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Full Length Research Paper

Performance assessment of canal irrigation in Pakistan

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Irrigated agriculture plays an important role in economic development of many countries world wide. Pakistan has a large system of irrigated agriculture. In this research, performance of an irrigation system in Punjab Pakistan has been investigated. Five indicators; Cost Recovery Ratio, Benefit Cost Ratio, Economic Delivery Efficiency, Relative Water Cost and Delivery Performance Ratio have been used to assess performance of the system. The data regarding cost of water paid by farmers, the irrigation benefits per unit water volume, operation and maintenance cost, and total production cost including the cost of irrigation, seed, fertilizer, pesticide, labour, etc. were collected by field measurements, interviews with farmers and market surveys. The data have also been taken from the records of Punjab Irrigation Department. The analysis shows that irrigated agriculture in Pakistan is potentially cost-effective. However, the establishment costs of the system are more, which shows the inefficiency of the managerial system. It was concluded that the Recovery Cost Ratio and Relative Water Cost of the system are 0.777 and 0.311 respectively. Low value of Delivery Performance Ratio indicates inequitable distribution.

Key words: Lower Jhelum, irrigation system, farmers, irrigated agriculture, operation, maintenance.

INTRODUCTION

Agricultural sector plays a vital role in poverty plummeting in many regions of the world. According to Michael (2007), 80% of food in Pakistan, 70% in China and 50% in India and Indonesia each is produced from irrigated agriculture. However some countries have very low amount of food produced by agriculture. For example only 9% of food is produced by agriculture in sub-Saharan Africa. There are enough water resources and land to produce sufficient food but only 16.8% of the land which has very good potential has been developed for irrigated agriculture (Ararso et al., 2009). The performance of irrigation systems has a major role in producing more food and making irrigated agriculture cost-effective. The superior irrigation management can improve the performance of irrigation system. Three water management options have been analyzed by Ararso et al. (2009) to improve food production in Sub-Saharan Africa.

Agriculture and irrigation practices of Cameroon, Democratic Republic of the Congo, Ethiopia, Nigeria, South Africa and Sudan have been analyzed. According to them the present management cannot provide food security in the region. Improvements in institutional organization and involvement of stakeholders can improve the situation. There is need for increasing productivity of the already cultivated land and cropping intensity by improved water management measures. The study of Gal et al. (2009) in Morocco and in the Oasis Area in Southern Tunisia suggests that appropriate relationship between irrigated schemes, farms and agro-food processors can be effective for improving food productivity. Chandra and Helen (2010) concluded that irrigation can play a critical role in alleviating poverty and hunger but the environmental and social consequences of large irrigation schemes need to be addressed properly. Chopankulov et al. (2008) have investigated cotton irrigation scheduling in central Asia. Ghumman et al. (2010) and Shakir et al. (2010) have investigated irrigation systems in Pakistan. There are several other studies, addressing irrigation and agricultural issues (Batt and Merkley, 2010; Hye and Siddiqui, 2010; Lecina et al., 2010; Frija et al., 2010,). But depending on the nature of the issues involved, there are still several areas, which

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need further work.

According to Saravanan (2010), emphasis should be focused on laying out broad principles in policy statements for participatory irrigation which may allow multiple actors to debate and share the principles for comprehensive assessment of water management decisions. He has suggested offering diverse forums for actors to debate and share available information. Sanjay et al. (2010) concluded that participatory approach is a key to success of developmental schemes in water sector and to protect environment and maximize benefits of schemes. The various governments of Pakistan focussed on improving institutions and overall governance in the water sector time to time but the real situation has never improved. As a major initiative of institutional reforms, Provincial Irrigation and Drainage Authorities (PIDAs) which are financially autonomous bodies have been created to formulate and implement policies of participatory irrigation. Area Water Boards (AWBs) – one per branch canal have been established.

Farmer organizations FOs – one per distributary – have also been established for participation of farmers. However the system is not improving. There is problem in recovery of abiana, establishment cost is unnecessary high, the crop yield is low as compared to that of many countries world wide. The farmers of tail reaches always complain about short irrigation supply. The large irrigated agricultural systems have their own identity and problems. So the assessment of its irrigated agriculture is utmost important. These are few points which led the authors take up this study. It is an effort to observe a large irrigation system at the gross-root level and assess its performance with respect to various parameters like equity, delivery of outlets, operation and maintenance (O & M) and establishment costs.

