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ECONOMIC EVALUATION OF DIFFERENT IRRIGATION SYSTEMS FOR WHEAT PRODUCTION IN RECHNA DOAB, PAKISTAN

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This study was designed to investigate causes responsible for low water productivity and demonstrate various irrigation techniques at farmers' fields for its improvement. A comprehensive questionnaire was designed and 230 farmers were interviewed in cotton-wheat area, mixed crop area, and rice-wheat area, in Rechna Doab located in Punjab, Pakistan. The results showed that majority of the farmers is concerned over shortage of canal water, energy and fertilizer related issues which were the main factors affecting their water productivity (WP). Field experiments showed that drip irrigation method gave WP of 2.26 kg m^{-3} for wheat crop and 40% water saving as compared with conventional irrigation method. Perforated pipe irrigation technique also resulted in relatively better WP of 1.46 kg m^{-3} and saved water up to 20%. Benefit Cost ratios for drip, perforated pipe and conventional were 2.47, 2.20 and 1.96, respectively. The Internal Rate of Return (IRR) for drip and perforated pipe irrigations over conventional irrigation practices were 40% and 36%, respectively. These findings suggested that flexible irrigation techniques in response to crop water requirements can improve land and water productivity, by building on farm water storages and conveying water through pipes to minimize the losses.
Keywords: Water productivity, efficient irrigation, benefit cost ratio, Rechna Doab, Internal Rate of Return (IRR)

INTRODUCTION

Pakistan is primarily an agricultural country and its agricultural production depends on adequate availability of irrigation water supplies because it lies in the arid to semi-arid region (Archer *et al*., 2010; Qureshi *et al*., 2011). The average annual rainfall varies from less than 200 mm in southern parts of the country to more than 1500 mm in the northern mountainous areas (Wake, 1989; Archer and Fowler, 2004; Archer *et al*., 2011). Therefore, the country has built the largest contiguous irrigation system comprising three reservoirs (Mangla, Tarbela and Chashma), 23 barrages/head works, 12 inter-river link canals and 45 canal commands, extending over 60,800 km and providing water to over 140,000 watercourses (GOP, 2013). The canal commanded irrigated area is about 16 Mha in addition to about 4 Mha of rainfed areas. The major sources of irrigation water are river supplies, with 70% of their water coming from melting of glaciers and 30% from monsoon rainfalls. These river supplies are seasonal and vary from less than 123 billion cubic meter (BCM) during dry years to more than 185 BCM during heavy rainfall and flood seasons. Although the system does not need any external energy to bring water to the fields but its efficiency is extremely low (about 35%) due to water losses taking place in the form of conveyance and application losses (Hussain *et al*., 2011). These water losses occur during their conveyance from head works on rivers to the fields through canal network and watercourses and also from the irrigated fields. In order to improve irrigation efficiency, there is a need to monitor and minimize these losses using efficient innovative methods.

There are a number of irrigation methods, which have the potential to apply irrigation water efficiently. Each method, however, works at the best under specific farming conditions (Bakhsh *et al*., 2008). For example, sprinkler irrigation is mostly suitable under undulating terrain where otherwise it is difficult to apply irrigation water under gravity. Similarly, drip irrigation is highly suitable for point application of irrigation water to orchards. Both sprinkler and drip are considered as the pressurized high efficiency irrigation systems. In Punjab, Pakistan, under irrigated canal command areas, the cultivated land is mostly flat and fields are leveled where farmers grow mostly row crops and apply irrigation water in the form of flooding (Ashraf *et al*., 2010). Now the situation has changed, the irrigation water is becoming scarce as the water availability in Pakistan has approached about 1000 m^3/capita, categorizing the country as a water deficit country. Moreover, projections show that with the current pace of increasing population, water availability will reach 915 m^3 / capita in 2020 (GOP, 2011). Under these circumstances, there is a need to apply irrigation water efficiently to increase water productivity, which has been reported to be as low as 0.1 kg m^{-3} of water (GOP, 2011).

