AGRICULTURAL WATER MANAGEMENT 92 (2007) 90–98

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/agwat

Impact of small dams on agriculture and groundwater development: A case study from Pakistan

M. Ashraf*, M.A. Kahlown, A. Ashfaq

Pakistan Council of Research in Water Resources, Khyaban-e-Johar Road H-8/1, Islamabad, Pakistan

ARTICLE INFO

Article history:
Accepted 15 May 2007
Published on line 9 July 2007

Keywords:
Small dams
Inflow–outflow
Rainfall
Groundwater
Pakistan

ABSTRACT

Water resources development and management is imperative for sustainable agriculture in water scarce areas. In Pakistan, the state of Punjab has constructed 32 small dams, in the Pothwar region, to store and conserve water for agricultural production. However, little information is available on the impact of these small dams on agriculture and socio-economic conditions of the area. This study was undertaken to evaluate the impact of three small dams, Jawa, Kasala and Dhok Sanday Mar, on agriculture and groundwater development in the area and to provide guidelines for the effective utilization and sustainable management of small dams in Pakistan. Data related to on-farm practices were collected during personal interviews using a pre-tested questionnaire. Water-table depth was measured from the open wells in the area with a water-table recorder. Secondary data such as inflow, outflow, rainfall, water charges and land use were collected from small dams organization.

After the construction of these dams and irrigation canals, cropping intensity and crop yield have increased. Due to availability of irrigation water there has been a shift of cropping pattern from wheat and forage crops to vegetable crops. Farmers are earning up to $2433 per ha per year. An analysis of inflow–outflow of the dams shows that, if properly managed, the storage is sufficient to irrigate all the crop lands within the command area. The depth to the water table has also decreased since the dams were constructed. The water table varies from 6 to 15 m in the irrigated areas served by the Khasala dam as compared to 7–39 m before the dam was constructed. The water table depths for the areas served by the Jawa dam ranged from 7 to 39 m before the dam was constructed to 9–25 m after construction. The shallower water table has made the groundwater accessible and as a result the number of wells has increased. This has reduced drudgery on the local inhabitants particularly for women who had to fetch water from far away for their domestic uses.

The area has potential for expanding both land use and cropping intensities, if innovative irrigation and agronomic practices are adopted. Moreover, mobilizing local water user associations, proper maintenance of irrigation infrastructure and technical support of the agricultural and extension services can enhance the productivity in the area.

1. Introduction

Pakistan's economy depends on agriculture, which contributes 24% of gross domestic product (GDP). Apart from producing food for the population, it provides raw material for agro-based industry. Out of about 22.16 million hectares (Mha) of country's total culturable land, 17 Mha is irrigated, giving about 90% of total agricultural production (MINFAL, 2004).

* *Corresponding author*. Tel.: +92 51 9258956; fax: +92 51 9258963.
E-mail address: muhammad_ashraf63@yahoo.com (M. Ashraf).
0378-3774/$ – see front matter
doi:10.1016/j.agwat.2007.05.007

About 17% of the cultivated area depends on rainfall for crop production. Rainfed areas are concentrated in the Pothwar plateau, the northern mountains and Northeastern plains of the country forming the largest contiguous block of dry-land farming in Pakistan. The rainfed area contributes only 10% of the total agricultural production. These areas are characterized by limited availability of water, which is the most important input for agriculture development. The occurrence of rainfall in these areas is highly erratic both in space and time with most of the rainfall occurring during monsoon (July to September). The Pothwar plateau spreads over 2.2 Mha, and the total cultivated area of the Pothwar plateau is around 1.0 Mha. About 4.2×10^9 m^3 of water is lost as surface runoff annually (Bhutta, 1999). Moreover, due to the uncertainty of rainfall, farmers normally minimize inputs to reduce the risk of loss in the event of drought and mainly depend on off-farm incomes for their sustenance. Agriculture in this area is therefore, just at subsistence level, primarily due to acute shortage of assured irrigation supplies. Other factors contributing to meagre agriculture in the area include small land holdings, obsolete methods of farming, and lack of institutional and infrastructure facilities. The present average land holding is generally less than 1.0 ha. The trend of division of land holdings and migration has disrupted the social balance in the Pothwar plateau and is hindering further economic development (Bhutta, 1999).

There could be two possible approaches to increase the agricultural production: either bringing more area under cultivation, or increasing the crop yield per hectare. Water is the most limiting factor affecting crop yield (Ashraf et al., 1999). Since 1961, the Government of Punjab through the Small Dams Organization (SDO) has constructed 32 small dams in Pothwar plateau and 19 more dams are under construction. These dams are designed to irrigate over 1420 ha. However, only 40% of the anticipated command area has been developed (NESPAK, 1991; Bhutta, 1999; Iqbal and Shahid, 1992). On average, 69% of the water in the reservoirs is being released and used for irrigation (Bhutta, 1999).