Study area

Irrigated agricultural system of Pakistan is one of the world's large agriculture systems. Several canals and watercourses irrigate a large area in three provinces of Khaiber Pakhtoon Khah, Punjab and Sindh. Apart from canal water, thousands of tube-wells are also in use to provide groundwater for agriculture in Pakistan. Irrigated agriculture of the Lower Jhelum Canal System has been investigated in this paper. This canal takes-off from the Jhelum River at Rasul Barrage. The system was commissioned in 1904. The greater part of Chaj Doab – Sargodha and Jhang districts lying between River Jhelum and Chenab are irrigated by the system. Four divisions: Rasul, Shahpur, Kirana and Sargodha are included in the command area. The designed discharge of Lower Jhelum Canal is 156 m^3/s. Its cultivable command area (CCA) is 614,475 ha and gross command area (GCA) is 660406 ha. Total Length of Lower Jhelum Canal System is 2,466 km and number of outlets are 3,050.

METHODOLOGY FOR PERFORMANCE ASSESSMENT

Many researchers, like Cakmak et al. (2010), Grusse et al. (2009), Kuscu (2009), Pavlov et al. (2006) and Bos et al. (2005) have documented various indicators for evaluation of the performance of a canal system. To assess the performance of the LJC system, the indicators defined by Pavlov et al. (2006) and Grusse et al. (2009) have been adopted. In depth economic analysis of the system has been made using these indicators. In depth study at distributary level, Farooka Distributary was selected as a sample. Farooka Distributary has a discharge of 3.0 m^3/s; its CCA is 13,608 ha and it has 59 outlets. Various indicators used in this paper are defined as follows:

Recovery cost ratio (RCR): Recovery cost ratio is the ratio of cost of recovery in form of abiana collected from farmers to the distribution cost.

Economic delivery efficiency (EDE): The economic delivery efficiency is the ratio between the operation and maintenance cost (O&M) and the distribution cost (D).

Relative water cost (RWC): The relative water cost is the ratio between the total irrigation cost (I) and total production cost (P). The cost of irrigation water has a very important role from the farmer's perspective. This indicator shows the share of irrigation cost in the total production cost of a certain crop. Total production cost includes the cost of irrigation, land preparation, fertilizer, pesticide, seed and labour etc.

Relative farm irrigation (RFI) cost: The relative farm irrigation cost is the ratio between on-farm irrigation cost and total irrigation cost. High values of RFI show that there is potential for the reduction of on-farm irrigation cost.

Benefit cost ratio (BCR): The benefit cost ratio is the ratio between irrigation benefits and irrigation costs.

Delivery performance ratio (DPR): The delivery performance ratio of an outlet is the ratio between the observed discharge and target discharge (design discharge).

Data collection and analysis

Distribution costs

In this research, all the costs are expressed in "US Dollars (US$) /1000 m^3/year". Production costs are expressed in "US$/ha". To determine the costs of water distribution, the Lower Jhelum Canal System was divided into the canal segments, called divisions. These divisions represent the main and secondary canal system. The data were collected for each division in terms of operation and maintenance (O & M) and establishment costs to estimate the costs of distribution per unit water volume for each segment. The distribution costs for all the divisions were combined to obtain the distribution cost of the entire Lower Jhelum Canal System. This gives the total expenditures for the water delivery through the main secondary and minor canals up to the farm gate. It is expressed as:

$$\text{Distribution cost} = \sum_{I=1}^{N} CO_{(I)} + \sum_{I=1}^{N} CE_{(I)} \quad (1)$$

Where n is the number of segments/divisions, $C_{o(i)}$ is the actual O&M expenditures for i^{th} canal segment and $C_{e(i)}$ is the actual establishment cost for i^{th} canal segment.

