IRRIGATION EFFICIENCY AND WATER USERS' PERFORMANCE IN WATER MANAGEMENT: A CASE STUDY ON THE HERAN DISTRIBUTARY SANGHAR, SINDH, PAKISTAN

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ABSTRACT

This study focuses on water use efficiency and water user's role in maintenance of the system for sustainable irrigated agriculture. The parameters assessed were water delivery to water users, water distribution, water use efficiency and farmers' role. The relevant data were collected in the field and through a literature survey.

Analyses of data indicate that DPR during the season varied from 1.0 to 1.60. The middle reach received slightly more than the head reach, and in the tail reach it varied from 0.6 to 1.80. Furthermore, water distribution among watercourses was also variable. The 7L- head watercourse received 30 to 82 percent more water than its design discharge (Q_d). The downstream watercourses (16R and 18AT) also received up to 183 percent more discharge than Q_d. However, the mid-reach watercourses (9AR and 13R) received the design share or less, though the flow of water was greater. In spite of unfair distribution there were no complaints from the water users about unequal distribution because there was enough water for everyone.

Furthermore, result indicated that total water supply was 6.62 mm/day and the crop water requirement was between 2.54 and 3.56 mm/day in the Rabi (winter) crop season. Thus, the total loss of water was estimated as 46 percent. This was also verified by estimating seepage losses in watercourses and the distributary, which were 4.5 percent and 26 percent, respectively.

However, the role of the Water Users Associations (WUA) in the maintenance of the distributary was significant. They collectively desilted the channel at a cost of about US$ 0.25 (Pak Rs. 21) per acre of land, which improved the head-tail water delivery performance ratio from 3.53 to 2.55 (Lashari and Murray-Rust 2002). But the maturity index has indicated that only 12.5 percent of the WUAs were at a sustainable level (Lashari et al. 2009).

INTRODUCTION

The Sindh is the second most populous province in Pakistan. With a growth rate of 2.8%, the total population is estimated at 41.2 million in the 23 districts of the Sindh. The population density in the Sindh is about 243 persons per sq km.

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About 68% of the rural population depends on agriculture, which employs over 46 percent of the labor force and accounts for more than 60 percent of foreign exchange earnings. Pakistan's economic development is, therefore, directly linked to the progress of the agriculture sector. The Sindh's contribution to Pakistan's agriculture GDP is 23% with its contributions of major products as: wheat 21%, cotton 23%, livestock 28%, sugarcane 31%, rice 42%, and marine fish 70%.

There are two growing seasons: the summer (Kharif) season, from May to September, and the winter (Rabi) season from October to March. Annual cropping intensities vary significantly across canal command areas. The average annual cropping intensity in the province is about 67%.

The average water use in the Sindh from 1991 to 2009 was estimated at 40.5 MAF, which includes more than 95% for agricultural purposes and the remaining 4-5 percent for domestic and industrial use. Groundwater abstraction for agriculture has been estimated about 5 MAF/year. The extraction of groundwater is being made by deep and shallow tube wells, and there are more than 50,000 tube wells.

The cultivable command area (CCA) is about 12.6 million acres. About 3.33 million acres are classified as fallow, which could be brought under cultivation if irrigation water were available. The actual irrigated area varies from year to year depending on the availability of canal water, with an average of 9.35 million acres. The irrigation system below the barrages comprises 14 feeders and main canals and 1,462 branch canals, distributaries, and minors.

The inequitable distribution of water, an unreliable supply of irrigation water, inefficient cropping patterns, lack of coordination among irrigated agriculture stakeholders, and lack of investment for the re-modeling of the irrigation system are major obstacles in conserving and efficiently managing water resources in the Sindh (Azad 2003). In the Sindh, the average irrigation efficiency is about 30 to 35 percent and water logging and salinity is a serious problem. Consequently, the yield of major crops is reduced by about 40-50 percent (IUCN 2007).