To improve water productivity either we have to increase the crop yields or minimize the water losses or manage both the parameters (Jehangir *et al.,* 2007). In Punjab, majority of the farmers have small land holdings of about less than 5 ha. These small farmers are mostly not in a position to afford the expensive irrigation systems such as sprinkler and drip irrigation systems. In Pakistan, energy prices are quite high and moreover, electric tube wells are subject to frequent load shedding problems. Tube wells fulfill more than 40% of the crop water requirement (Briscoe and Qamar, 2007). Under conventional irrigation methods, tube well water takes longer time to reach the fields and sometimes, due to load shedding of electric power, seepage losses from filled water courses are high (Enciso and Peries, 2005).

Keeping in view the above situation of fuel energy prices, frequent breakdown of electricity and farming of close growing crops; there is a need to introduce cheap and innovative methods to improve water productivity and irrigation efficiency. Although there are efficient irrigation methods but their economic viability is not known and also there are questions on the payback period and benefit cost ratio of these methods. This paper aimed at investigating different irrigation techniques, which can be adopted easily by the farmers. These techniques do not need any extra technical know-how for their successful operations along with evaluating economic viability of these methods for benefit of the farmers and policy makers. The specific objectives of the study were to identify the causes responsible for low water productivity and suggest various retrofit measures for its improvement, conduct field experiments at farmers' fields to demonstrate benefits of the proposed efficient irrigation system for improving water productivity, and evaluate economic viability of proposed irrigation techniques in terms of B/C ratio and Internal Rate of Return (IRR) for benefits of the farmers.

MATERIALS AND METHODS

Study area: This study was conducted at four sites: Samundri (30.48° N, 71.52° E), Chiniot (31.72° N, 72.97° E.), Hafizabad (32.03° N, 73.11° E.), and Postgraduate Agriculture Research Station (PARS), Faisalabad (31.2° N, 73° E). These sites are situated in Rachna Doab- a land between the Ravi and Chenab Rivers- located in Punjab province of Pakistan as shown in Figure 1.

To investigate soil classification and texture in the study area, soil samples were collected from each site and were sent to Ayub Agriculture Research Institute (AARI). The results described that Samundri site has clay loam soil, with 34% sand, 26% silt, and 40% clay. The soil has organic matter of 0.62% with pH ranging between 7.5 and 7.8. Chiniot site is fertile, alluvial soil and can be classified as sandy loam, with 78% sand, 7% silt and 15% clay. The organic matter in the soil is 0.78% with pH ranging between 7.8 and 7.9. The soil of Hafizabad site is also alluvial, fertile, and classified as sandy clay loam, with 57% sand, 12% silt, and 32% clay. The soil of PARS site is predominantly medium to moderately coarse, which is generally low in organic matter contents having pH between 7.0 and 8.5. The soil of PARS is categorized as sandy loam, with 60% sand, 25% silt, and 15% clay.

The study area (all sites) has a very diverse climate, with hot summer and cold winter. The maximum temperature in summer reaches up to 49°C and in winter, the minimum temperature may fall near freezing point. Summer season in the study area starts from April and continues until October and winter season, on the other hand, starts from November and continues till March. June and July are the hottest months, whereas December and January are the coldest months. An average annual rainfall at Samundri, Chiniot, Hafizabad, and PARS sites is about 350, 399, 790, and 386 mm, respectively (ASP, 2010).

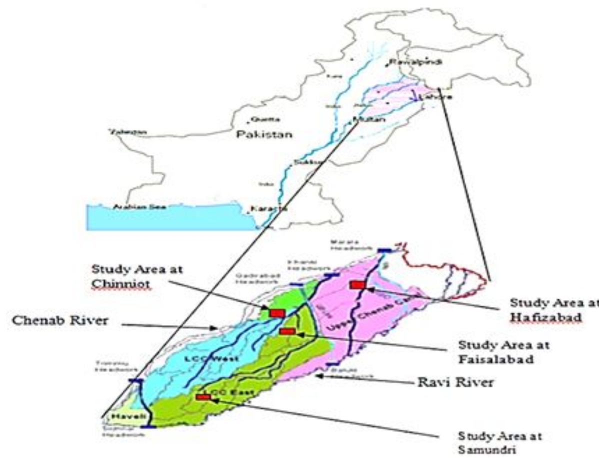

Figure 1. Location map of the study area

Field surveys: During phase-I of the study, a comprehensive questionnaire was designed to determine water productivity for wheat crop at all sites to explore the causes of low water productivity and the factors affecting it. The questionnaire was pretested in the field to identify deficiencies in the proforma as well as to incorporate various concerns of the farmers for their better understanding of the questions.