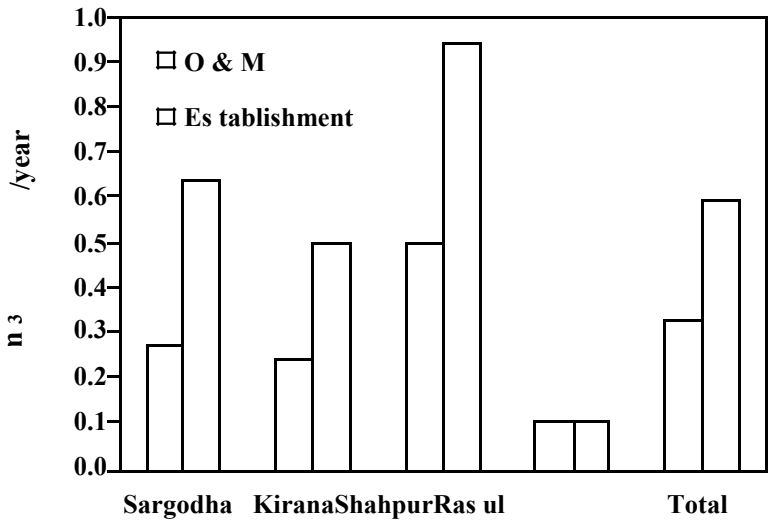

Figure 1. Establishment, operation and maintenance cost.

Table 1. Cost of production of wheat (US$/ha).

Farm	Land preparation	Seed	Fertilizers	Pesticide	Labor	Ground water irrigation	Canal irrigation	Harvesting and threshing	Total production cost
Head	63.52	30.49	111.56	13.64	26.16	51.82	2.03	92.79	392.02
Middle	62.44	31.52	113.13	11.36	29.82	61.87	2.03	88.36	400.54
Tail	60.16	29.56	107.85	11.98	34.20	70.61	2.03	84.66	401.05

Table 2. Cost of production of rice (US$/ha).

Farm	Land preparation	Seed	Plantation	Fertilizers	Pesticide	Labor	Ground water irrigation	Canal irrigation	Harvesting and threshing	Total production cost
Head	103.08	24.05	60.74	61.52	31.28	36.67	217.92	3.44	66.66	605.36
Middle	101.80	24.79	56.72	66.95	31.13	35.69	241.34	3.44	67.97	629.84
Tail	95.33	25.33	56.72	58.26	31.80	30.69	263.56	3.44	61.67	626.80

The O&M and establishment costs worked out in this way are shown in Figure 1.

Recovery (Abiana)

Recovery is the cost collected by the irrigation department from the farmers for the delivery of water from main source to the farm gate. A fixed amount is collected from the farmers in form of Abiana, for the Kharif and Rabi seasons. The information about the water fees was collected in detail for each division. To obtain the recovery of the entire Lower Jhelum Canal the following formula was used:

$$R = \sum_{I=1}^{N} R_{(I)}$$

Where R_i is recovery for the ith system and R is total recovery for the system having n number of segments.

Total production cost

Lagal et al. (2009) have shown that the relationship between irrigated schemes, farms and agro-food processors may provide a roadmap to improve productivity of irrigation water. They conducted a study in the area of the Tadla irrigation scheme in Morocco and southern Tunisia. To investigate such aspects total production cost of crops from irrigated land was estimated in present paper. Two major crops of two main seasons that is Wheat (Rabi) and Rice (Kharif) have been considered. Real life field data have been collected to find out the total production cost of these major crops. Survey was conducted for Farooka Distributary, Rurala Distributary, Charnali Distributary, Old Khawtan Distributary, New Khawtan Distributary and Mallowal Distributary. Twenty four farmers, having (2) land in the range of 1.5 to 20 ha, were selected from each distributary for calculating the production cost. The production cost includes cost of land preparation, irrigation, seeds, fertilizers, weedicides/pesticides, labor etc. Wheat and Rice production costs are given in Tables 1 and 2.

