# SUSTAINABLE IRRIGATION WATER MANAGEMENT: A CASE STUDY ON SECONDARY CANAL OF SINDH PROVINCE OF PAKISTAN

Bakhshal Lashari[1]
Mohammad Ayaz Memon[2]

## ABSTRACT

Sustainable irrigation water management requires a strong relationship among water users. The established Watercourse Associations (WCAs) at the tertiary level canal and Farmer Organization (FO) at the secondary level canal need to develop strong institute. The potential conflicts in water distribution equity among the water users and improvement in reliability of water delivery can be mitigated through appropriate technical and socio economic interventions such as water measuring mechanisms, proper maintenance, and investment on irrigation infrastructure improvements.

The Farmer Organization (FO) in the Daulatpur Minor was established in 2000, but the process of social mobilization for forming a Farmer Organization was started in 1999. The present study was carried out for the period from October 2006 to April 2007 (one crop season) for the purpose to assess water delivery to farmers, water use efficiency and farmer's role for sustainable irrigation water management.

The results on system performance demonstrate that the Daulatpur Minor received irrigation water for only 69 days out of 168 days allocated for winter crop season, thus the Minor remained closed for 99 days at various time and interval. However, the amount of water delivered to farmers was in excess as deliveries were estimated to be 8307 ac-ft (6.97 mm/day) including losses of the watercourse compared to the required 5056 ac-ft (4.24 mm/day) for the crop and water delivery to farmers along the distributary length was varying up to 95 percent. Consequently, water productivity achieved only Rupees (Rs) 1.10 /$m^3$ which, is equivalent to US$ 0.018 /$m^3$.

In order to manage irrigation water in a sustainable fashion, the Farmer Organizations played a role in maintaining the channels jointly. In all, they contributed labor and equipment while removing over 43,000 cubic meter of sediment. The imputed cost of these contributions was almost Rs. 12 per acre (US$ 0.2 per acre), which is much less when compared to government expenditures on operation and maintenance of channels. Due to removing the sediment, the head-tail water delivery ratio improved from 1.68 to 1.14 (Lashari B and Murry-Rust H.D (2002).

Further, the paper suggests that a water committee may be established at a district management level where various stakeholders are involved to further strengthen the newly established organizations for a better and more sustainable management of irrigation water.

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[1] Professor, Institute of Irrigation and Drainage Engineering, Mehran University of Engg and Tech Jamshoro, Sindh, Pakistan.
[2] Assistant Executive Engineer, Irrigation and Power Department, Government of Sindh Pakistan

## INTRODUCTION

Pakistan has a long history of irrigation. The country also has considerable experience in planning and implementing large irrigation development projects. The successful completion of these projects has made irrigated agriculture the country's engine of economic growth. Pakistan is arid to semi-arid country, located between the longitudes 61° east to 76° east and between latitude 23° north to 37° north. Total area of Pakistan is 196.7 million acres (79.61 million hectares). Population of the country is about 160 million and nearly 67.5 percent of it lives in the rural areas. Agriculture is the main stay of Pakistan's economy, contributing 35 percent to the gross domestic product and providing 60 percent of the labor force. Total annual cropped area is about 48.73 million acres (19.72 million hectares). Major crops grown are wheat, rice, cotton, maize and sugarcane which together make about 63 percent of the total cropped area.

The water delivery of the irrigation system of Pakistan has deteriorated due to neglected maintenance, inefficient operation, lack of coordination among water users, effective policies and their implementation and non functioning of many tertiary (watercourse) level irrigation system. Water distribution and deliveries to most of the farmers are erratic and unreliable. Typically, farmers have failed to make proper investment at the farm level such as laser leveling and farm layout that help a lot to improve the irrigation efficiency. Farmers at the tail ends of distribution system usually suffer from water shortage during critical growing periods that reduce yields and greatly increase the risks of spending for fertilizers and other input. In Sindh province of Pakistan, change in cropping pattern, influence of big farmers, political interference and rent seeking are the major problems of irrigation water mismanagement. In order to increase reliability, equity and efficiency, the accountability and discipline of system management needs to be developed.

The goals of sustainable irrigation water management should be to produce enough food for future generations within at least the limits of existing water resources to deliver water in equitable and reliable way to the users. To follow the rules and procedures defining rights and responsibilities, and penalties for breach of rules and when irrigation water is insufficient to meet crop demand limited irrigation management strategies should be considered to achieve the highest possible economic return [Perry C.J. (2001), Schneekloth J.P, etal (2001), Wahaj R Linden and Prathapar S. A (2000), Kupper M and Zaigham H (1998), Keith O and Raymond P (1999)].

