whole are different. In the

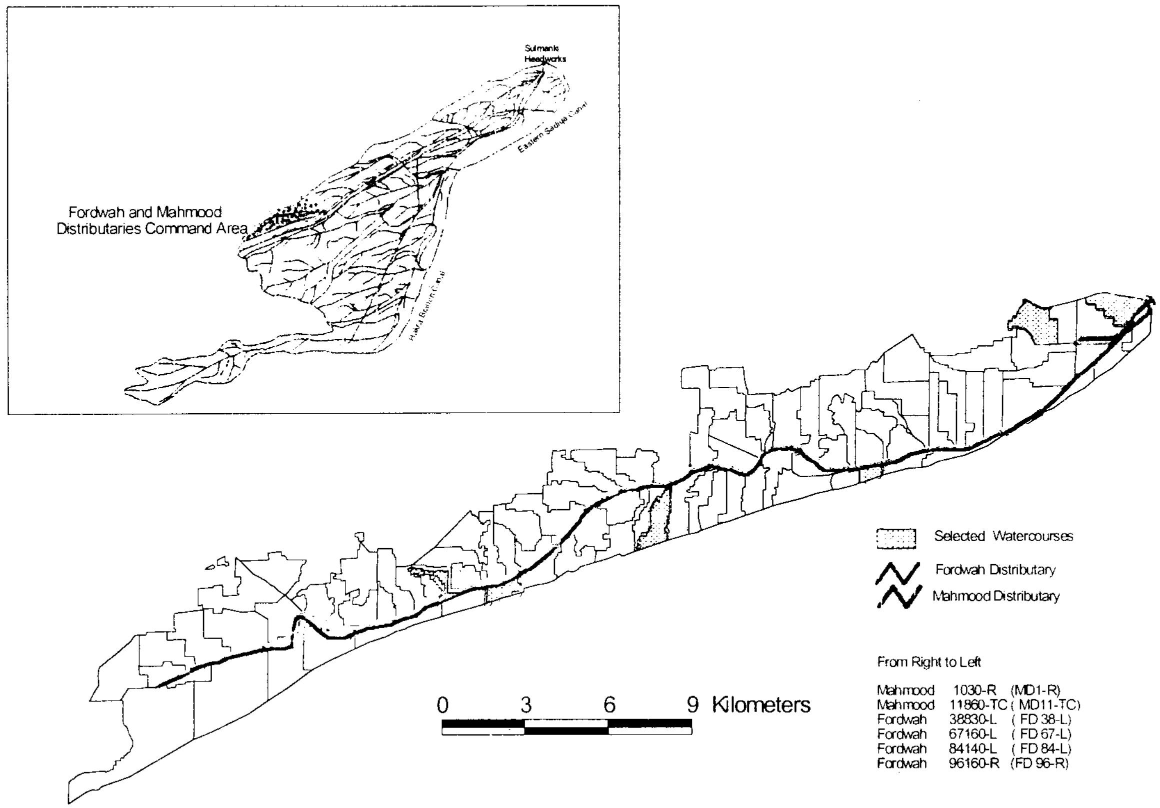


Figure 1. Location of the selected watercourses in Fordwah and Mahmood distributaries.

command of selected watercourses along the Mahmood distributary, wheat, sugarcane, and fodder are usually grown in rabi. Vegetables are also grown specifically along the head of Mahmood distributary. In kharif, rice, cotton, sugarcane, and fodder are the main crops grown. Along the Mahmood distributary, the percentage of area under sugarcane is higher than the percentage of area cultivated under wheat that is considered the main rabi crop of this climatic zone. Moreover in kharif, rice is the second biggest crop in MD 1-R, the head watercourse of Mahmood distributary. Selection of crops indicates that water is not a limiting factor in Mahmood distributary.

In the command of Fordwah distributary, wheat, sugarcane, fodder and vegetables are grown during rabi, whereas main crops in kharif are cotton, sugarcane, fodder and vegetables. In kharif, cotton is the main crop, whereas rice is mainly grown for domestic consumption along this distributary. In the command of watercourses along Fordwah distributary, percentage of area cultivated under sugarcane decreases towards the tail of the distributary. Wheat, on the other hand, is grown on more than fifty percent of total cultivated area in almost all the selected watercourses along Fordwah distributary.

Cropping Intensities

The system was designed for 80% annual cropping intensity with 32 % in rabi and 48 % in kharif. Design engineers envisaged lower cropping intensity in rabi as compared to kharif, which is not the case at present. Besides considerable increase in the annual cropping intensity farmers generally cultivate more area in rabi than in kharif mainly because of less water requirement in rabi[1].

Most of the farmers along the Fordwah distributary grow wheat that needs less water as compared to sugarcane that is the other dominant rabi crop in the area. The lowest annual cropping intensity is in FD 38-L (129 %), the smallest watercourse in terms of area and number of farmers, mainly because of barren area. In rest of the selected watercourses, the annual cropping intensities are almost double than the design cropping intensities. These are 166, 156, 153, 174, and 162% in MD 1-R, MD 11-TC, FD 67-L, FD 84-L and FD 96-R, respectively.

IRRIGATION WATER CHARACTERISTICS AT WATERCOURSE AND FARM LEVELS

Canal Water

Water allowance provides the basis for authorizing design discharge and therefore defines the size of the outlet (manual of irrigation practices, 1963). Generally, water allowance is expressed in cusecs per 1000 acres of Culturable Command Area (CCA). Water allowance for the selected distributaries' command areas and therefore of selected watercourses command areas is 3.6 cusecs per 1000 acres. However, actual water supply may be different than the water allowance and water allocation of the outlets.

At the farm level water is entitled to the land in terms of irrigation turn time. Therefore only landowners have water rights. When owners bring in tenants very often rights to use allocated water to the land is also given to the tenants. Farmers are usually satisfied with this water allocation of time-sharing.

Groundwater

Ground water use is very common in the study area specifically in the watercourses along the Fordwah distributary. Almost all the farmers are using groundwater for irrigation in the study area however the frequency and amount is higher in Fordwah distributary than in Mahmood distributary. It is considered a source of supplemental irrigation, mainly because

[1] Though in non-perennial distributaries, the cropping intensity in kharif is still higher than the cropping intensity in rabi since canal water supply is also available in kharif.

groundwater is expensive to use and is of marginal quality.

To assess depth to watertable three observation wells, at head, middle and tail, of all the selected watercourses were installed. Readings were taken twice a month. The depth to watertable increases towards the downstream of the Fordwah distributary, whereas along Mahmood distributary it decreases a little towards the tail. The average depth to watertable for the selected watercourses, in meters, is 1.70, 1.69, 2,06, 3.06, 4.30, 4.89 in MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L and FD 96-R, respectively. Therefore, there is very little chance of crops getting water directly from the watertable to supplement crop water requirements.

