Research Article

An Economic Analysis of High Efficiency Irrigation Systems in Punjab, Pakistan

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Abstract | The growing demand for water resources highlights the need for improved management of this diminishing resource to ensure high water productivity. In order to cope with this situation, it is imperative to make use of available water resources more efficiently through high-efficiency irrigation systems (HEIs). The present study aimed to conduct the economic analysis of high efficiency irrigation systems in Punjab province of Pakistan. We also measured and compared the water productivity of modern and conventional-irrigated farms. We used primary data collected from 120 farmers located in Nurpur Thal, Bhalwal, Sargodha and Lodhran districts of Punjab province. These areas were purposively selected based on relatively higher concentration of HEI infrastructures installed on the farms. Sprinkler irrigation system was mainly installed on wheat crop while the drip irrigation systems were installed on mango orchards. Therefore, one half of the sample consisted of modern and conventional farmers growing wheat crop and the other half of the sample consisted of modern and conventional farmers growing mango orchards. Economic analysis measures of benefit-cost ratio (BCR) and net present value (NPV) were estimated. The results of the study showed that the users of high-efficiency irrigation systems (sprinkler and drip irrigation) earned higher gross margins. The BCR and NPV values showed that installation of HEI systems was an economically feasible option. In addition, water productivity at modern farms was higher than those of conventional farms. Our results showed that most of the farmers using HEIs were large farmers, therefore, we suggest that policy interventions should be directed at increasing the adoption rates among small farmers. This could be done by spreading awareness among the farmers about the economic benefits offered by HEIs.

Received | May 26, 2018; **Accepted** | October 22, 2018; **Published** | November 17, 2018
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Citation | Razzaq, A., A. Rehman, A.H. Qureshi, I. Javed, R. Saqib and M.N. Iqbal. 2018. An economic analysis of high efficiency irrigation systems in Punjab, Pakistan. *Sarhad Journal of Agriculture,* 34(4): 818-826.
DOI | http://dx.doi.org/10.17582/journal.sja/2018/34.4.818.826
Keywords | Benefit-cost ratio, NPV, Economic analysis, Drip irrigation, Sprinkler irrigation, Water productivity, Punjab, Pakistan

Introduction

Pakistan is an agricultural economy, and the overall economic performance of the country largely depends on the performance of agriculture sector. The rate of economic growth of Pakistan is affected by whatever happens to its agriculture. Past experiences show that the periods of high/low economic growth of national economy generally coincide with the trends in the growth of its agriculture sector of Pakistan (Ali, 2000).

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Pakistan has an immense need to ensure food security which has also become a national priority amid a rapidly growing population. Food security of Pakistan is threatened by several issues among which the water scarcity calls for urgent attention. Solutions aimed at addressing the food security issue such as improved varieties and better management practices cannot be fruitful in the absence of water. The problem of reduced water availability for agriculture sector due to its high demand in other competitive uses could be managed by increasing water use efficiency in crop production (Raza et al., 2012).

Irrigation development plays a vital role in improving farmers' income through improved agricultural productivity, cropping intensity, employment opportunities, and wage rate (Dhawan, 1988; Vaidyanathan et al., 1994; Bhattarai and Narayana Moorthy, 2003). However, Pakistan is facing a serious water shortage. Pakistan was an abundant-water country in 1947 with an annual per capita water availability of 5650 m^3. However, the water resources of the country continued to deplete due to Indus Water Treaty, 1960, decreased trans-boundary flows of water into the rivers, and exponential population growth. Currently, the annual per capita water availability in Pakistan stands at only 964 m^3 which brings it very close to the stage of 'acute water shortage'. The excessive reliance on groundwater further aggravates the situation as groundwater fulfils more than 60 percent of Pakistan's agricultural needs. This excessive reliance on groundwater is causing environmental problems such as salinity and contamination of aquifers (GOP, 2014).

Irrigation water supplies can be improved by the addition of new water reservoirs as well as by adjusting irrigation water losses, i.e. conveyance and on-farm losses. One of the available options to regulate field losses and increase on-farm water productivity is to replace the conventional flood irrigation with high efficiency irrigation systems (HEIs).