In Pakistan, there are differences in water deliveries to different sub systems. Head-end areas receive significantly more water than their share, while tail-end areas receive comparatively less. The actual water distribution pattern failed to meet the targets agreed upon at the start of each season [(Kijne J.W, Murray-Rust D.H and Snellen W.B (2002), Vander Valde E.J (1991) and Bhutta N and Vander (1992)].

In order to improve the management of irrigation system a water budget for a tertiary (Watercourse) level is essential which provides much more reliable estimates of the time distribution of water supply required at the main subsystem outlet throughout the irrigation season. When this task is completed for many of the tertiary level in an irrigation project, then a more equitable water distribution will occur and crop yield can be expected to increase. The low rate for water charges (Rs 50/acre to Rs 125/acre) can be one of the main cause for irrigation mismanagement which results in the denial of water to the tail-end communities of the system (Skogerboe and Merkley (1996).

## STUDY AREA

The Study was carried out in the command area of Daulatpur Minor which is off taking at RD 115 (23 mile) of West Branch System of Jamrao Canal (Fig 1). The salient features of the Minor are given in Table 1.

Table 1. Salient Features of the Daulatpur Minor

| Description | Details |
|---|---|
| Name of Minor | Daulatpur |
| Off taking from West Branch at RD | 115.0 |
| Design Discharge (cusecs) | 49.0 |
| Length of Minor (RD) | 31.9 |
| Number of Watercourses | 28 |
| Number of Lined Watercourses | 14 |
| Gross Commanded Area (Acres ) | 11603 |
| Cultural Commanded Area ( acres ) | 10765 |

RD is reduced distance which is equal to 1000 feet.

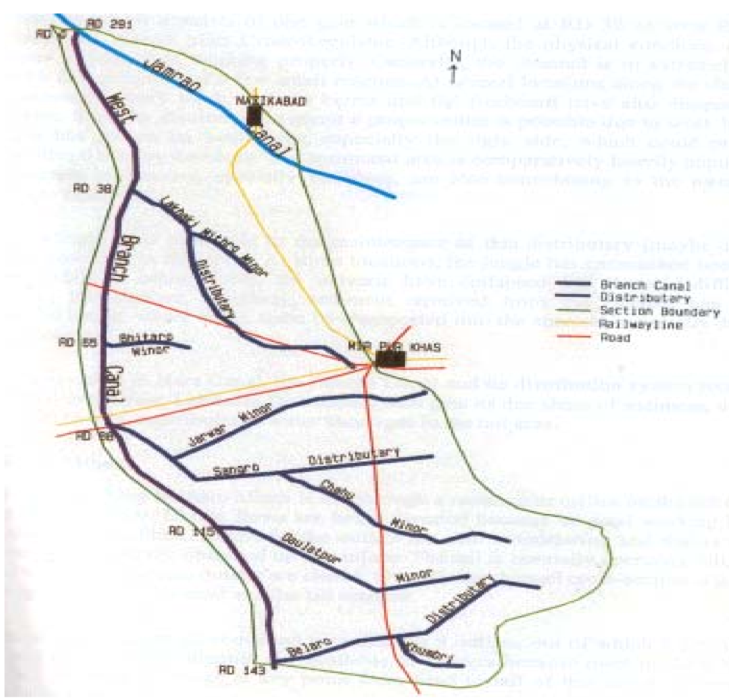


Figure 1. Location Map of the Minor off taking from West Branch Jamrao Canal.

## DATA COLLECTION

To obtain a reliable data for flow of water in the Minor, all control structures (head regulator and all outlets) of the Minor were calibrated and rating tables were developed for all control structures. Daily water levels at head regulator and at outlets were recorded. Using the rating tables, the water levels were converted in discharges. The collected data was for the period from October 2006-March 2007 (winter crop season 2006-07).

To collect crop data the crop survey for three sample watercourses each from head, middle and tail sections were carried out. For crop survey watercourse command area maps were obtained from Irrigation and Power Department, Government of Sindh, Pakistan which describes the boundary, blocks and survey numbers. Each block consists of 16 acres of land.

To determine crop water requirement, the manual 1995 developed by Irrigation and Power Department (IPD) Government of Sindh was used which describes the crop water requirement of each crop based on climatic conditions and soil class.