After developing the questionnaire, three sites (Samundri, Chiniot, and Hafizabad) were selected to get primary data. For this, 80 farmers from Samundri, 66 from Chiniot, and 84 from Hafizabad were randomly selected from five villages in the vicinity of each site. From each village, about 13-16 farmers were interviewed for collecting detailed information regarding their farming practices and crop yields.

The survey data was analyzed to determine the general characteristics of the study area such as education level, age of respondents, farmers land holdings, soil fertility level, cropping pattern and intensity, crop yields, irrigation water sources and their quality. The existing water productivities of wheat crops for each site were calculated by using the following relationship.

$$\text{Water Productivity (WP)} = \frac{\text{Crop Yield(kg/ha)}}{\text{Total volume of water applied}(m^3/ha)}$$

The estimates about the crop yields were provided by the farmers. The total water applied was determined by using following relationship.

$$\text{Total water applied } (m^3/ha) = \frac{(Q_{TW} \times T_{TW}) + (Q_{CW} \times T_{CW})}{\text{Area (ha)}}$$

Where Q_{TW} is discharge of tube well in m^3/sec, T_{TW} is total time of irrigation (sec) with tube well water, Q_{CW} is discharge of mogha (m^3/sec) and T_{CW} is total time of irrigation (sec) with canal water.

Field experiments: During phase-II of the study, field experiments at farmer's fields were conducted at four experimental sites (Samundri, Chiniot, Hafizabad, and PARS) under a Randomized Complete Block Design (CRD). Wheat crop was grown at each site for the year 2012-13. On Samundri site wheat was grown using conventional irrigation and two efficient irrigation techniques- drip and perforated pipe irrigation, and on other sites wheat was treated with conventional irrigation and two efficient irrigation methods- perforated pipe and with open end irrigation methods.

Management practices such as cultivation, planking, sowing, fertilizer application, irrigation application and harvesting were performed at each site.

Schedule of management activities performed at Samundri site is shown in Table 1, as an example. After harvesting, wheat yield was determined at each site using steel frame of 1 m^2 in size.

***Economic analysis*:** The procedure adopted by Chaudhry *et al.* (1992) in estimating and subsequently apportioning the cost and returns of various items was used in this study. The interest rate was taken as 12 percent. In case of perforated pipe and drip irrigation methods, depreciation cost was also included for one season of production (Seckler *et al*., 1987). The economic analysis was carried out as given below:

***Gross margin*:** Gross margin was estimated for the purpose of making comparisons. The formula used to calculate the gross margins is as under:

Gross margin = Total revenue – Variable cost

***Net return*:** Net Return is the difference between total revenue and total cost. The formula of the net return is as under:

Net return = Total revenue – Total cost

***Discounted capital budgeting techniques*:** Three measures are often used in finding the present worth of the future values of a project: BCR, NPV, and IRR. These were used by Uzunoz and Akcay (2006) and also by Satyasai (2009), and are employed in this analysis. For simplicity, it is assumed in this analysis that costs and revenue stay constant in"current" rupees at observed values in 2012. In other words, we assume zero inflation and those input-to-output prices remain constant. Otherwise we would have to increase the nominal ("current") value of costs, revenue, and margins in the future years and use some forecasts of future relative prices. It is also assumed that perforated pipe and drip irrigation systems have zero salvage value at the end of their useful lives and the total cost of the investment in these projects is made in the first year. The incremental net costs and benefits of a project (perforated pipe and drip irrigation) were used to estimate the economic returns of perforated pipe and drip irrigation over conventional irrigation system (Ashfaq *et al*., 2009). To evaluate economic efficiency of drip irrigation in comparison to perforated pipe, the Internal Rate of Return (IRR) was considered to be the most appropriate tool for this analysis (Asmon and Rothe, 2006).