RESULTS AND DISCUSSIONS

Canal Water Supply

Practically, actual water supply is not the same as watercourse command design discharges. It may be less than, equal to, or greater than the WCDD. Although, this difference in the design discharge and the actual water supply is highly influenced by the water supply from upstream, it may also be a result of farmers' interventions.

Farmers sometimes get their outlet (locally called as "*mogha*") enlarged that has direct implication on the water supply of the watercourse. However in the records of Irrigation Department the dimensions of the *mogha* are not changed. In this report canal water supply is differentiated between i) actual canal water supply (ACWS); ii) canal water supply as per entitlement (CWSE) that is the actual canal water supply if mogha is not enlarged; and iii) canal water supply through mogha enlargement (CWSME) that is the additional canal water supply because of mogha enlargement. In case the mogha is not enlarged ACWS and CWSE are the same.

For the watercourses along the Mahmood distributary, actual average seasonal supplies for both Kharif 1997 and Rabi 1997-98 were much higher than their respective WCDDs because of higher water delivery to the distributary. Whereas, the actual average seasonal discharges of all the selected watercourses along Fordwah distributary were much less than their respective WCDDs in kharif 1997. In rabi 1997-98 actual discharges of FD 38-L and FD 96-R were higher and FD 67-L and FD 84-L were lower than their respective design discharges. Co-efficient of variations of discharges of all the watercourses improved in Rabi 1997-98 (Table 1). One of the reason of such high discharge fluctuation in Kharif 1997 was disturbed water supply from May to August 1997 because one of the link canal that carry water from Baloki headworks to Sulemanki headworks was damaged.

To evaluate the canal water supply situation at the selected watercourses, the Delivery Performance Ratio (DPR) for both Kharif 1997 and Rabi 1997-98 are presented in the Figure 2. Delivery Performance Ratio is the ratio between the actual water supply to the target. Since there is no target supply for *mogha* design discharge is used to calculate DPR. DPR is equal to 1 if actual supply matches the targeted supply. The daily delivery performance ratio was averaged to get seasonal values. An interesting observation is that the DPR of the watercourse MD 11-TC is same for both the seasons however it does not mean that there was less fluctuation in the daily actual discharges to this watercourse. Nevertheless, the CV of the daily actual discharges is least for this watercourse in Kharif 1997 as compared to other selected watercourses. The DPR of almost all the watercourses improved in Rabi 1997-98 except MD 1-R because of decreased water delivery to the Mahmood distributary.

Table 1. Actual and designed discharges to the selected watercourses in Kharif 1997 and Rabi 1997-98.

Watercourse	Design discharge (cusecs)	Actual average discharge (cusecs)		CV of daily actual discharge	
		Kharif 1997	Rabi 1997-98	Kharif 1997	Rabi 1997-98
MD 1-R	1.26	1.84	1.67	0.76	0.34
MD 11-TC	1.48	2.07	2.15	0.70	0.45
FD 38-L	0.38	0.31	0.51	0.92	0.50
FD 67-L	1.38	0.67	1.21	0.82	0.39
FD 84-L	0.95	0.51	0.78	0.79	0.32
FD 96-R*	0.64	0.45	0.71	0.83	0.28

* The average discharge given here is a result of water supply and acquired allocation as the mogha was enlarged but not recorded in the Outlet Register.

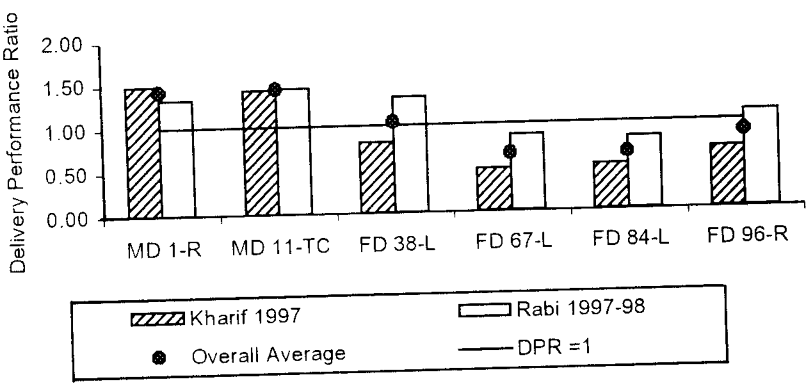


Figure 2. Delivery performance ratio of the six selected watercourses in Kharif 1997 and Rabi 1997-98.

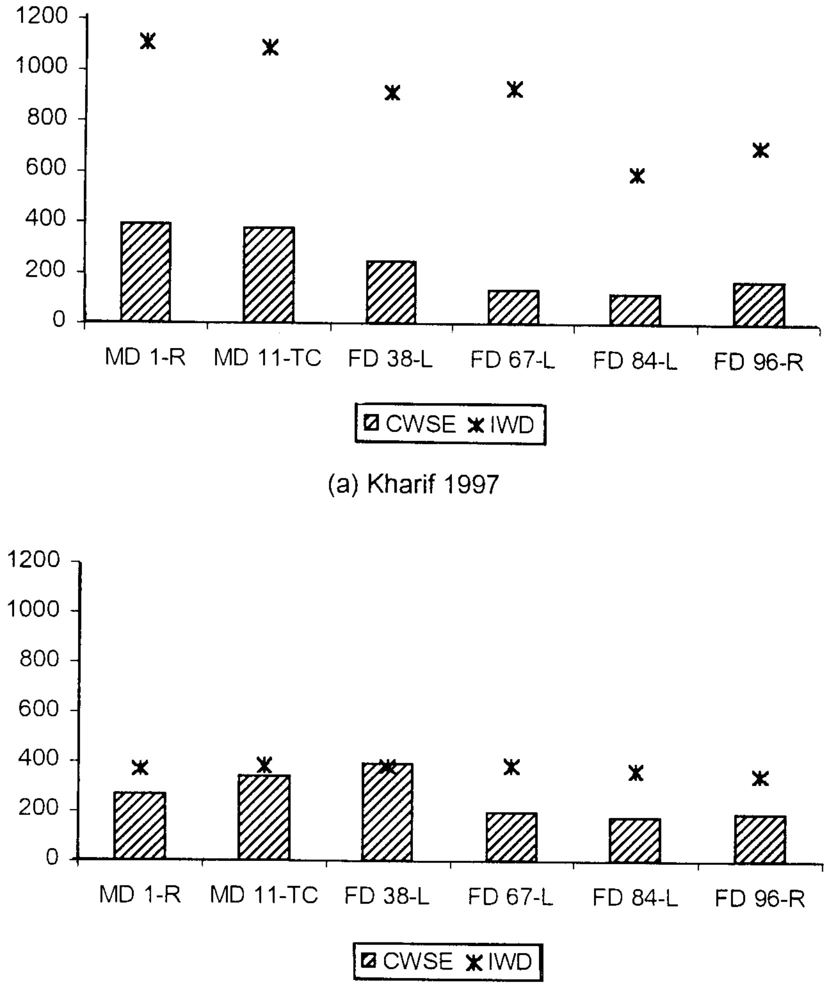
Gap Between Irrigation Water Demand and Canal Water Supply According to the Entitlement