To improve irrigation water management, to produce enough food for future generations within at least the limits of existing water resources, and to deliver water in an equitable and reliable way to the users, the irrigation management strategies which define rights and responsibilities, and penalties, for violations of the rules, and when irrigation water is insufficient to meet limited crop demand, should be considered to achieve the highest possible economic return (Perry 2001; Schneekloth et al. 2001; Wahaj et al. 2000).

The actual water distribution pattern in the Sindh have failed to meet the targets agreed upon at the start of each season. There are different water deliveries to different sub-systems in Pakistan. Head-end (upstream) areas receive significantly more water than their share, while tail-end (downstream) areas receive comparatively less (Kijne et al. 2002; Vander Valde 1991).

In order to solve the irrigation and drainage problems, the Government of Pakistan adopted a new program to establish a self-sustaining irrigation and drainage system. This involves: (a) transforming Provincial Irrigation Departments into Provincial Irrigation and Drainage Authorities (PIDAs); (b) creating Area Water Boards (AWBs); and, (c) organizing farmers into Farmer Organizations (FOs). Under such reforms, all provinces established irrigation and drainage authorities through Acts passed by the assemblies in their respective provinces. This was called the PIDA act of 1997. This was, in fact, the first major move to introduce participatory irrigation management throughout the country.

Since the establishment of the Sindh Irrigation and Drainage Authority (SIDA), three AWBs have been formed: Ghotki Feeder Canal Area Water Board, Nara Canal Area Water Board, and Left Bank Canals (Fuleli and Akram Wah Canals) Area Water Board (Fig. 1). Additionally, 369 Farmer Organizations (FOs) which are at the third tier on the SIDA system, have been formed and formal IDMT Agreements have been made with 315 FOs. This research study focuses on irrigation water management and the water user's role in maintenance of the system

MATERIAL AND METHODS

Study Area

The study was conducted at Heran Distributary which is an off-take from the Nara main canal at the Sukkur Barrage. Under the institutional reforms program water users association (WUA) was formed on the Heran distributary command area in 1998. The irrigation management transfer (IMT) of the distributary to WUA was made on 2002, and since then WUA is responsible for water distribution, water fee collection, and maintenance of the distributary. The location map and salient features of the distributary are given Fig. 1 and Table 1.

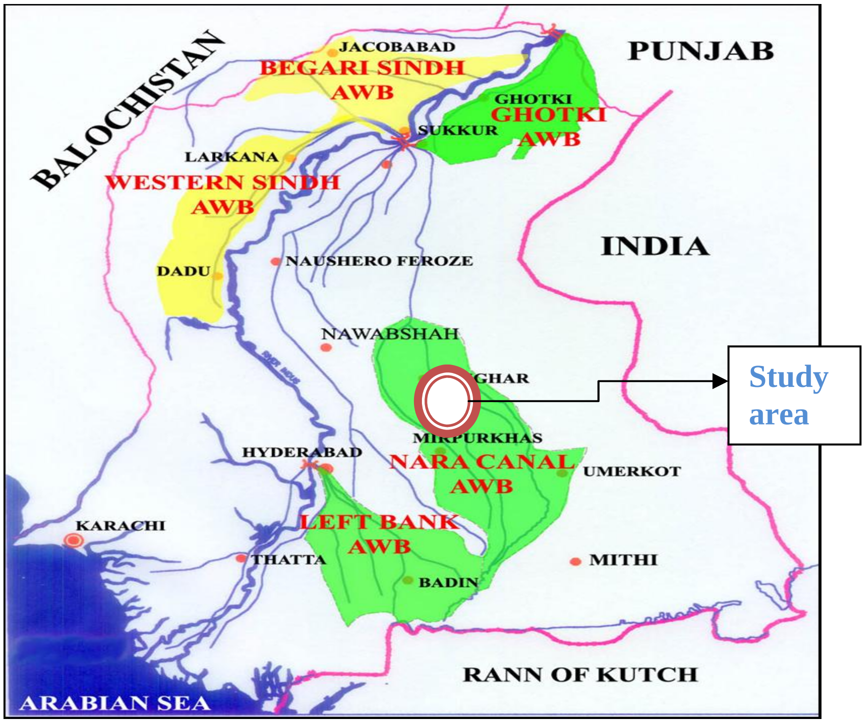

Figure 1. Location Map of Heran Distributary, Sanghar.