These small reservoirs are subject to high evaporation losses due to the high surface area to volume ratio. On average, small reservoirs can lose 50% of their impoundments to evaporation in arid and semi-arid areas (Sakthivadivel et al., 1997). The small dams in Pothwar are also subject to high evaporation losses. On average these dams lose about 1.74 m/year, which is about 20% of their storage capacity. The seepage and percolation losses in small reservoirs can be about 20% of reservoir volume against 5% in large dams (Keller et al., 2000). The cost per unit of water in small dams is also relatively high. The cost per 1000 m^3 of water ranges from \$1 to 32 (1 US\$ = Rs. 60) for large reservoirs, whereas it is from \$7 to 110 for medium and small dams ((NESPAK, 1991; Keller et al., 2000). These small dams; however, act as buffer during dry season and dry years and should be managed properly (Mugabe et al., 2003). Since the evaporation losses and unit cost of water storage in small dams are relatively high, it becomes imperative that the stored water be used judiciously and efficiently.

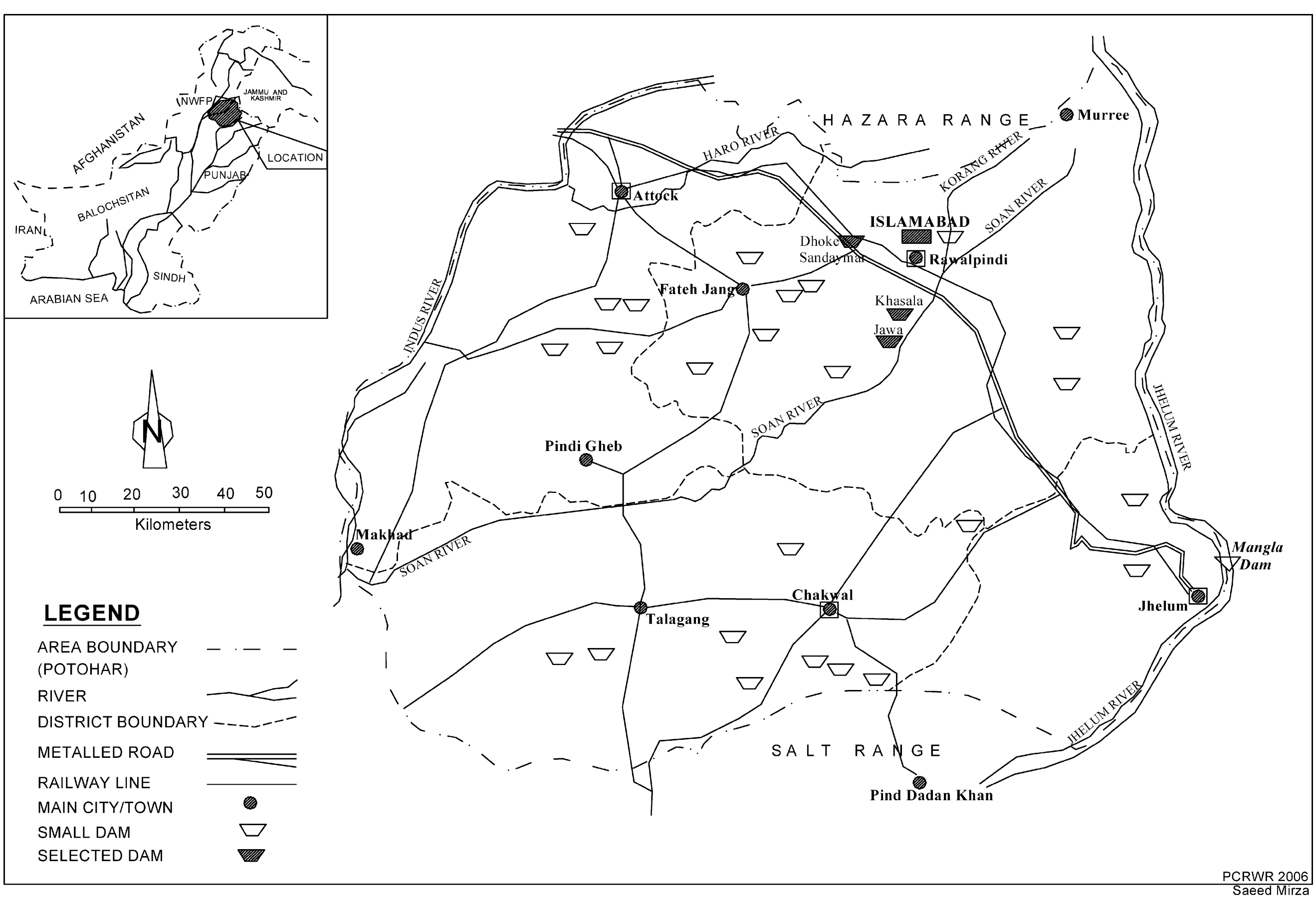

Fig. 1 – Location of the selected dams.

Water resource development and management are concomitant. Without proper management, the water resource developed can be lost without playing a significant role in the crop production and socio-economic development of the area. Proper management requires adequate knowledge of water availability, water requirement and productive water use (Mugabe et al., 2003). The objectives of this study were to: (i) evaluate the impact of small dams on agriculture and groundwater development; (ii) identify causes of low cropping intensity in command areas; and (iii) suggest strategies for improving land and water productivity.