Annual potential evapotranspiration of the area was 1787 mm for the year 1997, whereas rainfall in this period was 274 mm[2]. Figure 3a&b present Irrigation water demand and canal water supply as per entitlement of the selected watercourses of the study area. IWD for the watercourses and selected farms was calculated by using CROPWAT (Smith, 1992) software. The rainfall was deducted from crop water requirement to get IWD. The demand is the result of increased cropping intensity and cultivation of more water demanding crops. Ground water extraction plays an important role in this increased cropping intensity. However, this study takes canal water supply as per entitlement (CWSE) as the starting point to show the gap between the supply and demand and considers tubewell water use as farmers' response to the canal water scarcity. In calculating canal water supply at the farm gate, the conveyance losses for every watercourse were considered. The application efficiency at the field was taken equal to 75%. In Kharif 1997, there is a big gap between the CWSE and IWD in all the watercourses.

[2] Data used to calculate evapotranspiration was obtained from Meteorological stations located in Bahawalpur (about 90 kilometers West from the field area) and Bahawalnagar (about 40kms East of study area). Rain was measured with rain gauge in all six selected watercourses and then average of each month is taken and summed up for a year.

Highest deficit is in the watercourse FD 67-L (796 mm) and then in the two watercourses of Mahmood distributary (705 mm in MD 1-R and 710 mm in MD 11-TC), while FD 84-L has least deficit (476 mm). In Rabi 1997-98, CWSE is quite close to the IWD in most of the selected watercourses. In the watercourse FD 38-L supply is even higher than the demand because of low cropping intensity (62 %). FD 67-L has biggest gap in the irrigation water requirement and actual canal water supply of 191 mm followed by FD 84-L with a gap of 186 mm.

Relative water supply is another index to compare water supply with the demand. The relative water supply (RWS) is ratio of supply to demand (Levine 1982). Though RWS is calculated using all the water used for irrigation regardless of its source. To find the contribution of each water management activity in fulfilling the demand RWS has been calculated with CWSE and each activity separately. RWS for all the watercourses with only CWSE is presented in the Table 2. This RWS is extremely low in kharif and is not enough to produce crops. Now, the question arises how do farmers manage this gap in the supply and demand of irrigation water at farm level? In the following section management strategies of farmers to manage this gap are described.



(a) Kharif 1997

(b) Rabi 1997-98

Figure 3. Demand Supply situation at the six selected watercourses in Kharif 1997 and Rabi 1997-98.

Table 2. Relative water supply calculated from canal water supply as per entitlement.

Watercourse	Kharif 1997	Rabi 1997-98	Year (1997-98)
MD 1-R	0.31	0.64	0.39
MD 11-TC	0.31	0.78	0.43
FD 38-L	0.23	0.91	0.43
FD 67-L	0.13	0.44	0.22
FD 84-L	0.17	0.43	0.27
FD 96-R	0.21	0.48	0.30

Farmers' Management of the Gap

In the previous sections the gap between canal water supply as per entitlement and irrigation water demand in the selected watercourses is shown. A farmer takes a number of actions, either individually or collectively to get more control over irrigation water at the farm level in order to match evaporative demand of the crops. This section discusses these strategies of farmers from different landholding classes (big, medium and small). Following are the water management strategies of farmers in the selected watercourses:

- Ground water use
- Remodeling of the *mogha*
- Purchase of canal water
- Exchange of canal water turn
- Siphoning of canal water
- Use of Orchard allocation for crops
- Excess water management

Groundwater use

In the study area, tubewell installation was started in 1960 though clear trend of groundwater exploitation was set in 1980s. Now, groundwater exploitation has become very common in the study area as a result of increased cropping intensities. In fact a farmer considers ground water availability at the start of the season when he plans which crops to be grown under how much area. Therefore presence of tubewells also influence the cropping intensities. Figure 4 presents the relationship between the tubewell density in a watercourse command area and its annual cropping intensity. Cropping intensity is increased with the increase in the tubewell density (number of tubewells per 100 hectares). This situation may not be true for the distributaries with high canal water supply.

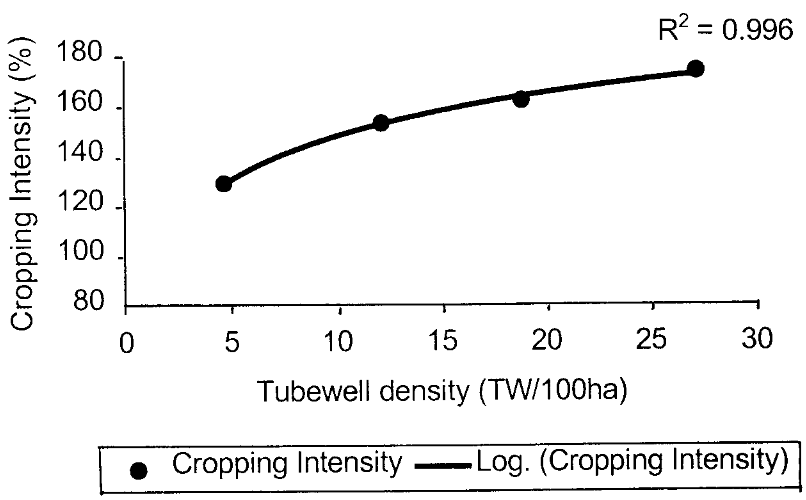


Figure 4. Tubewell density in a watercourse command area versus its cropping intensity in Fordwah Distributary.

Out of total irrigation water used, 34 percent in Kharif 1997 and 13 percent in Rabi 1997-98 came from groundwater. Overall 70 % of total water users in the watercourses studied were using groundwater in addition to the canal water. Because of comparatively better canal water supply, lower percentage of farmers (58 %) along Mahmood distributary are using ground water as compared to 86% farmers along Fordwah distributary. Farmers not using ground water were mostly small farmers with land holding less than 4 acres (1.76 ha).

In the selected watercourses, water from 38% tubewells was found to be "unfit for irrigation"[3] but the owners were still using it. Farmers use their own indicator to assess the quality of the groundwater (see Kielen, 1996). They prefer to irrigate crops with canal water, first, it is of better quality as compared to groundwater and second, pumped water is far more expensive than canal water. Nevertheless, when they decide to use groundwater they prefer to mix it with canal water, mainly because it improves the stream size, allows for more area to be planted, and leads to improvement in the quality of groundwater.