Currently, the common mode of irrigation in Pakistan is flood irrigation method (FIM) which is highly inefficient in terms of water use for crop production. This is evident by the fact Pakistan's agricultural water productivity is only 0.13 kg/m^3 which is one-third of the neighboring India and one-sixth of China's water productivity (GOP, 2014). Various management practices like *warahbandi*, farmer organizations, and *khaal panchayats* have been introduced from time to time to improve water use efficiency, but these strategies largely failed to achieve the goals of higher water use efficiency at farms. Micro-irrigation (MI) is yet another strategy which was introduced in Pakistan with the objective of increasing water use efficiency. MI or high-efficiency irrigation (HEI) methods mainly include pressurized irrigation techniques such as drip irrigation, and sprinkler irrigation. Even though these techniques are expensive, but their adoption is becoming vital under the growing demand for irrigation water. Drip irrigation requires less energy as compared to sprinkler irrigation technique, therefore, it is more likely that the use of drip irrigation on public and private farms will be encouraged by irrigation and other relevant departments through their subsidy schemes. This irrigation method is being used in other countries to raise orchards and crops in zones that face water scarcity or have poor quality groundwater. Drip irrigation could be a great support to ensure efficient use of water. A well-planned subsurface drip irrigation structure leaves almost no water to runoff, deep percolation or evaporation. As compared to surface irrigation, water saving within a range of 30 – 70 percent can be achieved by drip irrigation method depending on the crop (INCID, 1994; Postel et al., 2001). In addition, drip irrigation can provide a significant increase in crop yield and reduce the problems like weed growth and soil erosion. It also reduces the cost of cultivation in labor-intensive operations (Narayanamoorthy, 1996; Narayanamoorthy, 2001). However, the overall cost of irrigation after including the installation and maintenance cost of HEIs may still be higher than the conventional irrigation methods. But it is worth noting that water saving irrigation techniques are more effective in reducing water consumption and increasing grain yield, so they can contribute to easing potential food and water scarcity (Hanjra and Qureshi, 2010; Tejero et al., 2011).

The sprinkler is a unique irrigation system. It is designed with the objectives of affordability, maximum water saving, and ease of installation. Sprinkler irrigation systems are usually more efficient than flood irrigation systems and provide efficient coverage for small to large areas. The system uses 35 – 40 percent less water than flood irrigation method (Narayana moorthy, 2008). The on-farm irrigation efficiency up to 80 percent have been achieved in India with sprinkler irrigation method (Sharma, 1984). The sprinklers are multipurpose, and their uses range from agricultural to residential, industrial, parks, play grounds, hotels, and public and private enterprises.

A considerable amount of literature shows that high-efficiency irrigation systems (HEIs) have a several advantages over conventional irrigation systems such as water saving (Hanson et al., 1997; Haq, 1990), higher yields (Humpherys et al., 2005), reduced weed growth, and improved germination (Sivanappan, 1977). Despite all these benefits and increasing global use of HEIs, these technologies are still not popular in Pakistan and the main obstacles toward their adoption include the heavy initial capital investment, lack of awareness and training. Within this background, this paper aims to conduct the economic analysis of HEIs. In addition, this paper also attempts to examine the socioeconomic profile of farmers who have currently adopted this HEIs, to estimate the installation and working costs of HEIs, and to measure the water productivity of modern and conventional farmers. The economic feasibility measures such as Net Present Value (NPV) and Benefit Cost Ratio (BCR) were also calculated to provide useful policy options regarding the scope of HEIs in Punjab province.

Materials and Methods

Study area, sample size, and data collection

The main objective of this study was to conduct an economic analysis of high efficiency irrigation systems in Punjab, Pakistan. Because the HEI is being practiced on a small area in Pakistan, therefore, this study was restricted to only those areas of Punjab where drip and sprinkler irrigation systems were already installed.

The sprinkler irrigation system was mainly installed to irrigate wheat crop, therefore, the study area selected for the sprinkler irrigation system included the regions of Khushab, Bhalwal, and Sargodha in Punjab province. The drip irrigation was mainly used for Mango orchards, so the area selected for drip irrigation farms included district Lodharan where most orchards were irrigated by drip irrigation.

We selected 120 farms from all these areas of Punjab province with 50 percent farms using the high-efficiency irrigation systems (HEIs), and the remaining 50 percent using the conventional irrigation system (CIS). Thus, our final sample included 30 farmers in each category of (i) sprinkler irrigated wheat growers, (ii) conventional irrigated wheat growers, (iii) drip irrigated mango growers, and (iv) conventional irrigated mango growers, making a total sample size of 120 farms. We used purposive sampling technique to select the farms due to the scattered distribution of the farms using HEI systems.