2. Methodology

Three small dams, viz., Khasala, Jawa and Dhok Sanday Mar (D.S. Mar) situated in Rawalpindi Division (Fig. 1), were selected for the study. The Khasala dam is 27 km from Rawalpindi on a stream called Khasala Kas. The latitude of the site is 33° 20′N and the longitude is 72° 58′E. The elevation of the watershed ranges from 381 to 427 m above sea level. The Jawa dam is 35 km from Rawalpindi at latitude 33° 26′N and longitude 72° 56′E and the watershed elevation ranges from 380 to 506 m. The D. S. Mar is 30 km from Rawalpindi on Grand Trunk (GT) road at latitude 33° 39′N and longitude 72° 51′E; watershed elevation ranges from 508 to 528 m. These dams have been constructed mainly for irrigation and groundwater recharge. The salient features (Small Dams Organization, 1980, 1985, 1992) of the dams are given in Table 1. The secondary data such as inflow, outflow, water rights, and costs, and land use pattern were collected from SDO.

The coldest month is January when the mean maximum temperature is 16 °C and the mean minimum temperature is 3 °C. June is the hottest month with a mean maximum temperature of 40 °C and mean minimum temperature of 24 °C. The maximum rainfall occurs during the monsoon season from July to August, with monthly averages of 200 and 220 mm, respectively. The average annual rainfall in the Rawalpindi Division is 968 mm, but varies considerably within the division: from 400 m/year in the northeast to 1800 mm/year in the southeast. The soil textures in the Rawalpindi Division range from sandy to silty clay.

A reconnaissance survey was conducted to obtain preliminary information about the dams: location, accessibility, command (or service) area and sources of relevant data. Participatory Rural Appraisal (PRA) was used to collect data for impact assessment of the developed water resources (Saeed et al., 2002). A questionnaire was developed and pre-tested in the field. After pre-testing, necessary changes were made in the questionnaire. It covered land utilization pattern, existing irrigation systems, cropping patterns and intensities, crop yields, farmer attitude towards innovative water management techniques, and social and economic parameters.

The selection of respondents was based on the total number of farmers at each dam. The criteria were to involve a maximum number of farmers from all levels, i.e., small, medium and big land holders, including farmers at the upstream and tail of the main canals. The farmers of all categories were selected randomly. The total number of farmers, based on the list of water rights provided by SDO, were 292, 181, and 21 for the Khasala, Jawa and D.S. Mar dams, respectively. The farmers interviewed were 42, 39, and 52 for these dams, respectively. Data were collected during interviews with the farmers. The

Table 1 – Salient features of selected small dams

S. no.	Description	Khasala	Dhok Sanday Mar	Jawa
1	Type of dam	Masonry	Masonry	Earth fill
2	Height of dam (m)	19	20	25
3	Length of dam (m)	124	561	143
4	Gross reservoir capacity (10^6 m^3)	2.98	0.80	1.94
5	Dead storage capacity (10^6 m^3)	1.13	0.16	0.83
6	Live storage capacity (10^6 m^3)	1.85	0.64	1.11
7	Life of project			
	(a) Calculated (years)	175	68	65
	(b) Adopted (years)	50	50	50
8	Mean annual run-off (10^6 m^3)	4.17	1.84	1.07
9	Spillway crest length (m)	40	92	110
10	Outlet type	Gravity (46 cm dia. pipe)	Gravity (61 cm dia. pipe)	(38 cm dia. pipe)
11	Capacity of irrigation sluice (lps)	170	99	142
12	Length of irrigation channels (m)	4315	4726	7164
13	Gross command area (ha)	648	263	324
14	Crop intensity (assumed, %)	140	120	100
15	Total cost of the project ($ million)	0.28	0.32	0.34
16	Culturable command area (ha)	506	263	323
17	Catchment area (km^2)	25	9	9
18	Spillway capacity (m^3/s)	315	189	41
19	Pond area at NPL (ha)	42.9	19.83	30.76
20	Completion year	1985	1990	1994
21	Annual operation and maintenance cost ($)	2400	2783	4000

Source: Small Dams Organization (1980, 1985, 1992).

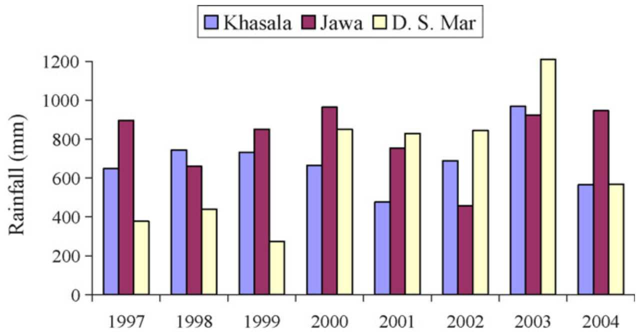

Fig. 2 – Average annual rainfall pattern at the selected dams.