Figure 5a&b show the RWS of the big, medium and small farmers with canal water use alone and with conjunctive water use (canal water + groundwater). Relative water supply in Kharif 1997 of all the farmers increased significantly with the use of groundwater however in Rabi 1997-98 the contribution of ground water in RWS was highest for the farmers with medium land holding size. These medium farmers also belonged to the watercourses with smaller DPR values.

During Kharif 1997, canal water supply was disturbed for four months. In the watercourses along Mahmood distributary more farmers started using groundwater. The number of farmers using groundwater increased from 23 to 58 %. Some farmers even installed their own tubewells that increased tubewell density from 4 to 6 tubewells per 100 ha.

Irrigation water demand of non-users of groundwater during Kharif 1997 was also quite high. Reason for this is that in Kharif 1997 canal water supply was very less as compared to actual canal water supply in earlier seasons. Figure 6 presents IWD and water used by the selected farmers at MD 1-R. The gap between the ACWS and IWD of all the selected farmers was huge however for 1-R09 this gap was partly filled by the use of ground water. Whereas for the 1-R 40 and 1-R 50 farmers who do not use tubewell water, this gap remained huge and their yields suffered. Sugarcane and rice yields of farmer, 1-R 09, were approximately fifty and forty-five percent higher than the sugarcane and rice yields of non-users of groundwater (i.e., 1-R 40 and 1-R 50).

Remodeling of the mogha

More reliable way to acquire additional canal water is to get the *mogha* dimensions enlarged. Remodeling of the *mogha* provides higher water supply. Additional water supply resulted from mogha enlargement is referred to as canal water supply through *mogha* enlargement (CWSME) in this study. In the selected watercourses one of the *mogha* (FD 96-R) had enlarged dimensions at the start of the research, while dimensions of rest of the *moghas* were approximately same as designed. The watercourses along the Mahmood distributary and FD 38-L were not enlarged , because of good canal water supply. Watercourse 67-L was downsized and repaired just before the research started whereas Watercourse FD 84-L was not enlarged because of lack of consensus among the shareholders over collecting funds. Nevertheless towards the end of the data collection dimensions of FD 67-L and MD 1-R were also changed[4]. Only FD 96-R is considered for analysis here to get clear picture, as other *moghas* were enlarged only at the end of the research period.

[3] Pumped water samples were analyzed from the Soil Fertility Punjab, Bahawalpur office. The criteria used to estimate the quality is the one used by WAPDA that could be found in WAPDA publication of 1975: Appraisal of Initial Chemical Quality of Groundwater in Kot Adu Unit of SCARP III, 1972-74. SCARP Monitoring Organization (SMO) Publication Number 78.

[4] Farmers of this watercourse broke the mogha in reaction to reduction in the distributary discharge. This distributary was receiving more than double of its design discharge. When this discharge was reduced to its design discharge farmers of MD 1-R broke the mogha, Irrigation department fixed the mogha with small increase in its width that resulted in a very small increase of discharge of this mogha.

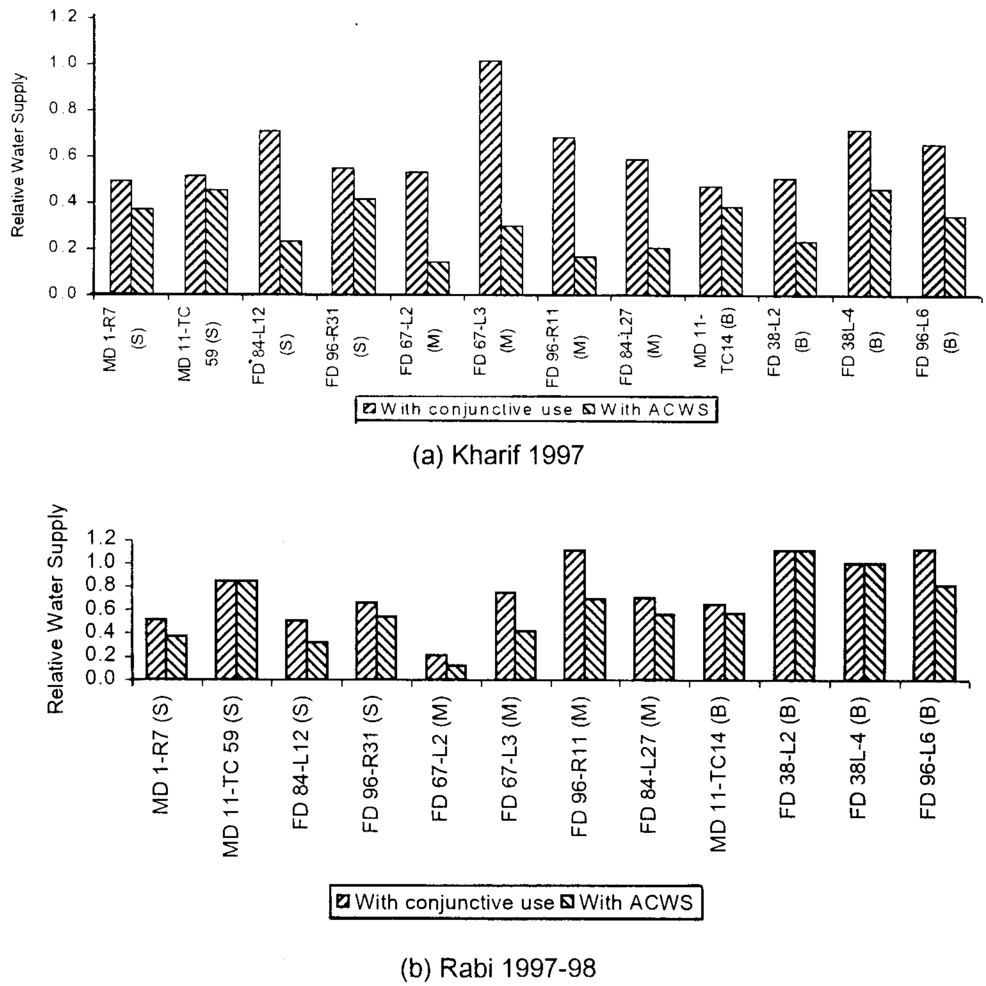


Figure 5. Relative Water Supply of selected farmers with and without groundwater use in Kharif 1997 and Rabi 1997-98.