Table 1. The Salient Feature of Heran Distributary, Sanghar

Description	**Value**
Design Discharge (cfs)	62.5
Distributary Length (ft)	34,800
Number of Watercourses	31
Number of Lined Watercourses (one-third of length)	31
Crop Command Area (acres)	15,410

Data Collection

To obtain discharges at the head, middle, and tail reaches, flow measurement gauges were installed and calibrated. Similarly, the outlet structures of sample watercourses were calibrated. The discharges were recorded on a daily basis for all three gauges and all five sample watercourses for the period from October 15, 2007, to March 15, 2008 (winter crop season 2007-08). Crop data were surveyed for four sample watercourses representing head, middle, and tail reaches. Other data, such as metrological information and organizational management, were also collected in the field, as well as from the concerned departments. Using the CROPWAT model, potential ET was calculated for the distributary command area. The literature was surveyed to assess the role of farmer organizations established at different times by different organizations.

RESULTS AND DISCUSSIONS

Water distribution. Figure 2 explains the supply to the distributary at head and distribution along the length of channel.

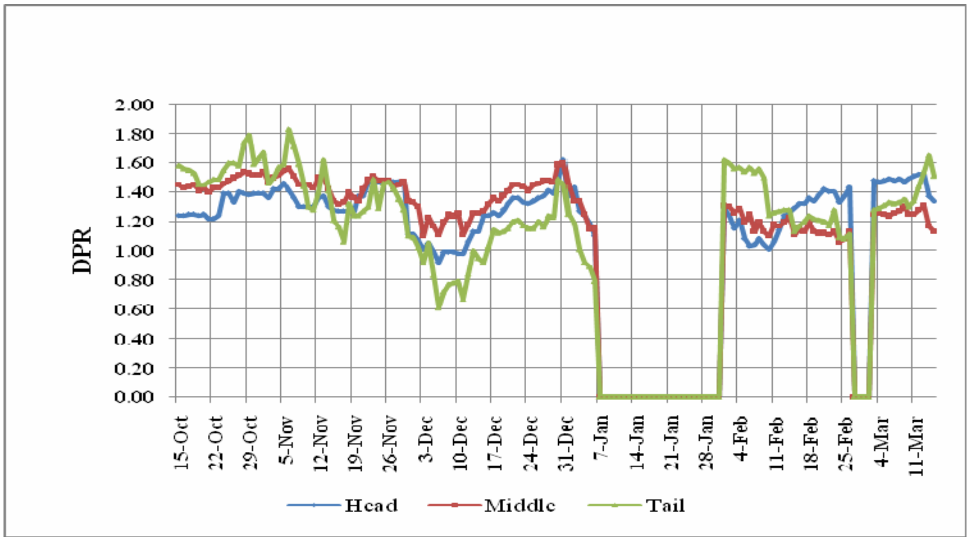

Figure 2. Water Distribution along the Channel Length

Observed data show that the delivery performance ratio-DPR (DPR is defined as ratio of actual discharge to designed discharge) at head of the distributary was between 1.0 – 1.6; at the middle it was slightly higher than at the upstream end (head), and at the downstream end (tail) the variation was from 0.6 to 1.8 during the Rabi season of 2007-08. The main reasons for such variation in the head, middle, and tail reaches were mismanagement and excessive supply of irrigation water. The canal was closed for maintenance from January 7-31, and there was a rotational closure of the distributary from February 27 to March 3 due to water shortage.

Table 2 describes the water distribution among watercourses along the channel length during the Rabi season of 2007-08.