***Benefit Cost Ratio (BCR)*:** Benefit Cost Ratio (BCR) is the ratio of present value of benefits to present value of costs, and may be given:

$$BCR = \sum \frac{B_t}{(1+r)^t} / \sum \frac{C_t}{(1+r)^t}$$

Where, B_t = benefit in each year, C_t = cost in each year, r = interest (discount) rate, t = no. of years (1, 2 …n,)

Project is viable and worth taking up when the BC ratio is more than 1.

***Net present value (NPV)*:** It is the difference between present value (PV) of benefits and PV of costs and denotes net worth of the project. It is representative of the dynamic investment appraisal and a discounted cash flow method. It may be given:

$$NPV = \sum \frac{B_t}{(1+r^*)^n} - \sum \frac{C_t}{(1+r^*)^n}$$

The decision criterion is selection of project with positive NPV and ranking the projects as per magnitude of NPV in case of capital rationing.

***Internal rate of return (IRR)*:** The earlier two measures are computed at a given rate of discount. Here the implied

Table 1. A typical schedule of management activities.

Sr.	Activities	Date	Sr.	Activities	Date
1	Pre-sowing irrigation (Rouni)	Nov 06,2012	8	Urea Fertilizer application @ 123.5 kg/ha	Dec 18, 2012
2	Cultivation with tine	Nov 18,2012	9	1st Irrigation	Dec 18, 2012
3	Cultivation with Rotavator	Nov 18,2012	10	Urea Fertilizer application @ 123.5 kg/ha	Feb 02, 2013
4	DAP Fertilizer application @123.5 kg/ha	Nov 18,2012	11	2ndIrrigation	Feb 02, 2013
5	Planking	Nov 18,2012	12	Urea Fertilizer application @ 123.5 kg/ha	Mar 21, 2013
6	Soil sampling before sowing	Nov 17,2012	13	3rd Irrigation	Mar 21, 2013
7	Sowing (variety Sahar)	Nov 19,2012	14	Harvesting	May 01, 2013

discount rate is computed such that PV of benefits equals PV of costs and NPV becomes zero. Thus, IRR is the rate 'r*' that can make NPV zero.

$$IRR = r^* \quad \text{such that } NPV = 0$$

The projects with IRR greater than the cost of capital should be selected and under capital rationing, projects with higher IRR get priority over the others.

RESULTS AND DISCUSSION

Factors affecting water productivity: A total of 230 farmers i.e. 80, 66 and 84 farmers were interviewed at Samundary, Chiniote and Hafizabad areas, respectively. Majority of the farmers had their education level under matric i.e. secondary school education and were also in the age group ranging from 30 to 50 years. From irrigation point of view, location of the site was important, so Samundari site was at tail of the irrigation network commanded by Gogera branch canal. About 74%, 64% and 61% of the interviewed farmers expressed their concerns about shortage of canal water, poor quality groundwater and fertilizer issues, respectively, which resulted in low WP. Similarly, 95%, 91% and 80% of the farmers showed their concerns of canal water shortages, energy and fertilizer issues, respectively, in the Chiniote area. The 89%, 85% and 49% farmers in Hafizabad area prioritized their concerns as energy, fertilizer and canal water shortages, respectively. Majority of the farmers were concerned about the shortage of canal water, energy and fertilizers, the main factors affecting their land and water productivity. Other factors such as seed, financial constraints, soil fertility and lack of mechanization were also reported as the factors affecting their crop yields and land and water productivity.

Field experimental results: The results indicated that all treatments were significantly different from each other at 5% probability level. On the average, treatment using drip irrigation produced maximum wheat yield of 5076.67 kg ha^{-1} while conventional irrigation treatment has minimum yield of 3483.76 kg ha^{-1} as given in Table 2. Drip irrigation and perforated pipe irrigation showed 46% and 25% increase in yields as compared to conventional irrigation. Similar results have been reported by Mahmood *et al*. (2005).