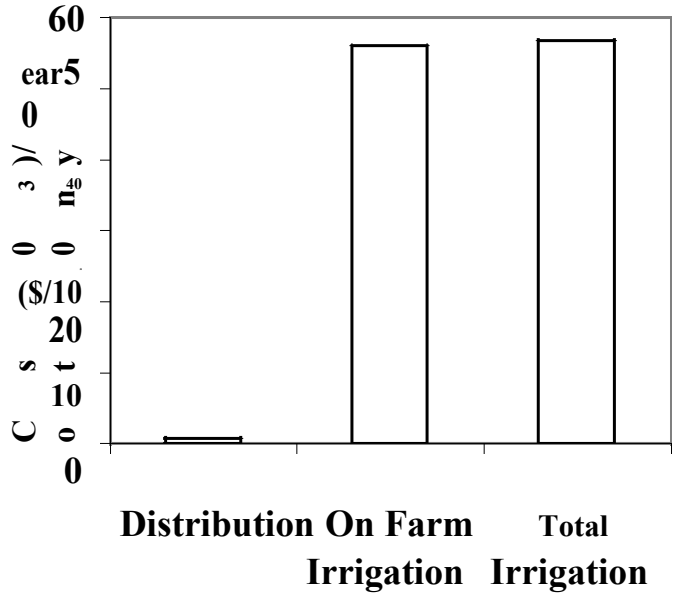

Figure 2. Distribution and on-farm cost.

Table 3A. Groundwater required for crops.

Crops	Total irrigation water requirement (mm)	Canal water supplied (mm)	Groundwater supplied (mm)	Groundwater supplied (1000 m^3/ha)
Wheat	294	183	111	1.11
Rice	713	220	493	4.93
Total	1007	403	604	5.89

Table 3B. Cost of 1000 m^3 of groundwater.

Crops	Groundwater supplied (1000 m^3/ha)	Groundwater cost (US$./ha)	Groundwater cost (US$./1000 m^3)
Wheat	1.11	53.5	48.2
Rice	4.93	209.9	42.59
Total	6.04	263.5	43.62/year

Total irrigation cost

In general, groundwater use is comparatively higher where the canal water supply is deficient. Imache et al. (2009) and Bekkar et al. (2009) have also studied this aspect in the Algerian-Mitidja and Morocco, respectively. According to them the surface irrigation system provides only a small proportion of irrigation water to farmers, who rely mainly on groundwater for irrigation. In present paper the cost of irrigation including groundwater has been collected for the sample canal namely Farooka Distributary. Outlet discharges were measured for each of the selected outlets at the head, middle and tail of the distributary. The amount of canal water applied at the field level was estimated. On-farm irrigation cost, and total irrigation costs are shown in Figure 2. Relative farm-irrigation cost is estimated as 0.984. The supply of canal water and groundwater for the major crops, with respect to the total irrigation water required, is given in Table 3A. The details of groundwater used during the Rabi (Wheat) and Kharif (Rice) at the head, middle and tail are given in Tables 3B and C, respectively.

RESULTS AND DISCUSSION

Figure 3 shows that the total recovery cost of the system as a whole is 0.777. It means that the system bears a loss of about 33%. So improvements in recovery are required to make the system self sustainable. Economic delivery efficiency (EDE) for different segments of the system is shown in Figure 4. The O&M and establishment costs have been shown previously in Figure 1. It is observed that the distribution cost constitutes a greater share of the establishment cost as compared to O & M. The small value of EDE (0.352) means that a large amount that is 64.8% of cost is spent

Table 3C. Variation of groundwater used for wheat and rice.

Location	% Increase in groundwater use w.r.t the head (rice)	% Increase in groundwater use w.r.t the head (wheat)
Middle	10.75	19.39
Tail	20.94	36.25