To learn farmer’s perception regarding their role in managing irrigation system, reforms in irrigation sector, economic benefits from the system and water related problems faced by the farmers, a semi-structured questionnaire was developed and used for data collection. The respondents were selected representing the whole system (Minor command area)

## RESULTS AND DISCUSSION

Figure 2 shows that the delivery performance ratio (DPR- defined as ratio of actual discharge to design discharge) at the Minor head was above 1.0. which indicates that the Minor has been getting water from 110 percent to 140 percent of design discharge in one hand and another hand it has been closed 99 days out of 168 days allocated for winter crop season. During “on period“ of 69 days the minor has received about 24.08 percent more flow than designed discharge whereas for the whole base period of 168 days (excluding annual closure during January) the average discharge is 30.46 $ft^3$/sec (or cusecs) which is 37.8 percent short against the design discharge. However, the amount of water delivered to farmers was estimated 8307 ac-ft (6.97 mm/day) against required 5056 ac-ft (4.24 mm/day) for the crop cultivated.

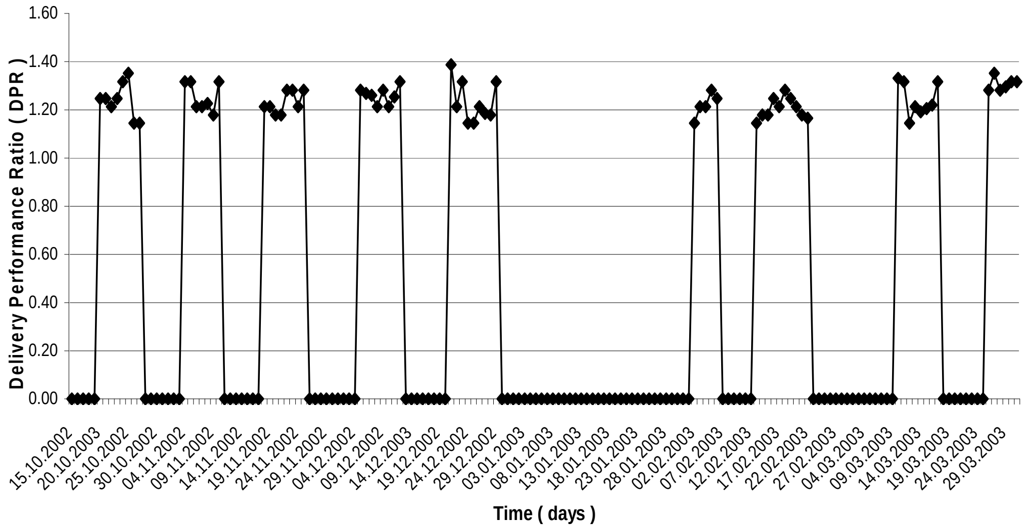


Figure 2. Water Delivery Performance Ratio at the Minor.

Results shown in Table 2 show that there is almost temporal consistency of water delivery on all three sample watercourses during whole crop season, however, the spatial variation is visible. It is unusual that middle reach watercourse is getting more water than head reach watercourse. Normally head reach gets more water, but some times when influential farmers are at middle reach then middle reach get more water.

Table 2. Water Delivery Performance Ratio for Sample Watercourses

| Observation Month | Sample watercourses | | |
|---|---|---|---|
| | 385/1AL | 377/2R | 384/3L |
| October | 1.37 | 2.22 | 1.47 |
| November | 1.57 | 2.19 | 1.46 |
| December | 1.56 | 2.02 | 1.35 |
| January | 0 | (Canal closure period) | |
| February | 1.58 | 1.95 | 1.30 |
| March | 1.47 | 1.96 | 1.30 |
| Average | 1.51 | 2.07 | 1.38 |

Results shown in Table 3 show that watercourse No. 385/1AL (head reach) was getting 51% more than designed discharge but the cropping intensity is 56% against the designed cropping intensity of 53%; similarly, middle reach watercourse No. 377/2R was getting 100 percent more water but the cropping intensity is very low i.e., 29 percent against 53 percent and at tail reach watercourse No. 384/3L was getting 38 percent more water than designed flow and cropping intensity is again very low. This all is due to cultivation of high delta crops like garden and sugarcane, unreliable supply of water and mismanagement of water.