The data of water productivity for all sites with different treatments are shown in Table 3. The Statistics 8.1 software was used to analyze the collected data.

Water productivity for drip irrigation was 2.26 kg m^{-3} as compared with that under conventional method of 0.94 kg m^{-3}. All treatments were significantly different from one another at 5% level of significance (Table 3).

Table 4 shows the economic analysis of per hectare wheat

Table 2. Irrigation methods effects on wheat yield at four sites (Kg ha^{-1}).

Treatments	Faisalabad (Samundri)	Chiniot	Hafizabad	PARS (Faisalabad)	Average
Conventional	3373.33c	3840.00c	3740.00c	2981.69c	3483.76d
Perforated	4230b (25%)	5184.67a (35%)	4370.00a (17%)	3613.13a (21%)	4349.45b (25%)
Open End	-	4586.67b (19%)	4123.33b (10%)	3338.59b (12%)	4016.20c (15%)
Drip	5076.67a (50%)	-	-	-	5076.67a (46%)

Table 3. Irrigation methods effects on water productivity (kg m^{-3}) at four sites.

Treatments	Faisalabad (Samundri)	Chiniot	Hafizabad	PARS (Faisalabad)	Average
Conventional	0.90c	1.14c	0.92c	0.80c	0.94
Perforated	1.46a	1.72a	1.36a	1.22a	1.44
Open End	-	1.55b	1.18b	1.07b	1.27
Drip	2.26b	-	-	-	2.26

Table 4. Economic analysis of wheat production under different irrigation systems in district Faisalabad.

Activity	Conventional method (Farmer survey, N=80)	Conventional method (Experimental data)	Perforated pipe (Experimental data)	Drip irrigation (Experimental data)
Total variable cost (Rs.)	72410.21	67464.99	59408.44	54853.76
Total fixed cost (Rs.)	8300.28	3734.64	16673.09	16926.81
Total Cost (Rs.)	80710.49	71199.63	76081.53	71780.57
Total Revenue (Rs.)	118933	115948	145393.5	177464.60
Gross Margin (Rs.)	46522.77	48482.99	85985.02	122610.80
Net Return (Rs.)	38222.48	44748.35	69311.93	105684
Benefit Cost Ratio	1.47	1.63	1.91	2.47

Table 5. Economic analysis of wheat production under conventional and perforated pipe irrigation system in district Chiniot.

Activity	Conventional method (Farmer survey) N=66	Conventional method (Experimental data)	Perforated pipe (Experimental data)
Total variable cost (Rs.)	60610.69	59724.60	58168.50
Total fixed cost (Rs.)	5158.84	4146.64	16954.08
Total cost (Rs.)	65769.53	63871.24	75122.58
Total revenue (Rs.)	129233.30	134377.90	181441.30
Gross margin (Rs.)	68622.60	74653.28	123272.80
Net returns (Rs.)	63463.76	70506.64	106318.70
BCR	1.96	2.10	2.42

Table 6. Economic analysis of wheat production under conventional and perforated pipe irrigation system in district Hafizabad.

Activity	Conventional method (Farmer survey) N=82	Conventional method (Experimental data)	Perforated pipe (Experimental data)
Total variable cost (Rs.)	55481.83	47380.03	44657.60
Total fixed cost (Rs.)	4776.80	4538.77	17395.42
Total cost (Rs.)	60258.64	51918.81	62053.02
Total revenue (Rs.)	98470.33	112187.4	139308.00
Gross margin (Rs.)	42988.50	64807.37	94650.40
Net returns (Rs.)	38211.69	60268.59	77254.98
BCR	1.63	2.16	2.24

Table 7. BCR, NPV and IRR for wheat crop under perforated pipe over conventional irrigation system in three districts of Punjab.