Table 2. Water Delivery Performance Ratio (DPR) in Sample Watercourses

Month	Delivery Performance Ratio (DPR)				
	7-L	**9-AR**	**13-R**	**16-R**	**18-AT**
October	1.64	1.11	0.95	2.83	1.4
November	1.61	1.02	0.86	1.95	1.13
December	1.45	0.88	0.75	1.82	0.76
January	1.29	0.9	0.7	1.44	0.89
February	1.47	0.88	0.82	1.35	1.42
March	1.82	0.73	0.88	2.12	1.45

Results indicate that 7L- head watercourse was getting 30 to 82 percent more water than its designed discharge (Q_d). The tail reach watercourses (16R and 18AT) were also receiving up to 183 percent more discharge than Q_d. However, the middle reach watercourses (9AR and 13R) were taking nearly the design share (or less), though the flow of water was more in this reach. In spite of unfair distribution there were no complaints from the water users for unequal distribution of water because there was enough for everyone.

Cropping pattern. The major crops of the Rabi season were wheat, fodder, and vegetable, and the annual crops were sugarcane and gardens, as shown in Tables 3 and 4.

Table 3. Cropping Patten of the Sample Watercourses for the Rabi Season (2007-08).

Crops	Cropping Pattern in Percent				
	7-L	**9- AR**	**13- R**	**18 AT**	**Average**
Wheat	64.2	61.5	56.2	60.7	60.6
Sugarcane	7.2	5.4	11.2	4.4	7.1
Fodder	12.8	6.1	14.4	14.6	12
Oil Seed	14.5	24.4	17.6	9.8	16.6
Vegetables	1.4	1.1	0.6	4.6	1.9
Garden	00	1.6	0	5.8	1.9

Table 4. Cropping Pattern in the Rabi Season for Different Years in the Hearn Distributary Command Area.

Crops	**(1995-96)**	**(1999-2000)**	**(2007-08)**
Wheat	65.6%	64.8%	60.6%
Sugarcane	8.8%	9.4%	7.1%
Fodder	15.7%	13.9%	12.0%
Orchard & Gardens	3.7%	7.2%	1.9%
Vegetables	6.1%	4.7%	18.5*

*includes oil seed and vegetable data

The cropping pattern from 1995 to 2008 indicates that wheat, sugarcane, and fodder were cultivated on almost equal areas. Nevertheless, vegetable increased 3-4 times in 2008 and garden crops declined in 2008. In fact, wheat is a stable crop, fodder is needed for livestock, and sugarcane is a cash crop. Thus, farmers always prefer to keep these crops as constant and regular crops, while vegetables vary from year to year depending on market prices, and gardens were damaged due to water logging and salinity.

Water supply (WS) and crop water requirement (CWR). Figure 3 depicts the actual water supply to the distributary and calculated crop water requirements based on cultivated area and crop types.