A well-structured questionnaire was used to obtain data from the farmers using HEIs and CIS. Both open-ended and close-ended questions were included in questionnaire. The questionnaire was pre-tested by interviewing eight respondents. After pre-testing, necessary changes were incorporated in the questionnaire in the light of responses of growers. The pre-tested questionnaire was then used to collect the data from selected farmers through personal interviews which the researchers conducted themselves. Information was obtained on socio-economic characteristics of wheat and mango growers, and production technology of wheat and mango under HEIs and CIS.

Analytical framework

The techniques used to conduct economic analysis and measure water productivity of wheat and mango growers are described in this section.

Economic analysis: Economic analysis is a "systematic approach to finding the optimum use of scarce resources, involving comparison of two or more alternatives in achieving a specific objective under the given assumptions and constraints. It explicitly considers the value of resources employed and attempts to measure the private and social costs and benefits of a project to the community or economy" (Howe, 1971).

Different types of decision criteria can be used for economic analysis, but Net Present Value (NPV) is the most widely used criteria. In this study, however, we used both Benefit-Cost Ratio (BCR) and NPV as decision criteria.

The calculation of net benefits can be done by net present value (absolute terms), or in the relative terms by the measure of benefit cost ratio and internal rate of return (Sinden and Thampapillai, 1995). Since we collected data on one crop season only, therefore, we excluded the IRR from the analysis. According to Au and Au (1983), one decision criterion is usually enough to assess the economic feasibility of a project. However, we used both the BCR and NPV as decision criteria to assess the economic feasibility of HEIs.

Benefit-Cost Ratio (BCR): Benefit cost ratio is de-

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fined as "the present value of the estimated benefits divided by the estimated costs". The present value of benefits and costs is estimated by using a suitbale discount rate, r. The discount rate is usually equal to prevailing rate of interest in the country. In this study, we assumed a discount rate of 12 percent and conducted the sensitivity analysis by calculaing BCR and NPV for other discount rates such as 10, 15, and 18 percent.

$$BCR = \sum_{t=1}^{n} B_t/(1+r) \Big/ \sum_{t=1}^{n} C_t/(1+r)^t$$

Where; Bt represents the benefits, Ct represent the costs, r is the discount rate, and t is time period in years. The time period is equal life span of HEIs. Published literature shows that the lifespan of HEIs is usually assumed to be 20 years Narayanamoorthy (2008). We use number of years and discount rate to anticipate benefits and costs accruing over time.

When using BCR, the decision rule is

- If BCR > 1, then accept the policy or project as an economically feasible option.
- If there are different policies or projects, select that one with the highest BCR value.

Net Present Value (NPV): NPV is defined as the estimated benefits minus the costs. Both the benefits and costs are discounted using a discount rate for ensuring fair comparisons. Mathematically it can be expressed as:

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

When, using NPV, the decision rule is

- If NPV is positive, the project is economically feasible/justifiable.
- If there are different policies or projects, select the one with the highest NPV.

The involvement of fixed capital in high effieicney irrigation systems demands to account for income and cost stream covering the life span of the investment. Following Narayanamoorthy (2008), some realistic assumptions were made owing to difficulty in uncovering the actual cash flows for the whole life span of drip and sprinkler irrigation systems. These assumptions are as follows:

1. NPV and BCRs are estimated assuming the the life span of drip systems and sprinklers as 20 years.
2. The production costs and income generated by the use of HEI systems is assumed to be consant during this whole period.
3. To assess the sensitivity of the investment, the calculations are repeated using four different discount rates which are 10, 12, 15 and 18 percent.
4. There is no technological change regarding production technology, i.e. the production of wheat and mango is assumed to remain constant during the entire lifespan of HEI systems.

Water productivity: Water productivity (WP) is a term commonly used "to describe the relationship between water (input) and agricultural product (output)". It is often used to express the effectiveness of irrigation water use and delivery. The water productivity is estimated as the ratio of output (kg/acre) and irrigation water used (cubic meter/acre):

WP (kg/m^3) = [Output (kg/acre)] / [Irrigation water used (m^3/acre)]

Data on output/yield were obtained directly from the farmers for both the wheat crop and mango orchards. Regarding measurement of water use, different methods were used as irrigation water was being applied by various sources such as sprinklers, drip systems, canals, and tube wells. The measurement of the volume of water actually used for wheat and mango in case of sprinkler an drip irrigation systems was easy. We multiplied the readings of water use obtained from flow meters installed on these systems with the total duration of irrigation for the whole season. However, a large number of non-registered small and fragmented farmers using groundwater lead to the absence of actual groundwater usage data on the district level, and data on farm-level was even more difficult to get (Qureshi et al., 2003).