Districts	At 10%		12%		15%		18%		IRR
	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	(%)
Faisalabad	1.45	18870.85	1.41	16580.78	1.34	13494.71	1.28	10776.05	36
Chiniot	1.64	27218.30	1.58	24461.19	1.51	20737.51	1.44	17447.95	45
Hafizabad	1.33	14555.62	1.29	12423.43	1.23	9555.60	1.17	7035.37	29

yield without land rent under flood (traditional) irrigation, perforated pipe and drip irrigation system in district Faisalabad. The data were collected from famers as well as at experimental station for the year 2012-13. Total cost of wheat production was calculated by adding the total variable cost and total fixed cost per hectare. The per hectare total cost incurred under drip irrigation system was recorded as the highest as compared to other two irrigation methods. This was due to high installation cost of drip irrigation system that was divided for each growing season. The total revenue, gross margin and net returns per hectare of wheat production were the highest at experimental site under drip irrigation system as shown in Table 4. It was found that the returns obtained from conventional and perforated pipe irrigation systems were far below than that under drip irrigation system. The Benefit Cost Ratio (BCR) for these irrigation systems was also calculated from the data of experimental station and also of farmer's surveys. BCR for drip irrigation system was calculated to be 2.47 which is the highest amongst three irrigation systems. The results indicated that by investing one rupee, returns were 2.47 rupees. Based on findings of the study, drip irrigation system lead to give higher profit as well as saves sufficient amount of irrigation water.

Table 5 depicts that the different costs of production and economic returns of producing one hectare of wheat under conventional as well as perforated pipe irrigation system at district Chiniot. Total cost of production under perforated pipe was high i.e. Rs. 75122.This is because of installation cost of perforated pipe incurred for three years of production. The highest total revenue for perforated pipe was Rs. 181441 estimated by adding the total production of wheat product valuewith wheat straw. Outcomes of 66 famers under conventional irrigation method were found to be at the bottom in terms of gross margin, net returns, and BCR. The results also revealed that gross margin, net returns, and BCR were again high for perforated pipe.

Table 6 reveals that economic returns for production of one hectare of wheat by incurring different types of cost for two methods of irrigation at district Hafizabad. The results showed that the total cost of wheat production was highest in case of perforated pipe system. The outcomes of one hectare of wheat production were significant in terms of total revenue, gross margin, net returns and BCR again for

Table 8. BCR, NPV and IRR for wheat crop under drip irrigation through incremental benefits and costs over conventional irrigation method in district Faisalabad (per hectare).

District	At 10%		12%		15%		18%		IRR
	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	(%)
Faisalabad	2.11	192911.8	1.99	165397.2	1.82	130789.9	1.67	102614.9	40.00

Table 9. BCR, NPV and IRR for wheat crop under drip irrigation through incremental benefits and costs over perforated pipe irrigation system in district Faisalabad (per hectare).

District	At 10%		12%		15%		18%		IRR
	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	BCR	NPV (Rs.)	(%)
Faisalabad	1.31	38429.00	1.23	27826.32	1.13	14620.2	1.04	4010.7	19.00

perforated pipe irrigation method at Hafizabad experimental site. The results of famer surveys in two districts namely Faisalabad and Chiniot were similar to district Hafizabad. The data from Hafizabd area also depicted lower values of total revenue, gross margin, net returns and BCR

Findings of above all three districts of Punjab significantly express the relative advantages of perforated pipe and drip irrigation system over conventional irrigation method.

The above Table 7 shows benefit cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) for wheat crop from the data collected for the year 2012-13. BCR and NPV were calculated from incremental benefits and costs of perforated pipe over conventional irrigation method of experimental site at different discount rates. It is evident from the table that at 10 percent discount rate, BCR was the highest for the district Chiniot and the lowest for the district Hafizabad. While at the similar discount rate, NPV was also highest for Chiniot district and lowest for the district of Hafizabad. At this discount rate, district Faisalabad occupied the central position both for BCR and NPV. Table 7 clearly indicates that at different levels of discount rates the results remain the same. District Chiniot was ahead than the district Faisalabad and Hafizabad.

With regards to Internal Rate of Return (IRR), again district Chiniot with 45 % IRR was at a leading place and similar are the results for other districts as in case of BCR and NPV at different discount rates.