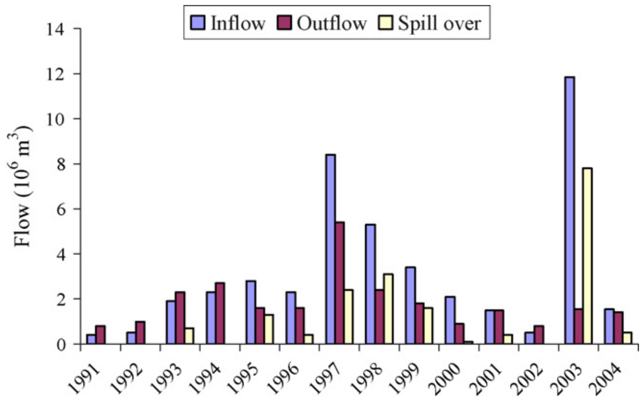

Fig. 3 – Yearly inflow–outflow of Khasala dam.

water table was measured with a water-table recorder from wells in the vicinity of these dams.

2.1. *Inflow–outflow of the dams*

There was high spatial and temporal variability of rainfall at these dams (Fig. 2; Table 2). The outflow represents only the releases for irrigation. Except when it rains, water is released for 12 h daily (0600–1800). The irrigation supply is mainly from the live storage of the reservoirs. The dam authorities release water according to farmer's needs and water availability. Fig. 3 shows annual inflow, outflow and spill-over from the Khasala dam. Inflow was usually somewhat greater than outflow. However, due to low rainfall, outflow plus spill over during 1998 and 1999, and from 1991 to 1994 was higher than inflow. For the 1991–1994 period, 6.8×10^6 m^3 was released against a total inflow of 5.1×10^6 m^3. The balance, 1.7×10^6 m^3, was released from live storage (1.85×10^6 m^3).

During 1993, 1994 and 2004, outflow plus spill-over for the Khasala dam exceeded inflow because of spill-over during the monsoon season (Fig. 3). Spill-over usually did not occur when inflow was less than 2×10^6 m^3/year. Outflow spreads over the whole year, and it may be from the live storage of the dam. During periods of high inflow due to rain, the outflow was reduced because farmers needed less water for irrigation. For example, in 1997 and 2003, inflows were very high as compared to outflows. However, when inflow was low, there was more outflow due to a greater need for irrigation water.

The average monthly inflow–outflow of the Khasala dam for the last 14 years is shown in Fig. 4. The maximum inflow occurred during July–August and maximum releases (outflow for irrigation plus spill-over) also occurred during these months. There was no inflow during November and December. During May and June, outflow was greater than inflow due to hot weather conditions and lack of rainfall during these months.

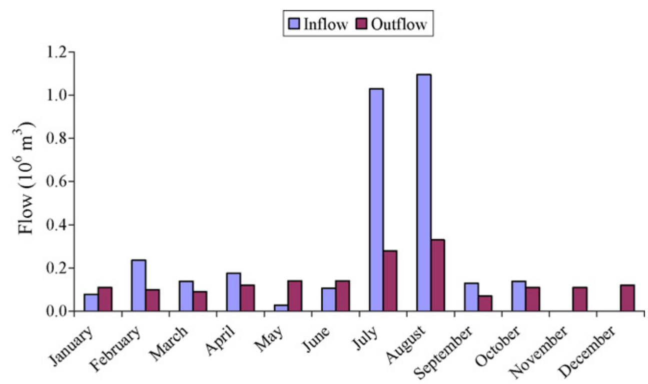

Fig. 4 – Average inflow–outflow at Khasala dam (1992–2004).

The Jawa dam became operational in 1997, and inflow was almost constant till 2000 (Fig. 5). However, inflow decreased during 2001–2002, increased during 2003 and again decreased during 2004. During 1998, 2001, 2002 and 2004, outflow was smaller than the inflow. The inflow from 1997 to 2004 was 7.62×10^6 m^3 and the out flow was 8.18×10^6 m^3. The excess of 0.57×10^6 m^3 was released from live storage (1.10×10^6 m^3). The inflow pattern was similar to the rainfall pattern (Fig. 2). There was very little spill-over during 1997, 1999 and 2000, and no spill-over during 1998 and from 2001 to 2004. The monthly inflow–outflow pattern for the last 8 years is shown in Fig. 6. There was almost constant inflow from January to April, none

Table 2 – Spatial and temporal variation of rainfall

Dam	Mean	Standard deviation	Standard dry year (mm)[a]	Mean year (mm)	Below mean year (%)	Below dry year (%)
Khasala	807	175	564	814	38	13
Jawa	686	145	642	743	50	25
Dhok Sanday Mar	674	313	889	1092	50	88

[a] The standard dry year from August 1977 to July 1978.

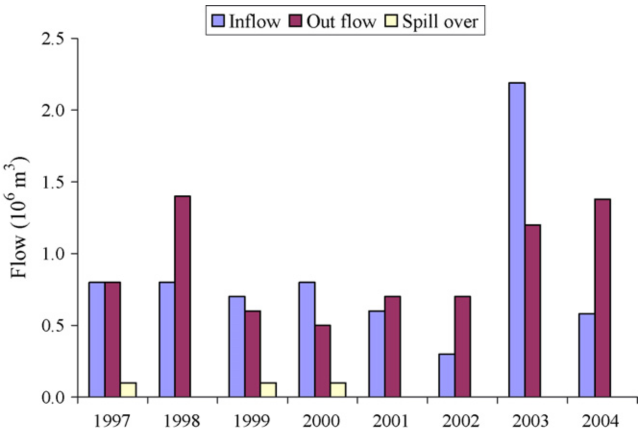

Fig. 5 – Yearly inflow–outflow of Jawa dam.

during November and negligible amounts during December. The inflow during the monsoon season was relatively high.