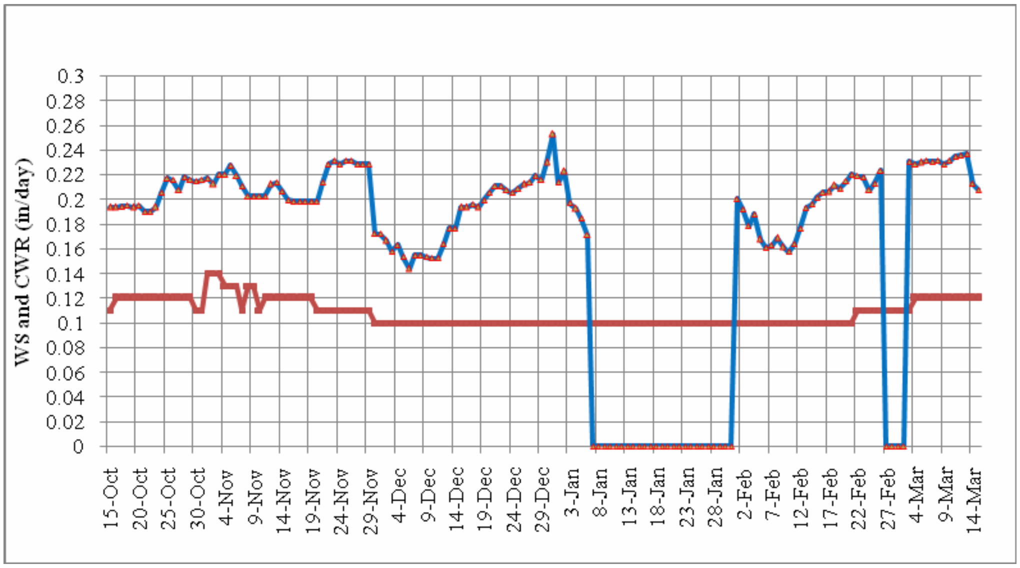

Figure 3. Water Supply and Crop Water Requirements in Rabi 2007-08

Analysis has indicated that the average supply at the head end of the distributary was 0.26 inch (6.62 mm) per day and the crop water requirement was between 0.10 inch (2.54 mm) per day and 0.14 inch (3.56 mm) per day from the beginning to the end of the cropping season. Thus, the values clearly demonstrate that the water supply (WS) was more than the crop water requirements (CWR). It is noted that the distributary was closed for canal maintenance from January 8 to 31, and was closed from 27 February to 3 March due to water shortage.

<u>Seepage losses</u>. Figures 4 and 5 discuss seepage losses in distributaries and watercourses in Pakistan and the study area. In the Heran distributary the seepage losses were about 4.5 percent and its watercourse seepage losses were 26 percent. The losses in the distributary were small due to adequate maintenance, while the watercourses were poorly maintained in the earthen portions, and sections at some places were wide and overtopping was common. Also, animal movement in the watercourses was noticed. The trend of seepage losses in distributaries and watercourses in Pakistan is almost the same except for a few cases.