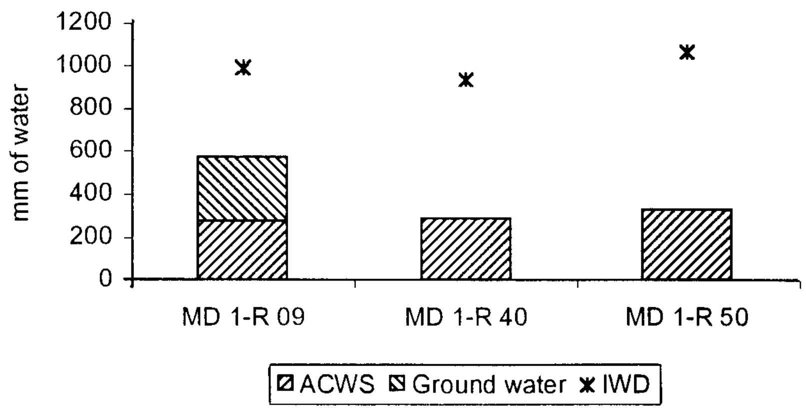


Figure 6. Irrigation water requirement and conjunctive water use by selected farmers in Kharif 1997.

The *mogha* of FD 96-R was enlarged about one year before the start of the research period (November 1996 to April 1998). Width of the outlet, b, was increased by 10% and the height of the outlet, Y was increased by 10.5 % with an overall increase in area of 21.5 %. This intervention resulted in increase of average daily water supply to the watercourse by 16% (Figure 7).

For this change in *mogha* dimensions farmers had to pay Rs 16000 (US $ 400) in total. A rough estimate reveals that farmers would have to spend Rs. 48000 (US $1200) to pump same amount of additional water for one year (from December 1997 to December 1998). This estimate was made using a tubewell with discharge of 19.5 l/s and the price to pump water for one hour as Rs 40 (about US $ 1). Therefore, farmers together saved about Rs 32000 (US $ 800). The additional water available from canal for irrigation has significant contribution in relative water supply. The RWS calculated by using only CWFE is 0.21and 0.48 for kharif 1997 and rabi 1997-98 respectively. With this additional water available RWS is 0.27 and 0.54 in kharif 1997 and rabi 1997-98 respectively.

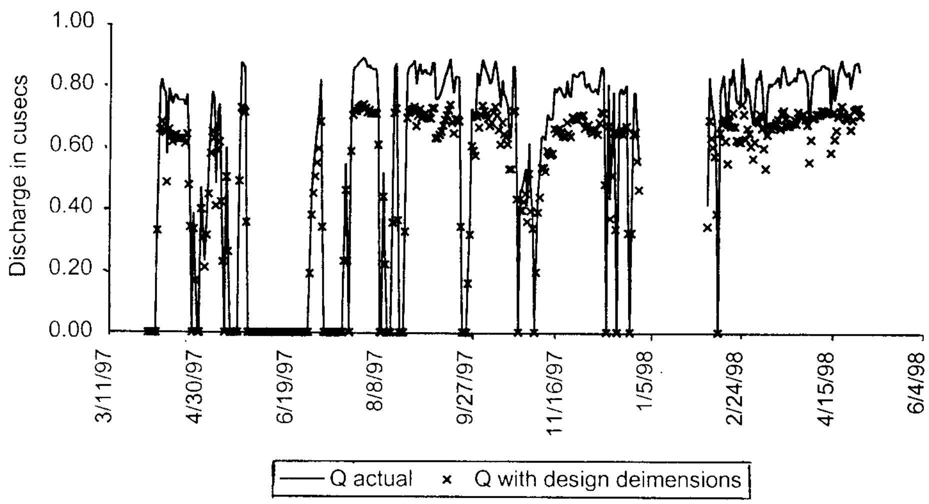


Figure 7. Discharge of FD 96-R watercourse with actual and design dimensions during April 1997-April 1998.

Purchase of canal water

Purchase of canal water is one kind of water acquisition. According to the Canal and Drainage Act (1873), water trading, which is defined as any kind of exchange of water turns or selling and buying of water turns, is forbidden. Though selling or buying of canal water turn exists, it is not very common in the selected watercourses. Only 2.5 % of total farmers in the selected watercourses are buying canal water turns. Canal water turn is not sold out unless it is really not required. Farmers who buy canal water turn are mostly big farmers and very often have more than one water turn in a watercourse command area.

Sometimes when farmers acquire cheap water they also over irrigate their crops. It happens when farmers do not get water during one water turn they try to irrigate the crop for longer time then is required just to make sure that they do not under-irrigate. Besides, a farmer also applies more water to the fields where salts need to be washed away with leaching.

Figure 8 presents IWD and water used by the farmer 11-TC 14 during one year (April 1997-April 1998) who bought canal water turn of other farmers in the watercourse. Week (wk) 1 to week 26 cover kharif season while rabi season falls

between week 27 to week 52. He is under irrigating in Kharif while over irrigating in some weeks in Rabi. However, total amount of water needed during the whole year is much higher than the amount used (1366 mm required and 705 mm used). Bought water turn has reduced a bit of stress. The gap is bigger in kharif, (i.e., 539 mm), than in rabi (i.e., 122 mm). The ratio of his water use is 73 % supplied (including his borrowed and given water), 10 % bought and 17 % groundwater. He would have had to pump water for 60 hours to get equal amount of water that he bought. This would have cost 3000 Rs more than what he spent in a year. RWS for the two seasons, kharif 1997 and rabi 1997-98 is 0.61 and 0.67 respectively. If he had not bought canal water turn RWS would have been 0.42 and 0.47 for kharif 1997 and rabi 1997-98 respectively.

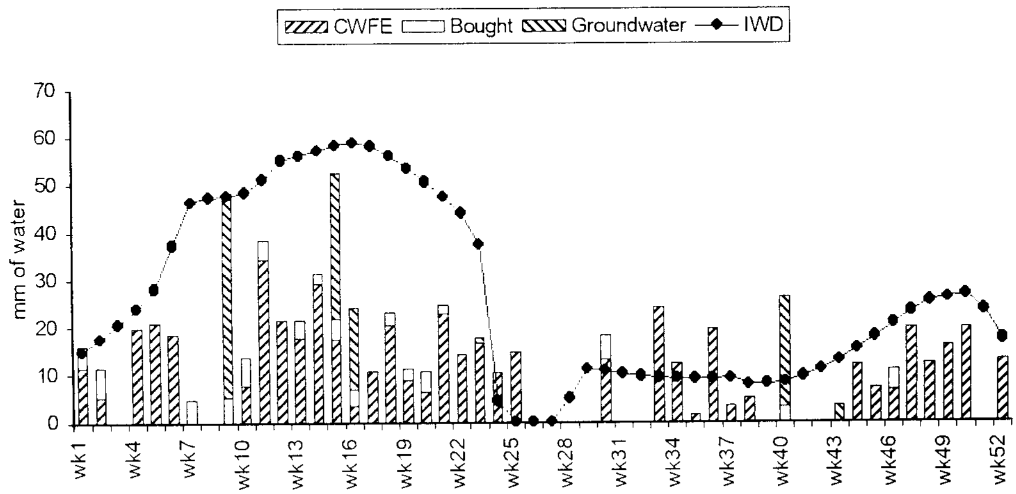


Figure 8. Demand and water use from different sources of MD 1-TC 14 farmer.