Table 3. Cropping pattern and intensities of a sample water course on the Minor

| WC NO. | Avg. DPR | CCA | Cropping Pattern ( % ) | | | | | | Cropping Intensity |
|---|---|---|---|---|---|---|---|---|---|
| | | ( Acres) | Wheat | Garden | Fodder | Sugar-cane | Banana | Onion | % |
| 385/1AL | 1.51 | 130 | 27 | 41 | 14 | 12 | 3 | 3 | 56 |
| 377/2R | 2.07 | 358 | 14 | 26 | 4 | 52 | 2 | 1 | 29 |
| 384/3L | 1.38 | 455 | 31 | 39 | 6 | 17 | 6 | 1 | 25 |

Table 4. Volume Indices for Sample Watercourses

| Water course number | Design Discharge (Cusecs) | Average Actual Discharge (Cusecs) | Average Discharge ( 168 Days ) (Cusecs) | Volume ( Acre- feet ) |
|---|---|---|---|---|
| 385/ 1AL | 1.22 | 1.86 | 0.76 | 254.5 |
| 377/ 2R | 0.95 | 2.02 | 0.83 | 276.39 |
| 384/3L | 1.43 | 1.95 | 0.8 | 266.81 |

Table 5. Efficiency and Sufficiency of Sample Watercourses and Minor

| Water course Number | Measured Volume ( Acre- Feet ) | Water Requirement ( Acre- Feet ) | Efficiency (%) | Sufficiency (%) |
|---|---|---|---|---|
| 385/1AL | 254.50 | 183.48 | 51.01 | 139.18 |
| 377/ 2R | 276.39 | 260.03 | 66.80 | 106.29 |
| 384/3L | 266.81 | 271.85 | 72.34 | 98.15 |
| Minor | 8307 | 5056.30 | 43.21 | 164.29 |

Tables 4 and 5 describe that average water deliveries (discharges) in three sample watercourses of head, middle and tail reaches are much higher than the designed discharge. Especially middle reach watercourse was getting more than 100 percent. While comparing the efficiency and sufficiency: the head reach watercourse has efficiency 51% against sufficiency of 139%, middle reach watercourse has efficiency 67% against sufficiency of 106% and tail reach watercourse has efficiency 72% against sufficiency of 98 and overall command area of the minor has efficiency 43.2% against 164.3% sufficiency.

Table 6. Water Productivity in the Minor Command Area during winter crop season 2006-07.

| Crop | Cropped area | Total income of each crop | Gross Total income | Water delivered | | Water productivity | |
|---|---|---|---|---|---|---|---|
| | (Acres) | (Rs) | (Rs) | (acre-ft) | $m^3$ | $Rs/m^3$ | $US\$/m^3$ |
| Wheat | 725 | 1436950 | 11281296 | 8307 | 10250875 | 1.10 | 0.018 |
| Garden | 729 | 3280500 | | | | | |
| Banana | 56 | 3334688 | | | | | |
| Fodder | 170 | 968320 | | | | | |
| Sugarcane | 384 | 1958016 | | | | | |
| Oilseed | 26 | 302822 | | | | | |
| onion | 37 | 110704 | | | | | |

Results shown in Table 6 indicate that the water productivity resulted in a rate of return of Rs. 1.1/$m^3$ (US\$ 0.018/$m^3$). This income is much less then compared to study conducted by Bastiaanssen (2002) for Pakistan which was Rs. 36/$m^3$. This is true because water availability in the Minor command area was only 69 days out of 168 days of the crop season. Thus the crop water requirement was not available at different crop growth stages which resulted in loss of crop yield.

The survey conducted in command area of the Minor which focuses on the role of various stakeholders of irrigated agriculture where most of the inputs and other relevant factors were investigated. The outcome of survey is depicted in the Table 7, which describes that major role for sustainable irrigated agriculture lies on Government of Sindh (GoS), Government of Pakistan (GoP), farmers and politicians then donors and then other organizations such as non-government organizations (NGOs), Sindh Irrigation and Drainage Authority (SIDA), FOs and insurance companies. Based on survey information a farmer advisory committee (Figure 3) was proposed to improve the system performance and also to improve crop yield by ensuring the inputs other than water.