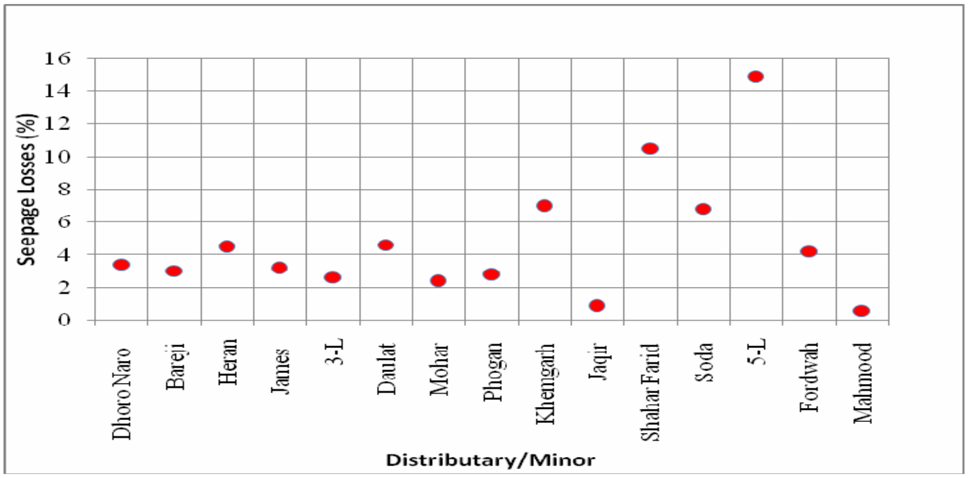

Figure 4. Seepage Losses in Distributary/Minor in Pakistan

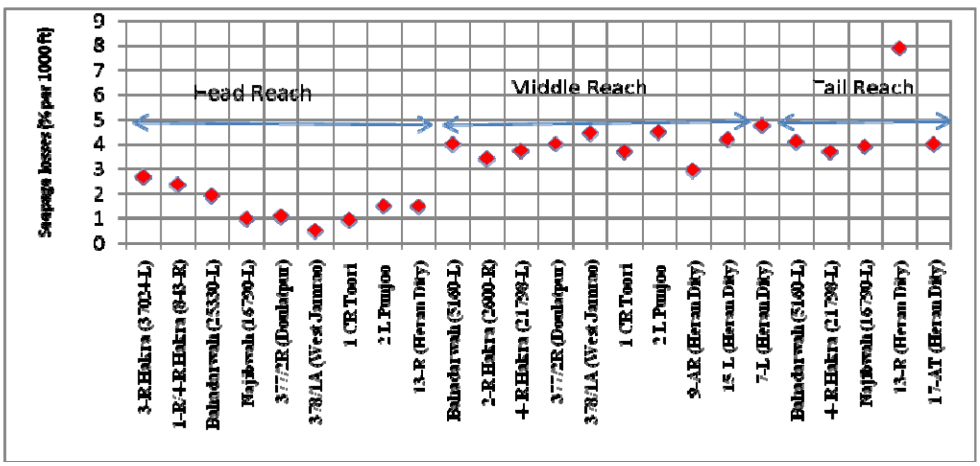

Figure 5. Seepage Losses in H-M-T Reaches of Watercourses

<u>Net water balance</u>. Figure 6 demonstrates the net water balance. Results show that except for the month of January, the excess of water was from 27 M ft^3 to 59 M ft^3 in the Rabi season. Thus, the total seasonal excess amount of water (+ net balance) was about 131 M ft^3. This excess amount not only contributes to the water table depth and water logging, but also reduces crop yield and creates water shortages to the tails of the overall network of irrigation system in the Sindh. The problem of water logging can be assessed through Fig. 7.

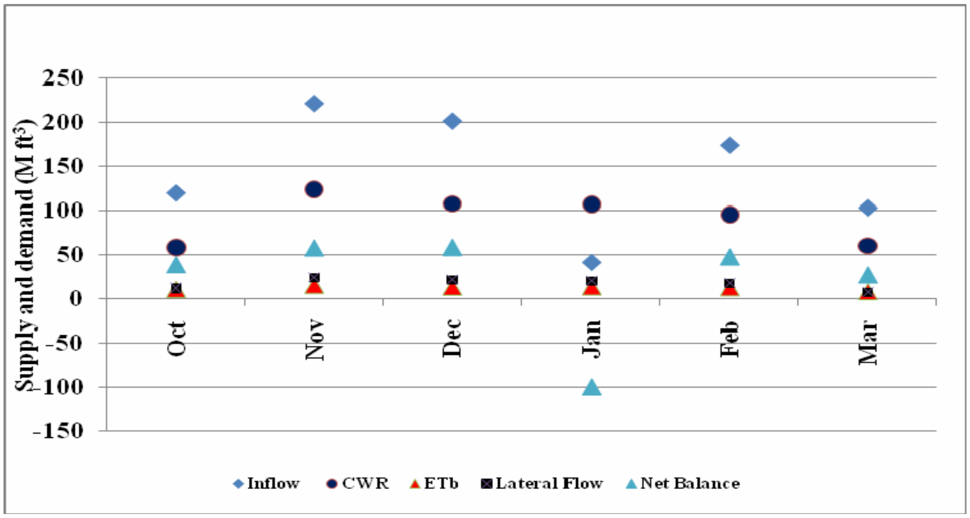

Figure 6. Net Water Balance in the Distributary Command Area

In the Sindh province, due to losses from the irrigation network and over-irrigation in the fields, water logging and salinity problems are very serious. The assessment was done from 1998 to 2009, which has indicated that in 1999 the waterlogged area, with a water table depth of 0-5 ft, was 5.43 million acres, which drastically reduced to about 0.64 million acres due to drought conditions from 1998-2001. However, the variation has been continued from year to year as indicated in Fig. 7.