Exchange of water turns

Farmers who have more than one water turn in one watercourse command also exchange water turn for one parcel of land with the water turn for another parcel of land. Two kinds of arrangements exist for canal water turn exchange; one is on adhoc basis while the other one is planned.

In adhoc arrangement, if a farmer realizes during or before his water turn that it is difficult to irrigate the desired number of *bunded*[5] units, he borrows part of or full water turn from another farmer. This borrowed water is given back in terms of time used and not in terms of quantity. Nevertheless it is made sure that the difference in quantities is not very big[6].

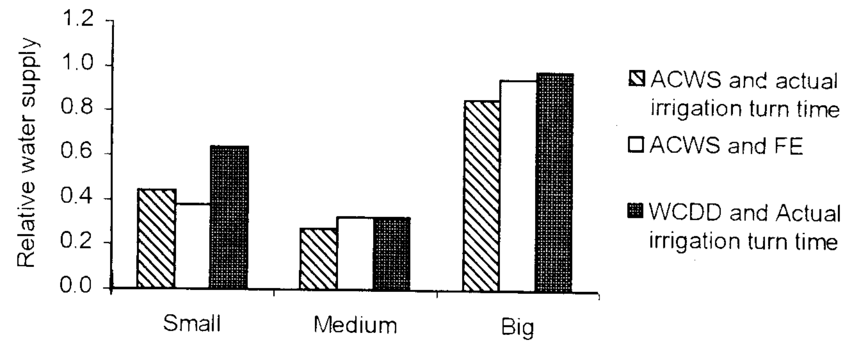
In the planned arrangements, the decisions are made at the start of a crop season. A farmer having very small water turns (very often less than half hour) that is not enough to irrigate one *bunded* unit during one water turn gives his water turn to another relatively bigger farmer for two to three weeks and gets a longer turn every third or fourth week depending on the deal. This deal is mostly made among the neighboring farmers. Though this arrangement is considered beneficial to both the farmers the quantity of water is not always compensated for. It is possible that the smaller farmer misses his longer water turn because of no supply and vice versa. That may be one of the reasons that this arrangement is not very common in the selected watercourses (12 % of cultivators had water turn less than half-hour though).

[5] One *bunded* unit is usually equal to 0.25 acres.

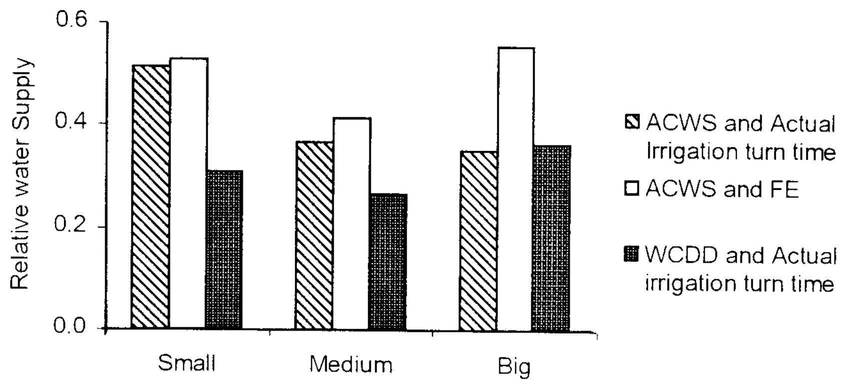
[6] Farmers though do not measure quantity, they have their own criteria to judge the quantity of water, for example if the watercourse is flowing at it's full capacity or is half full (Hoeberichts, 1995).

The effect of canal water exchange on the gap at the farm level is difficult to show. An effort is made here to present the difference in the RWS of selected farmers if they do not take part in canal water turn exchanges. Two watercourses are selected for this analysis: one is FD 67-L that has *mogha* with almost design dimensions, low canal water supply and no physical intervention by the farmer and the other one is MD 11-TC with very high canal water supply. Relative water supply is calculated in three scenarios, i) ACWS at the farm gate and actual irrigation turn time; ii) ACWS at farm gate and Farmer's Entitlement (FE), if he would not have exchanged his water turn; and iii) WCDD and actual irrigation turn time of a farmer.

Figure 9a&b presents relative water supply in different scenarios of a small, medium, and big farmer in FD 67-L and MD 11-TC watercourses. It is clear that the RWS is not effected significantly for most of the farmers even if they do not exchange water turns at CWSE. However the timing of irrigation is also important for crop production therefore farmers practice canal water turn exchange. For watercourse FD 67-L situation would improve if they get WCDD every time canal water reaches at their *mogha.* WCDD with actual timing would be the last option for the farmers along MD 11-TC watercourse since they are getting much higher discharge than their WCDD. This also implies that water turn exchange will decrease in FD 67-L whereas increase in MD 11-TC in case ACWS is equal to their respective WCDDs.



(a) FD 67-L



(b) MD 11-TC

Figure 9. Relative water supply of a small, medium and big farmer during Kharif 1997.

Siphoning of canal water

Some farmers prefer good quality canal water through siphoning over marginal quality expensive pumped water. The longer breaks in the canal water supply also lead to such illicit water acquisition practices by the farmers. Although this method to acquire canal water is not common in the study area, only 8 % of the total population of selected watercourses were found involved in this activity. However, the timing at which it happens is important, as the downstream farmers also need this water. It was not possible for the researcher to measure the amount of water that was acquired through siphoning. However the number of times a farmer took this action was recorded.

Figure 10 presents weekly demand and water use situation of the farmer 38-L 02. He did not receive any water from week 7 to week 14. Later in the season (wk 15 to wk 24) he acquired additional canal water through siphoning. Whenever he received canal water turn and hardly operated his tubewell. This supplementary water helped him to achieve 34% higher yield for sugarcane than the average yield in Pakistan.