Table 7. Stakeholder's Role in Sustainable Management of Irrigated- Agriculture

| Indicators | Roles of Different Stakeholders | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Irrigation Water | SIDA | FO's | GoS | GoP | Farmers | Donor | Insurance | Politician | NGO's |
| fertilizer | √ | √ | √ | √ | √ | √ | x | √ | √ |
| Seed | X | X | √ | √ | √ | √ | X | √ | √ |
| Pesticides | x | x | √ | √ | √ | x | x | √ | √ |
| Agriculture Machinery | x | x | √ | √ | √ | x | x | √ | √ |
| Risk management | x | x | √ | √ | √ | √ | X | √ | x |
| Loans & Credit | x | x | √ | √ | √ | √ | √ | √ | x |
| Market | √ | √ | √ | √ | √ | x | x | √ | √ |
| Taxes | √ | √ | √ | √ | √ | √ | x | √ | x |
| Training | √ | √ | √ | √ | √ | √ | x | √ | x |
| Awareness | √ | √ | √ | √ | √ | √ | x | √ | √ |
| Coordination | √ | √ | √ | √ | √ | √ | √ | √ | √ |

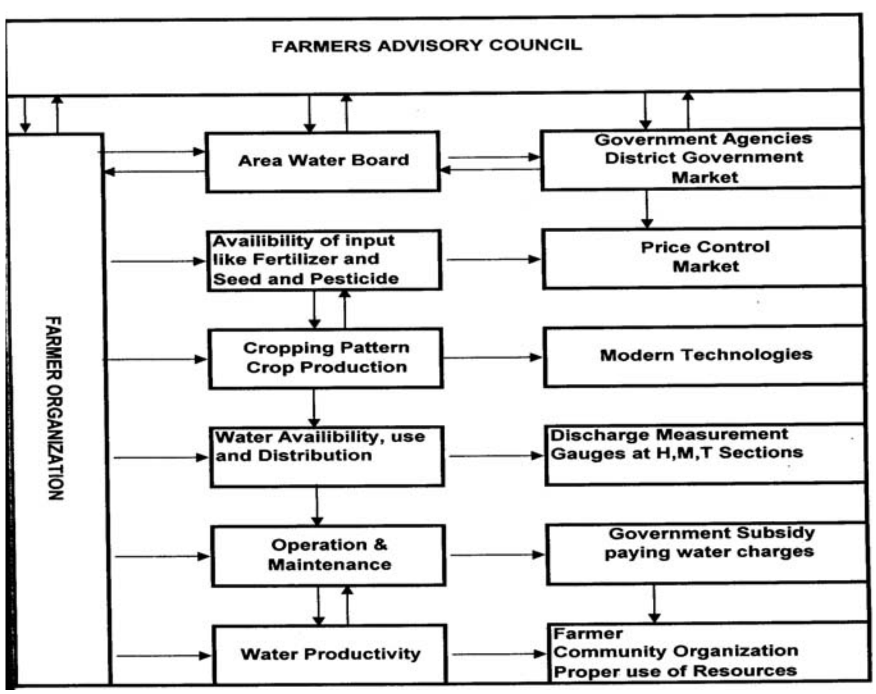


Figure 3. Composition of Farmers' Advisory Committee.

## CONCLUSIONS AND SUGGESTIONS

The water delivery to the command area of the Minor has been only 69 days out of 168 days of total cropping period. However, water delivery during the irrigation period of the Minor has always been more than the designed discharge and was between 115% and 140% of designed discharge. But this flow did not bring good yield of the crop because of continuous interruption in the flow of water which was not meeting the crop water requirement at different crop growth stages.

The water use efficiency for the command area of the Minor was found to be 43.2 percent while the sufficiency may have been as high as 164 percent. In fact, this inefficiency was occurred due to cultivation of high delta crops, rotational closure of the Minor (Unreliable supply) and mismanagement of water.

The unreliable supply and untimely availability of irrigation water to the farmers have seriously affected on crop yield and consequently, the crop production in the command area of the Minor has come to Rs. 1.10/$m^3$ (US$ 0.018/$m^3$). While the previous studies conducted by Bastiaanssen etal (2002) for Pakistan which was estimated Rs. 36/$m^3$.

The joint efforts of farmer organizations (FOs) contributed in terms of labor and equipment while removing over 43,000 cubic meter of sediment. The imputed cost of these contributions was almost Rs.12 per acre (US$ 0.2 per acre), which is much less when compared to government expenditures on operation and maintenance of channels. Due to FOs' physical intervention in many channels (Distributaries/Minors) the head-tail water delivery ratio improved from 1.68 to 1.14 (Lashari B and Murry-Rust D.H 2002). Therefore, the joint efforts of FO, GoS, GoP and politicians along with other support from the other stakeholders can improve crop productivity and yield significantly.

It is therefore, suggested that the farmer's advisory committee should be established at every district level where stakeholders of irrigated agriculture are members of the committee (Fig 3) which will help to ensure the reliable supply of all irrigated agriculture inputs to improve the productivity of crops. This committee also plays a main role in the sustainable water management and strength of the FOs.

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