Inflow at the D.S. Mar dam was almost equal to the outflow except for 1997, 1998 and 2003 (Fig. 7). Spill-over occurred only during 1997, 1998, 2003 and 2004. The catchment area is becoming urbanized resulting in reduced runoff. Generally urbanization results in increased runoff, but in this case most of the runoff is collected through the sewage system and disposed off elsewhere resulting in decreased surface runoff to the reservoir. Moreover, some water from the dam is also being used by the increasing number of households. Overall this dam is the smallest of the studied dams and both inflow and outflow are less than the other two dams. The maximum average inflow over 12 years (Fig. 8) occurred during the month of August due to monsoonal rainfall. The inflow has been greater than outflow during February–March and from July to September. However, from October to January, the inflow has been less than the outflow. When outflow was greater than inflow, water released from live storage (0.64×10^6 m^3) was sufficient to meet the excess water releases. Overall, there was 12.1×10^6 m^3 inflow from 1993 to 2004 against which the overall release was 4.1×10^6 m^3 (34% of the total inflow).

Table 3 shows that the annual water released from the three dams and annual rainfall were sufficient to meet the crop water requirements at the envisaged cropping pattern and cropping intensity. The water requirement at Jawa dam is

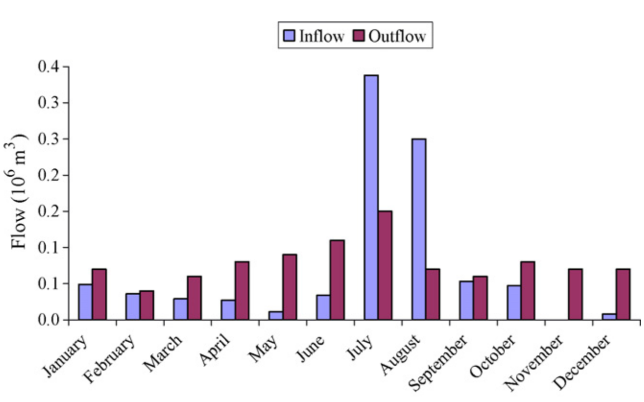

Fig. 6 – Average inflow–outflow at Jawa dam (1997–2004).

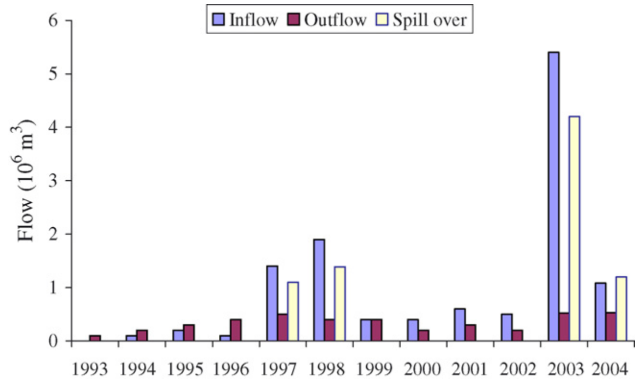

Fig. 7 – Yearly inflow–outflow of D.S. Mar dam.

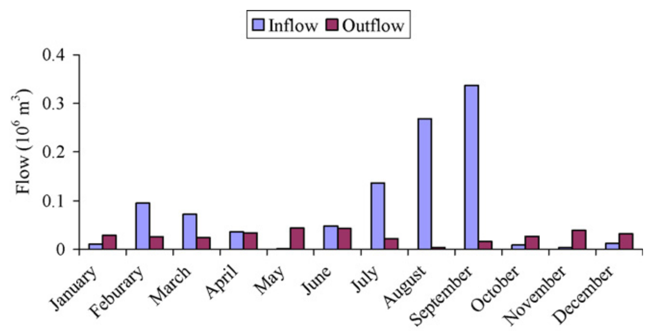

Fig. 8 – Average inflow–outflow at D.S. Mar dam (1996–2004).

comparatively less because the envisaged cropping intensity at the service area of this dam is 100% compared to 140% at Khasala and D.S. Mar dams. The water released from D.S. Mar dam, was almost 50% less than the other two dams. As discussed earlier, most of the command area of this dam has been urbanized due to which less water is released from the dam for irrigation purposes.

2.2. *Water charges*

Farmers pay for the water they use. Before 2003, the water rates were charged on the basis of the area and crops grown (Table 4). Water charges were higher for those crops, which had high water requirements such as sugarcane, rice and vegetables than those that require less water such as chickpea (*cicer arietinum*), lentils (*Lens culinaris*) and mungbean (*vigna radiate*).