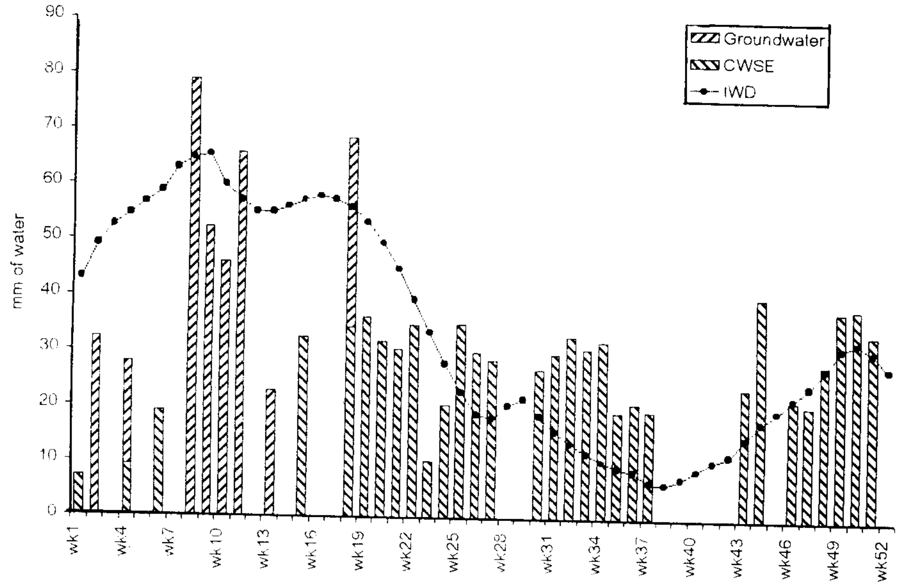


Figure 10. Demand and water use situation of the FD 38-L 2 farmer during Kharif 1997 and Rabi 1997-98.

Use of orchard allocation for crops

If a farmer plants orchards he gets additional allocation for that plot[7]. However, they first have to plant the trees and get it inspected by the Irrigation Department officials in order to get water allocated for the orchards. But in many cases the orchards disappear after a few years but water allocation remains. Hence, some farmers get extra water for their crops.

Three farmers, FD 96-R18, FD 96-R19 and FD 67-L26 in the two selected watercourses along Fordwah Distributary have water allocation for orchards though they are cultivating crops in those fields. They are all owner cultivators and only one has direct access to groundwater. The other two buy groundwater if needed which is not very often because of the longer canal water turn. If these water users did not have this extra time they would have to buy groundwater every time they needed water.

A rough estimate tells us that FD 67-L26 would have spend RS 4000 (US$ 87) and FD 96-R18 and FD 96-R19 would have spend RS 3000

[7] This allocation is double than the normal allocation for a piece of land.

(US$ 65) to get same volume of groundwater. Whereas now each one of them has to give approximately RS 330 (US$ 7) per year as "*abiana*" (water fee) for Orchards.

Excess water management

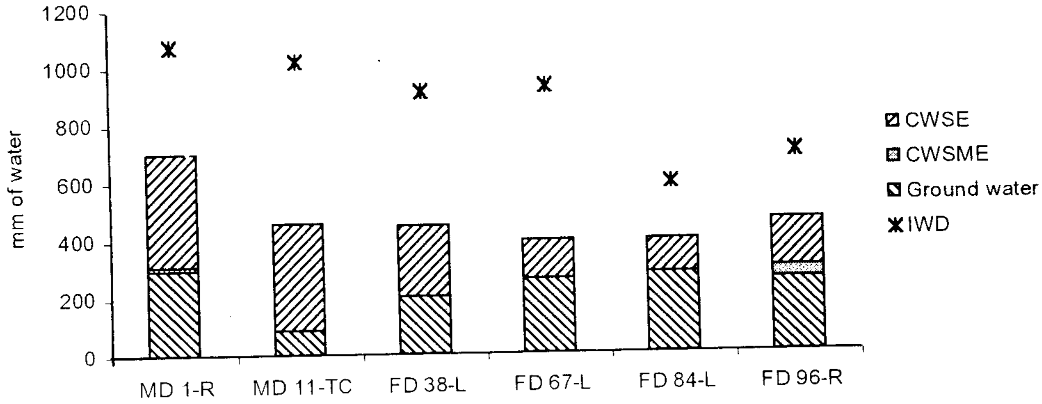
In the absence of drainage infrastructure sometimes farmers have to close their *mogha* to make sure that excess canal water does not destroy their crops. Closing of the *mogha* is illegal and may cause breach in the distributary. This happens mostly during the monsoon rains or during the harvesting periods when farmers do not need to irrigate their crops.

Farmers at the extreme tail of the distributary can not close the *mogha* since water can not go further downstream. In case of MD 11-TC, the tail watercourse of Mahmood distributary, farmers have access to a natural low-lying area locally called "*budh*". If a farmer decides not to irrigate his field and he knows that other farmer(s) may need to irrigate he just leaves the water to flow in the watercourse that leads to the *budh*.

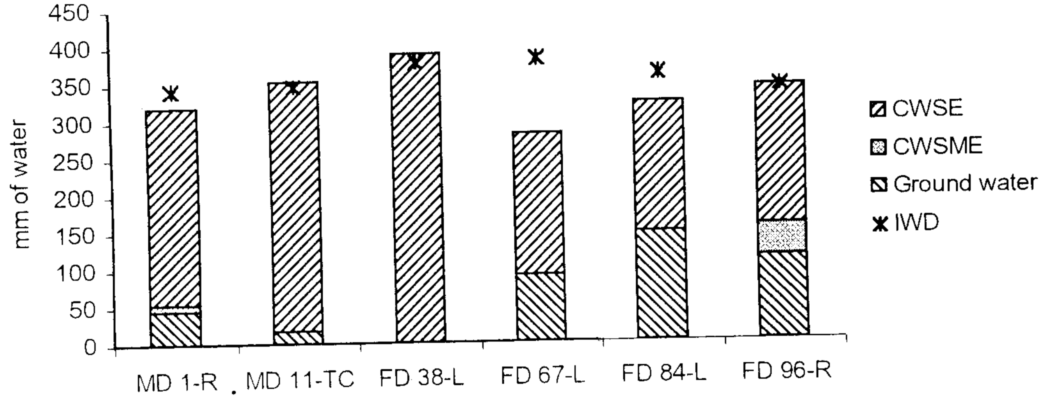
Effect of Farmers' Management Practices on the Gap

Groundwater and transaction of canal water turns are the most widely practiced among the farmers' strategies to manage the gap between canal water supply and irrigation water demand at the farm level. Canal water exchanges, mostly practiced on adhoc basis help in meeting the demand on time. It has less influence on the seasonal RWS therefore it is difficult to show effect of canal water turn exchange at the watercourse level. Activities contributing most in meeting IWD are ground water use and enlargement of *mogha*. The role of CWSME and groundwater use in reducing the gap between irrigation water demand and CWSE at watercourse level is presented in Figure 11a&b.