Table 8 shows the incremental net benefits and costs obtained from drip system in comparison to traditional irrigation method for wheat production on per hectare basis. Internal Rate of Return (IRR) for this study was calculated to be 40 percent. It means that it will recover all costs at 40 percent interest rate and still break even. The results also indicated the Benefit Cost Ratio (BCR) at different discount rates. At 10 percent discount rate, highest BCR was calculated for drip irrigation system i.e. 2.11. While at 12, 15 and 18 percent discount rates, BCR was estimated to be 1.99, 1.82 and 1.67, respectively for drip irrigation system. Similarly, Net Present Value (NPV) at different discount rates was also calculated. The results showed the highest NPV for drip irrigations system at 10 percent discount rate. The results also indicated decrease in BCR and NPV as discount rate increases.

The results of table 9 also show the absolute advantages of drip irrigation over perforated pipe irrigation for production of wheat crop. Additional costs also incurred for installation of drip irrigation system which have 10 years of useful life. The results showed an estimate of Internal Rate of Return (IRR) of 19 percent. Benefit Cost Ratio (BCR) was calculated by taking ratio of the total revenue and total cost. The results showed highest BCR at 10 percent discount rate (i.e. 1.31). At 12, 15 and 18 percent discount rates, BCR was estimated to be 1.23, 1.13 and 1.04, respectively for drip irrigation system. Similarly, Net Present Value (NPV) was also highest at 10 percent of discount rate and decreases as discount rate increases. NPV was zero at 19 percent discount rate. After estimation of discounted capital budgeting techniques, it was finally concluded that drip irrigation experiment was more profitable rather than traditional and perforated pipe. From findings of the study, it was found that drip irrigation system had absolute advantages over traditional as well as perforated pipe irrigation systems. Moreover, the analysis showed that drip irrigation system got priority due to higher IRR over traditional irrigation system rather than perforated pipe irrigation system.

***Conclusions*:** The study aimed at investigating the causes responsible for low water productivity and suggesting feasible and efficient irrigation techniques for its improvement. Followings are the salient conclusions drawn from the study:

- Canal water shortages, poor groundwater quality, fertilizer, seed, energy, financial constraints and low soil fertility issues were reported and are ranked here based on majority of the respondents from the survey area.
- Drip irrigation, perforated pipe irrigation and flood irrigation practices showed irrigation efficiencies of 95-98%, 65-76% and 50-59% respectively, for wheat at the experimental sites.
- Drip irrigation, perforated pipe irrigation and flood irrigation produced water productivity of 2.26, 0.98-

1.72 and 0.60-1.14 kg m^{-3} respectively, for wheat at the experimental sites.

- Benefit cost ratio for drip irrigation was found to be 2.47 and internal rate of return (IRR) over conventional irrigation method was 40%.
- Benefit Cost ratio for perforated pipe irrigation ranged from 1.91 to 2.42 depending on site conditions and IRR over conventional irrigation practices was 29%.

1. ***Policy recommendations:*** There are many ways to improve crop water productivity and irrigation efficiency; however, it needs to be site specific. Every method is not viable at every farm. So there is a need to develop technology packages for each zone based on its characteristics such as soil type, topography, crops to be grown, water source and quality and above all skill and commitment of the farmers. Followings are the proposed guidelines based on field survey, field experiments and observations to promote adaptation of the high efficiency irrigation system (HEIS) for improving water productivity and farm income:
2. Drip irrigation is the most efficient but at the same time it is an expansive option, which also needs technical knowledge as well as intensive training for its successful operation. There is a need of improvements in this technique, for its economic and easy operation to ensure high irrigation efficiency. Perforated pipe irrigation provides an option to convey water with 100% efficiency from source to the field along with improving irrigation efficiency because of enhanced water supplies delivered at the field outlet i.e. nakka.
3. Currently, there is lack of technical viable design of HEIS. So there is an urgent need of a design from those professionals, who are not involved in the sale of the system i.e. third party design or farmer friendly design.
4. Prior to installation of HEIS, there is a dire need of proper training of the farmers, who will be the actual operator/user of the system.
5. Backup support and indigenization of the system and its components should be encouraged.
6. Capacity building of the manufacturers, suppliers, installers, local technicians – Service Providers and farmers is required along with providing irrigation scheduling and fertigation scheme for improving crop productivity.

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