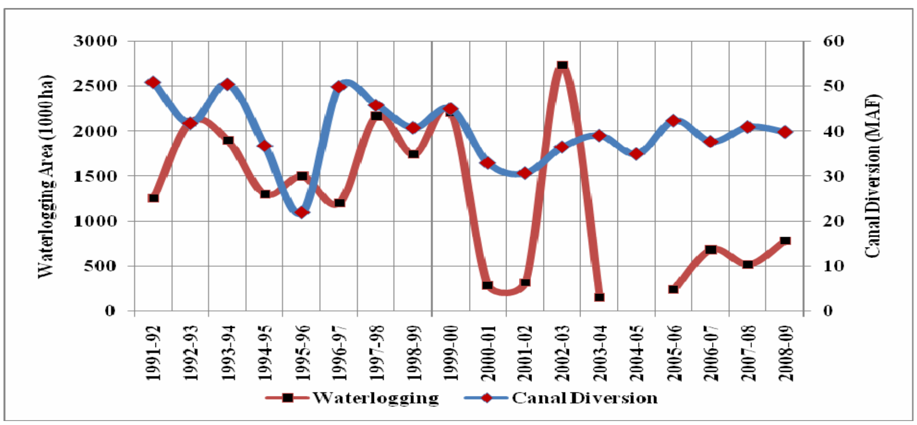

Figure 7. Waterlogging in Sindh Province

Sustainability of Farmer Organizations. The maturity index (organizational, conflict resolution, financial, O&M, environment, and capacity aspects) of 160 out of 369 FOs in the Sindh were determined. It was found12.5 percent of the FOs are at a sustainable level, 55 percent the FOs are at a stable level, 25 percent of the FOs are fragile, and 7.5 percent are weak (Lashari et al. 2009).

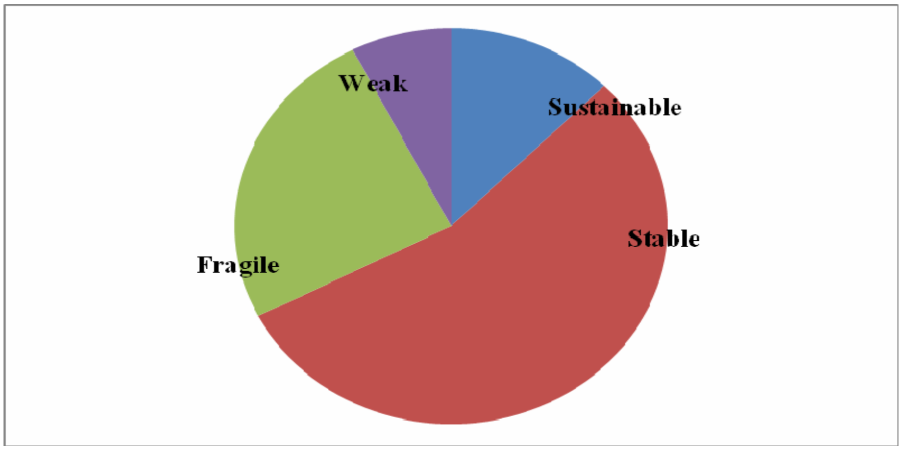

Figure 8. Farmer Organizations (FOs) strength in Sindh

The pilot project on farmer-managed irrigation systems carried out on the Heran distributary by International Water Management Institute (IWMI) has indicated that the FOs carried out remarkable maintenance of the distributary in which they collectively desilted the channel at a cost of about US$ 0.25 (Pak Rs. 21) per acre of land and improved the head-tail water delivery performance ratio from 3.53 to 2.55 (Lashari and Murry-Rust 2002).

SUMMARY AND CONCLUSIONS

Supply to the distributary was almost double the design discharge, but distribution among water users was observed to be unfair and no water users complained about unfair distribution. The reasons were an abundant supply of water and the fact that everyone was obtaining some water illegally. This increased supply not only impacted the efficiency of the system, but also decreased the crop yield and increased water logging in the command area of the distributary and throughout the Sindh province of Pakistan. Also, it was noticed during the study period that the downstream ends of the irrigation system of the Sindh suffered from an acute shortage of water.

The institutional reforms in the Sindh have not yet proved to be effective in providing equitable, reliable, and adequate supplies to cultivable lands for enhancing agriculture productivity and sustainable development. The FOs which were formed are still in the learning and capacity-building stages and cannot achieve the set objectives of efficient management of irrigation water, though there have been some FO success stories.

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