Total RWS and contribution of water from different sources in total RWS is presented in Table 3. Groundwater has significantly fulfilled this gap for FD 84-L and FD 96-R in both the seasons. Ground water use in three selected watercourses, FD 67-L, FD 84-L and FD 96-R, is even higher than total canal water available in kharif 1997. These are the watercourses with less DPR (Figure 2). Contribution of water acquired through mogha enlargement is negligible for MD 1-R however it is significant for FD 96-R. The combined effect of all the water management activities on the gap between CWSE and IWD at the farm level is shown in Figure 12 for small, medium and big farmers for Kharif 1997 and Rabi 1997-98. The RWS of almost all the farmers increased in Rabi 1997-98 except FD 67-L2, FD 67-L3 and FD 84-L12. The RWS of FD 67-L2 is extremely low (0.2) in rabi that is reflected in low wheat yield (0.8 ton/ha). Generally, all the farmers are practicing stress irrigation in kharif. However RWS of small farmers is less than the medium or big farmers even in rabi mainly because they use less ground water and their cropping intensities are higher than the cropping intensities of medium or big farmers. Big farmers have least cropping intensities therefore less stress irrigation. A strong relation is found in RWS and productivity per unit of land. Figure 13 shows a strong linear relationship between the RWS and Rs/ha of these farmers. No distinction was made among the small, medium or big farmer in this analysis. However two farmers who were growing rice and another farmer who was stealing water are not included.



(a) Kharif 1997



(b) Rabi 1997-98

Figure 11. Total water use versus irrigation water requirement in Kharif 1997 and Rabi 1997-98.

Table 3. Relative water supply and contribution of irrigation water from different sources in RWS of selected watercourses in kharif 1997 and rabi 1997-98.

Watercourse	Kharif 1997				Rabi 1997-98			
	RWS	Contribution of irrigation water from different sources in RWS (%)			RWS	Contribution of irrigation water from different sources in RWS (%)		
		CWSE	CWSME	Ground water		CWSE	CWSME	Ground water
MD 1-R	0.65	56	2	42	0.93	83	3	14
MD 11-TC	0.45	82	0	18	1.02	95	0	5
FD 38-L	0.49	54	0	46	1.03	100	0	0
FD 67-L	0.42	34	0	66	0.73	68	0	32
FD 84-L	0.66	29	0	71	0.89	54	0	46
FD 96-R	0.66	36	8	56	1.00	54	13	33

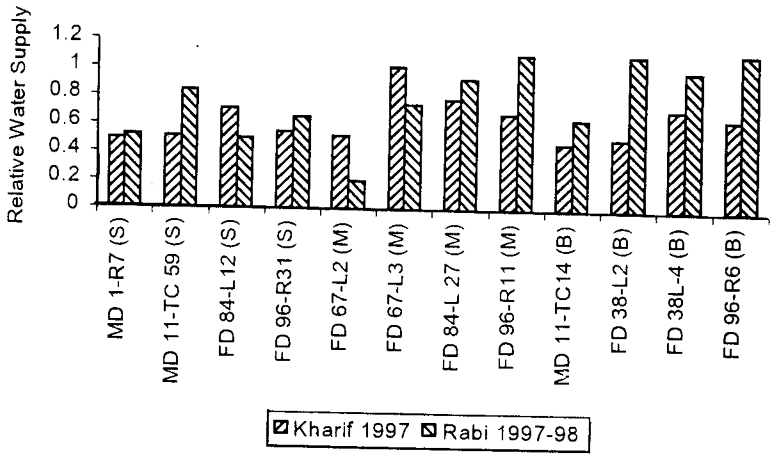


Figure 12. The Relative water supply of the selected farmers in Kharif 1997 and Rabi 1997-98.

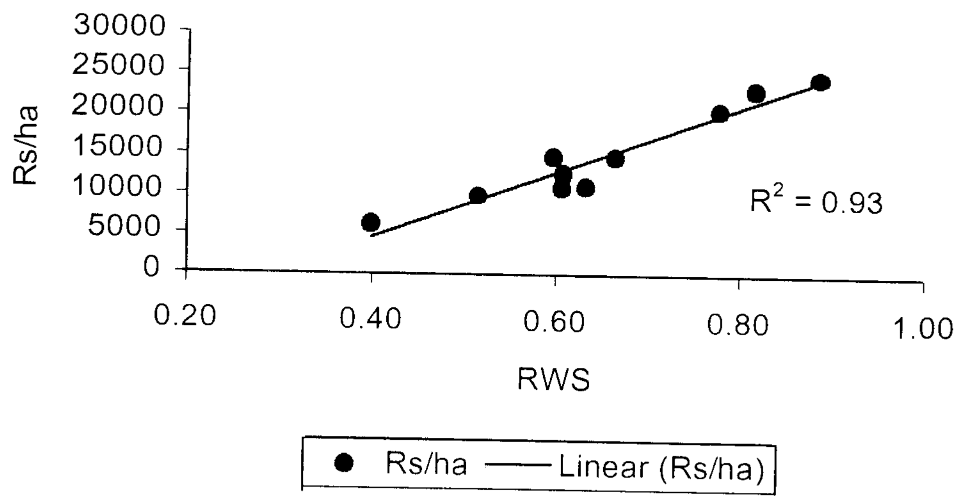


Figure 13. Relationship between the Relative water supply and productivity of land for selected farmers.

SUMMARY AND CONCLUSIONS

Generally, irrigation water demand is greater than farmers' entitlement for canal water at farm level. Specifically, during kharif season the fluctuating canal water supplies are not enough to fulfill evaporative demand of crops. Farmers' responses to this gap between supply and demand of canal water were studied in six watercourses along the two tail distributaries of the Chistian sub-divion. Water management strategies of all 281 farmers in these selected watercourses were monitored. These farmers are categorized in three land holding sizes: small, medium, and big. Relative Water Supply (RWS) was used to show the significance of farmers' responses to minimize the gap between demand and supply.

It was observed that a farmer takes a number of individual and collective actions to acquire better control over irrigation water at farm level in order to meet evaporative demand of crops. Some farmers manage to get additional canal water supply through remodeling of the *mogha* and siphoning of canal water. Exchange of

canal water turn is very commonly practiced in the selected watercourses to cope with the uncertainty of canal water supply. Ground water pumpage was 66 % of the total canal water supply during kharif.

The main conclusions of the study are:

- All the actions farmers undertake to acquire additional canal water are illicit. However, only a very small percentage of farmers indulge in individual illicit practices other than exchange of canal water turns.
- Exchange of canal water turns is illegal according to the Canal and Drainage Act (1873) but it is widely practiced as it helps farmers in dealing with the day to day uncertainty of canal water supply. Therefore, it is recommended that this activity be legalized.
- The most common practice that farmers undertake to reduce the gap between supply and demand of irrigation water is groundwater use. In the study area ground water fulfil 59 % of the gap between canal water supply and irrigation water requirement in kharif.
- Of all the actions that farmers undertake to manage the gap between the irrigation water demand and canal water supply, ground water has highest contribution to RWS.

ACKNOWLEDGEMENTS

Authors would like to thank Mr. Asif Yaqoob, Mr. Muhammad Fayaz and Mr. Munawar Shah for the data collection in the field. Asima Bashir, Asghar Hussain and Mehmooda Tabassum appreciated for technical support in data entry and presentation. Thanks are extended to Ms Sofiya Saeed for editing.

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