Table 5 shows the annual water rates charged by the dam authorities and indicates water rates generally increased gradually, probably due to the increasing area under irrigation with time. However, at D.S. Mar, the annual total water charges decreased after 1998 possibly due to the decrease in water released. The water charges received from Khasala and Jawa dams in 2004 were about the same, 1170 $/year, which was about three times less than the operation and maintenance cost of the Khasala dam and about five times less than that for the Jawa dam (Table 1). However, in case of D.S. Mar dam, the annual water charges received in 2004 were about 259$. Therefore, its operation and maintenance cost was 12 times

Table 3 – Annual water released, rainfall and water requirements at the selected dams

Site	Average water released (10^6 m^3/year)	Average water released (mm/year)	Average rainfall (mm/year)	Average crop water requirement (mm/year)[a]
Khasala	1.84	284	807	471
Jawa	0.91	281	686	348
Dhok Sanday Mar	0.34	130	674	524

[a] Based on the envisaged cropping pattern and cropping intensity.

Table 4 – Annual water rates for various crops grown in the command areas of small dams

Crops/category	Grade	Water charge ($/ha)
Sugarcane (*Saccharum arundinaceum*)	1	15
Vegetable garden [except turnips (*Brassica rapa*)]	3	9
Tobacco (*Nicotiana acuminata*), cotton (*Gossypium*)	4	8
Rice (*Oryza sativa*)	5	7
Fibre crops except cotton (*Gossypium*), chilli (*Capsicum annuum*), water melon (*Citrullus lanatus*), melon (*Cucumis melo*)	6	6
Sesamum seeds (*Sesamum indicum*)	7	5
Preserved trees (Owned by Department of Forestry)	8	5
Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*) and all crops which are not included in schedule	9	5
Maize (*Zea mays*)	10	4
Millet (*Panicum miliaceum*), masoor (*Lentils*), all pulses	11	4
All fodders which require 2 or 3 irrigations [e.g. sorghum (*Sorghum bicolor*), chickpea (*Cicer arietinum*) and turnip grass (*Brassica rapa*), etc.]	12	3

greater than its income (Table 1). The area that could be cropped in the command area of Khasala, Jawa and D.S. Mar dams is 506, 323 and 263 ha, respectively. If we take average of the last 12 years, in case of Khasala and D.S. Mar dams and 8 years in case of Jawa dam, the annual water charges in dollars per ha for Khasala, Jawa and D.S. Mar dams were $1.2, $1.6 and $1.01, respectively. In case of D.S. Mar dam, the water charges received were the lowest mainly due to the small cultivated area. Since July 2003, the annual water rates have been fixed at 5.6 $/ha for the entire area served, not the area actually irrigated.

2.3. *Data collected through field survey*

2.3.1. *Land holdings and family size*

Only a few farmers hold land greater than 4.0 ha. The average land holding ranges from 1.0 to 8.7 ha. Table 6 shows that the average family size of the farmers is 16, 7 and 8 at Khasala, Jawa, and D.S. Mar, respectively. In the irrigated area served by the D.S. Mar dam, people have larger land holdings than in areas served by Jawa and Khasala dams: the average irrigated land is 1.13, 1.0 and 8.7 ha at Khasala, Jawa and D.S. Mar, respectively.

2.3.2. *Source of irrigation water*

Table 7 shows that at Khasala dam, about 75% water is obtained from the dam whereas at D.S. Mar dam, 100% water is received from the dam. At Khasala and Jawa dams' service area, 5–22% of irrigation water is from groundwater pumping. However, the case at D.S. Mar dam is entirely different as there are no wells. Hundred percent of the farmers receive water supply from the dam and no rainfed agriculture is practised in the service area of this dam.

2.3.3. *Groundwater development*

Besides supplying water for irrigation, these dams have many indirect benefits. They help recharge the groundwater, provide water for domestic and municipal purposes, control erosion and floods in hilly and plain tracts, help develop fish culture and also provide recreational activities (Ashraf et al., 2000).

Prior to the construction of dams, the farmers were unable to irrigate their land from the wells because the water table was deep and out of the suction range of the centrifugal pumps. Table 8 shows that at present, the water table varies

Table 5 – Water charges received from each dam

Years	Water charges ($/year)		
	Khasala	Jawa	Dhok Sanday Mar
1992–93	135		30
1993–94	339		140
1994–95	280		187
1995–96	354		223
1996–97	388	18	318
1997–98	699	318	357
1998–99	792	314	476
1999–00	619	217	393
2000–01	637	297	202
2001–02	866	864	220
2002–03	1037	1023	304
2003–04	1175	1157	259
Average	610	526	269

Table 6 – Average land holding (per total number of family members) and family size

Description	Khasala	Jawa	Dhok Sanday Mar
Land holding (ha)	1.3	1.0	8.7
Family size (no.)	16	7	8

Table 7 – Source and availability of irrigation in the study area (%)

	Khasala	Jawa	Dhok Sanday Mar
Source of Irrigation			
Dam	75	25	100
Well	5	22	–
Rainfed	20	53	–
Water availability			
Kharif (April to September)	60	70	100
Rabi (October to March)	40	30	100

from 6 to15 m and 7 to 39 m in the service areas of Khasala and Jawa dams, respectively. Prior to construction of the dams, the corresponding water table depths were 9–25 m and 12–45 m. At the tail of the irrigation canals from these dams, the water-table depth is 5–7 m, because the tail lies between the dam and Soan River. The groundwater is recharged both from the dams and Soan River. The number of wells in this area has increased from 135 to 500 (Table 8). A similar increase in the water table occurred close to the Shalpur dam, which was built in 1986 (WRRI, 1995).