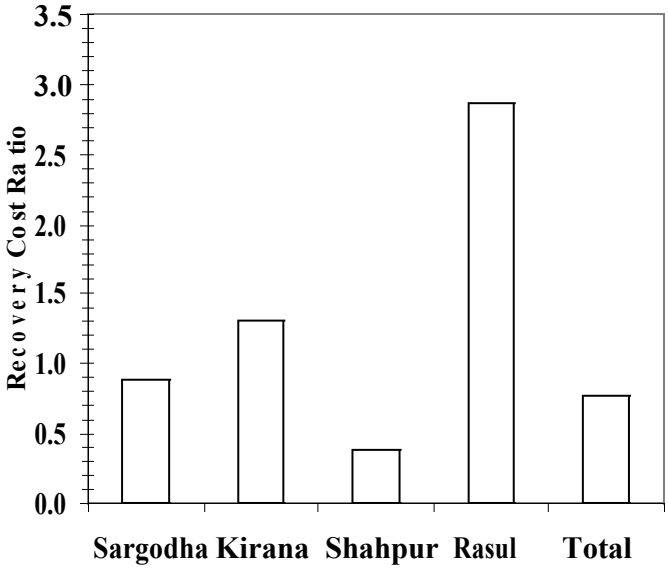

Figure 3. Recovery cost ratio.

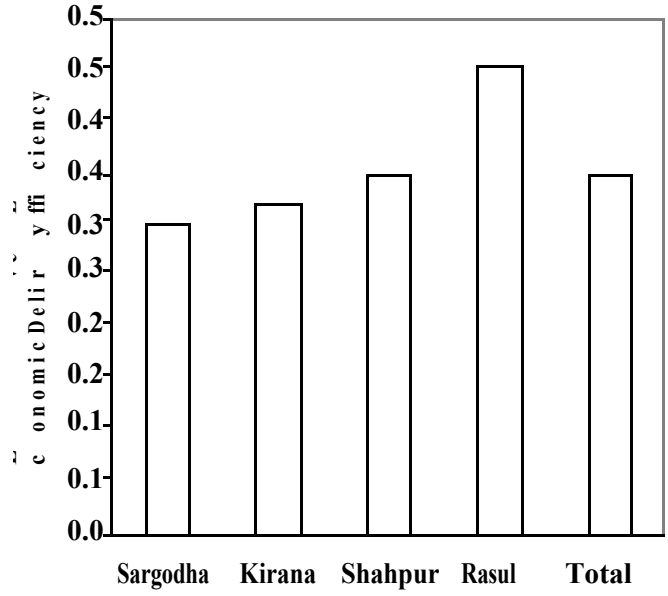

Figure 4. Economic delivery efficiency.

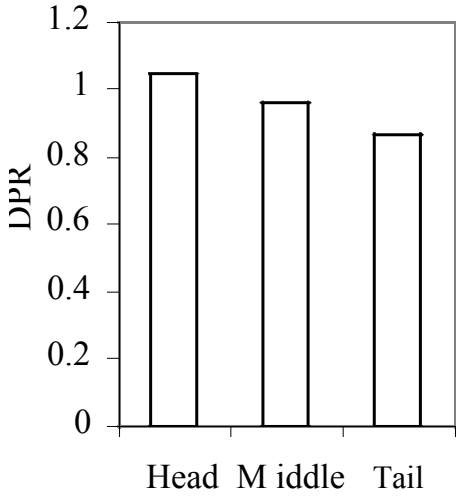

Figure 5. Delivery performance ratio.

on the establishment. In order to make the system more reliable and beneficial, it is necessary to decrease the establishment cost. The Irrigation Department is over-staffed and needs right-sizing. Corruption, political interference and social problems are the main hindrances which need to be addressed seriously.

Relative water cost (RWC) and relative farm irrigation (RFI) costs were found to be 0.255 and 0.971, respectively which show that the distribution cost of canal water is much lower than that of on-farm irrigation cost. Total cost of irrigation water depends on the amount of groundwater used to supplement the canal water. Tables 3A, B and C give the cost of groundwater which shows that the groundwater is very expensive. Furthermore, the average canal water supplies during the Kharif and Rabi are almost the same, whereas there is a huge difference between the demands during these seasons. Rice, the major crop of Kharif season requires 3 to 4 times more water as compared to wheat, the main crop of Rabi. The shortfall is obviously eked out through groundwater. The delivery performance ratio (DPR) of the outlets located at different locations of distributary that is the head, middle and tail is shown in Figure 5. The average DPR of representative distributary was 0.957. The DPR of the head, middle and tail outlets was 1.043, 0.962 and 0.865, respectively. The pattern clearly reflects that the head outlets draw more than their share (the design discharge) at the cost of the tail outlets. Equity, as related to water delivery system, requires the delivery of the fair share of water to the farmers throughout the system. Relative neglect of design and operational factors are the major explanation for the gap between the potential and actual