2.3.4. *Income of farmers*

In kharif (April to September), per hectare income ranges from \$833 to 1000 and in rabi (October to March) it is \$1000–1433 for Khasala and Jawa dams (Table 9). However, it is \$217–617 in kharif and \$417–617 in rabi for D.S. Mar dam. The reason for relatively high income for Khasala and Jawa dams is the growing of vegetables whereas at D.S. Mar, the farmers normally grow wheat and fodder. The farmers obtain higher returns by growing high value and marketable crops. Due to the availability of reliable water supply, the farmers were able to produce high-value and marketable crops and get high returns. This provided an opportunity for poverty reduction in the area.

2.4. Main issue

The field visits and discussions with the farmers helped to identify the following major issues for improper utilization of the available water.

2.4.1. *Illegal water cutting*

The farmers reported that the influential people divert water when it is not their turn to do so. The canals are broken at several points and water is being illegally diverted. The farmers at the tail region hardly receive enough water for their farms. Shahid et al. (1996) also reported that the obvious reason for underdevelopment of irrigated lands was the irregular blockage of water by influential farmers to keep the irrigation water supplies confined to their farms. This practice not only skewed the distribution of irrigated area but also resulted in wastage of huge investment made on the construction of water channels, which remain dry most of the time. This is attributed to lack of weekly rotational schedule, and insufficient field staff to operate these correctly including monitoring for irregular blockage of irrigation water along the canal. Equity in water distribution is very important factor for the management of water resources (Ahmad, 1999). Inequity in water distribution results in frustration, lack of interest in farming and maintenance of watercourses, distrust among water users and disputes over water rights among the users. Inequity in water distribution is the result of non-functional water user associations (Ali and Chaudhary, 1996; Hussain and Perera, 2004).

2.4.2. *Improper maintenance of watercourses*

The entire watercourses are poorly maintained, full of sand and bushes and water overtops the watercourses. The watercourses are broken at several places and also the cleaning of watercourses is not done regularly. The designed outlets at several points are broken which reduces the supply of water available to farmers at the tail end of the canals. Due to improper maintenance of irrigation system, 33–65% water is lost in transit (Ahmad, 1999; Skogerboe, 1996; Kahlown and Kemper, 2004). The proper repair and maintenance of these watercourses is very important for getting long-term benefits of the investment made on these dams.

2.4.3. *Poor field channels*

Due to cheap water availability and lack of knowledge, flood irrigation is commonly used. The field channels are earthen, not designed and constructed properly and are poorly maintained. A considerable amount of water is wasted in the field channels. Due to undulated fields, huge amount of

Table 8 – Effect of dams on water-table depth

Name of dam	Water-table depth (m)		No. of tubewells/dugwells	
	Before construction	Present	Before construction	Present
Khasala	9–25	6–15	75	130
Jawa	12–45	7–39	60	120
Dhok Sanday Mar	5–90	2–7	0	25

Table 9 – Average income of farmers in study area (\$/ha)

Season	Khasala	Jawa	Dhok Sanday Mar
Kharif (April to September)	833–1000	833–1000	217–617
Rabi (October to March)	1000–1433	1000–1433	417–617
Total	1833–2400	1833–2400	8000–1067

water is wasted. There is need to level these fields precisely, so that scared water could be used efficiently.

2.4.4. *Non-existence of water user associations (WUAs)*

Water rights do not match needs and are not properly followed. The WUAs do not exist in these areas. There is no formal body to look after the watercourses of the area. Due to non-functional and non-existence of WUAs, there are many disputes among the farmers on water distribution. Skogerboe (1996) stressed the needs of sustainable WUAs that would maintain their improved watercourses along with more effective use of water through improved water management practices.

2.5. *Lack of agricultural support services*

Agricultural extension services play a pivotal role in the motivation of farmers towards the formation of water user association, adoption of improved irrigation and cultural practices, introduction of high valued crops, efficient use of water and proper use of non-water inputs. However, it was observed that extension services were hardly available in the service areas of the dams. Similarly, On Farm Water Management (OFWM) activities were very limited in these areas. Improving agronomic and farm water management practices, particularly promoting the use of improved varieties of seeds and enhancing the role of extension services to farmers for dissemination of up-to-date knowledge are very important to improve land and water productivity (Hussain and Perera, 2004). A well co-ordinated and integrated approach by the SDO, OFWM and Agriculture Extension Department is needed, starting with operation, maintenance of main watercourse and field channels for overcoming inequities that occur along the watercourse and assisting farmers with improved irrigation and agronomic practices (Skogerboe, 1996; Early et al., 1976). Moreover, the current extension system responsible for the promotion of water-saving practices faces poor incentives and low budget to carry out this work.

3. Conclusions and recommendations

After the construction of these dams, the land use, crop intensities and crop yield have increased. There is a shift of cropping pattern from the traditional cropping towards high valued crops due to the availability of water. The water table has risen and has become accessible for pumping due to which number of dugwells has increased.

The conventional methods of irrigation are still predominant. If water is properly managed, and used, more area could be irrigated with existing infrastructure and facilities. Furthermore, an analysis of the dams inflow–outflow shows that inflow is sufficient to irrigate the targeted command/service areas. There are several bottlenecks in the full utilization of these dams such as: (i) illegal water cutting; (ii) non-functional water user associations; (iii) improper maintenance of watercourses; (iv) broken outlets; (v) poorly maintained field channels; (vi) undulated fields; and (vii) lack of agricultural support services, etc. An integrated programme should be formulated and implemented in command areas for effective utilization of available water as well as developed infrastructure.

Acknowledgements

The study was conducted with the financial assistance from Pakistan Science Foundation under grant No. R&D/CDYST/C-PCRWR/AGR (15). The authors acknowledge the support of Small Dams Organization in data collection. The assistance of Mr. Samar Gul and Mr. Ali Bahzad Assistant Directors, PCRWR in data collection is highly appreciated.

REFERENCES

Ahmad, S., 1999. Achievements and issues of irrigation in the 20th century. In: Chandio, B.A. (Ed.), Proceedings of The National Workshop on: Water Resources Achievements and Issues in 20th century and challenges for the next millennium, Pakistan Council of Research in Water Resources, Islamabad, Pakistan, pp. 188–201.

Ali, A., Chaudhary, M.R., 1996. Water conveyance and distribution at watercourse level. In: Khalid, R., Robina, W. (Eds.), Tertiary Sub-System Management. International Irrigation Management institute, Lahore, Pakistan, pp. 12–23.

Ashraf, M., Hassan, F.U., Khan, M.A., 1999. Water conservation and its optimum utilization in barani areas. J. Sci. Tech. Develop. 18, 28–32.

Ashraf, M., Hassan, F.U., Khan, M.A., 2000. Sustainable environment management: impact of agriculture. J. Sci. Tech. Develop. 19, 51–57.

Bhutta, I.A., 1999. Achievements and issues in 20th century in small dams (rainwater harvesting). In: Chandio, B.A. (Ed.), Proceedings of The National Workshop on: Water Resources Achievements and Issues in 20th Century and Challenges for the Next Millennium, Pakistan Council of Research in Water Resources, Islamabad, Pakistan, pp. 64–69.

Early, A.C., Eckert, J.B., Freeman, D.M., Kemper, W.D., Lowdermilk, M.K., Radosevich, G.E., Skogerboe, G.V., 1976. Institutional Framework for Improved on-Farm Water Management in Pakistan. Colorado State University, Fort Collins, Colorado (Special Technical Report, Water Management Research Project).

Hussain, I., Perera, L.R., 2004. Improving Agricultural Productivity for Poverty Alleviation through Integrated Service Provision with Public-Private Sector Partnerships: Examples and Issues. International Water Management Institute, Colombo, Sri Lanka (Working paper 66).

Iqbal, M.S., Shahid, S.A., 1992. An Assessment of Agricultural Development in the Rehabilitated Small Dams Command Area. Punjab Economic Research Institute, Lahore Pakistan.

Kahlown, M.A., Kemper, W.D., 2004. Seepage losses as affected by condition and composition of channel banks. Agric. Water Manage. 65, 145–153.

Keller, A., Sakthivadivel, Seckler, R.D., 2000. Water scarcity and the role of storage in development. International Water Management Institute (IWMI) Research Report No. 39.

MINFAL, 2004. Agricultural Statistics of Pakistan, 2000–2001. Ministry of Food, Agriculture and Livestock, Government of Pakistan.

Mugabe, F.T., Hodnett, M.G., Senzanje, A., 2003. Opportunities for increasing productive water use from dam water: a case study from semi-arid Zimbabwe. Agric. Water Manage. 62, 149–163.

NESPAK, 1991. Evaluation of Small Dams in Punjab and N.W.F.P., vol. II-Part A–C. Government of Pakistan, Ministry of Planning and Development Division.
Saeed, M.M., Ashraf, M., Bruen, M., 2002. Diagnostic analysis of farmer's skimming well technology in the Indus basin of Pakistan. Irrig. Drain. Syst. 16, 139–160.
Sakthivadivel, R., Fernando, N., Brewer, J., 1997. Rehabilitation planning for small tanks in cascades: A methodology based on rapid assessment. International Water Management Institute Research Report 13. Colombo, Sri Lanka.
Small Dams Organization, 1980. Khasala Dam. Revised PC-1. Small Dams Organization, Islamabad, Pakistan, pp. 100.
Small Dams Organization, 1985. P C-1, Feasibility Report and Project Estimate of Dhok Sanday Mar Dam. Small Dams Organization, Islamabad, Pakistan, pp. 63.
Small Dams Organization, 1992. P C-1 of Jawa Dam. Small Dams Organization, Islamabad, Pakistan, pp. 69.
Shahid, S.A., Ashraf, M., Mazhar-ul-Haq, K.A., 1996. Evaluation of Small Dams Project in Punjab. Punjab Economic Research Institute.
Skogerboe, G.V., 1996. Physical versus institutional development in the evolution of watercourse improvement in Pakistan. In: Khalid, R., Robina, W. (Eds.), Tertiary sub-system management. International Irrigation Management institute, Lahore, Pakistan, pp. 2–11.
WRRI, 1995. Participatory research and development. Water Resources Research Institute (WRRI), National Agricultural Research Council, Islamabad, Pakistan.