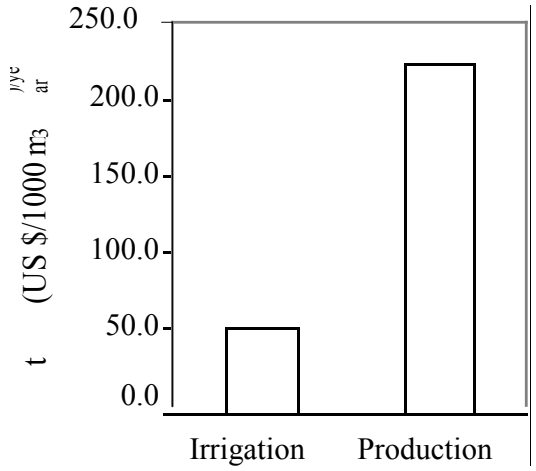

Figure 6. Comparison of Irrigation and production cost.

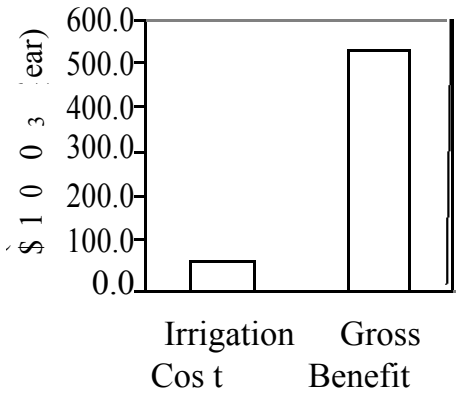

Figure 7. Comparison of irrigation cost and benefits.

performance of the irrigation system. Tempering is usually observed during high demand time. During the peak water demand farmers do not get water as per crop water requirements, so they start tempering the outlets. The head outlets get more than their design discharge due to which the tail outlets suffer.

For a successful irrigation system, the value of irrigation benefits must exceed the irrigation costs. There is a significant difference in yields of wheat and rice crops across the head, middle and tail reaches. In general, yields are higher for head reaches than those for middle and tail reaches. It was estimated that wheat crop yield for the head reaches was 16.79% higher than that of the tail reaches. Rice crop yield for the head reaches was 19.26% higher than that of the tail. Obviously, the key factor influencing these differences in crop yield for various locations is the canal water availability and the amount of groundwater used to supplement the shortfall in canal water. The quality of canal water is generally better for irrigation as compared to the groundwater which directly affects the yield of crops. The gross and net margins show that their highest values are achieved where there is higher yields and lower cost of production. Gross and Net Benefit Cost Ratio is 7.652 and 4.440 respectively. The crop productivity of Pakistan is far less than that of the neighbours, China and India, and many other countries (Ahmad et al., 2004; Shah and Zaman, 2007). Wheat yield of Pakistan is lower than that of China, Russia, France, Germany, United Kingdom, Argentina (Government of Pakistan, 2009). Figures 6 and 7 show the comparison between total irrigation cost and gross and net benefits, respectively. Benefit cost ratio is found to be 9.21. It is observed that the irrigation system in its current conditions is profitable.

Conclusion

The following are the key conclusions of the present study:

1. Only 77.7% cost is recovered in the form of Abiana against the total distribution cost of the system due to which the system is not self sustainable.
2. The wheat crop yield at the head is 16.79% higher than that at the tail. The rice crop yield at the head is also higher than that at the tail due to the use of expensive groundwater.
3. 97.1% cost is spent on on-farm irrigation, whereas only 2.9% is spent on distribution.
4. Irrigation in Punjab is profitable and its profitability may further be increased by decreasing on-farm irrigation cost.
5. Economic delivery efficiency of 0.352 shows that the establishment cost is higher than that of O&M cost. Only 35.2% cost is spent on the O&M and remaining 64.8% is the establishment cost making the system bureaucratic.
6. The system does not fulfil the criterion for equity.

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