Therefore, to measure groundwater usage by conventional farmers we used an approximate estimation model following Eyhorn et al. (2005), Srivastava et al. (2009) and Watto and Mughera (2015). The information on number of irrigations, duration of each irrigation, tubewell engine horsepower, the diameter of the suction pipe, and boring depth was collectted from farmers to incorporate in following model to measure the volume of water in liters which was then converted to cubic meters.

$$Q = \frac{t \times 129574.1 \times BHP}{[d + (255.5998 \times BHP^2)/d^2 \times D^4)]}$$

Where; Q is the volume of water in liters, t is total duration of irrigations, d denoted the boring depth, D is diameter of the suction pipe, and BHP is the engine power of the tubewell. This formula gave the extraction of water in liters which we converted to m^3.

In addition, some of the conventional farmers were using canal water to irrigate their fields. To measure the water usage of these farmers, we obtained the information on water discharge in a specific water channel from the irrigation department. Next, to obtain actual water usage data we multiplied the measures of water discharge with the total time of irrigation which was reported by the farmers during the survey.

Results and Discussion

In this section, we provide the results of this study such as the socioeconomic profile of respondents, installation and working costs of HEIs, estimated values of NPV and BCR, and water productivity under HEIs and CIS.

Socioeconomic characterisitic of respondents

It is necessary to understand the socioeconomic characteristics of current adopters of HEIs in order to to design pracitcal policies to encourage the use of such systems. The socioeconomic profile of respondents is presented in Table 1. The age of farmers did not show any significant variation among farmers under both the HEIs and CIS. This finding idicated that the age of a farmer did not affect the choice of irrigation system. The family size of respondents ranged from 7-8 persons per family for all type of farmers, so the family size was also found to be neutral in determining farmers' attitude toward the choice of irrigation technology. The education of farmer revealed that farmers using HEIs were relatively more educated than those who used CIS to irrigate their crops. Therefore, education might be a factor affecting the farmers' choice of HEIs. The landholding size of farmers showed considerable variation within the farmer categories. The landholding size of farmers using HEIs was almost twice the landholding size of CIS farmers. This finding showed that landholding size or the economic status of farmers could be a significant determinant of farmers' choice of HEIs. The area allocated to wheat crop or mango orchards was also higher for HEIs users which might be an indication that HEIs once installed on farms could increase the area allocated to a specific crop, or the farmers using HEIs were mostly large farmers.

Economics of wheat crop and mango orchards grown under HEIS and CIS

We estimated the gross margins of wheat and mango growers under both type of irrigation systems to find out if there were any gains to farmers using HEIs.

Gross margins of wheat growers: To estimate the gross margins of wheat growers we first estimated the costs associated with wheat production. Table 2 shows the results of per acre average costs of wheat production for farmers using sprinkler irrigation and conventional irrigation to irrigate wheat crop. The results revealed that there was not much difference in costs of different cultural activities among both types of farming systems except for irrigation and harvesting cost. The irrigation cost on sprinkler irrigated farms was about 64 percent higher than the conventional irrigated farms. In addition, for sprinkler irrigated farms there was an associated installation cost which was assumed to be 40 percent of total cost because farmers had to pay only 40 percent of total installation charges and the rest was to be paid by the government. The cost of casual hired labor was higher for sprinkler irrigated farms which might be due to the commercial nature of these farms as large farmers in Pakistan rely more on hired labor unlike the conventional farmers who prefer to employ family labor for harvesting of the crop.

There was a considerable difference between the yield of conventional and sprinkler irrigated farms. The yield on sprinkler irrigated farms was about 61 percent higher than those of conventional farms which might indicate that sprinkler irrigation increases the yield of wheat crop by providing water to crop on its critical stages (Table 3). Of course, there could be other factors which might explain this difference. However, given the negligible differences among inputs usage like seed, fertilizer and chemical use on both type of farms, sprinkler irrigation may have contributed to higher yield at sprinkler irrigated farms.

The gross margins of sprinkler irrigated farms were higher than the conventional irrigated farms even after we included the high working and installation costs of sprinkler systems (Table 4). This was mainly due to a substantial yield difference between the two type of farms. The gross margins of sprinkler irrigated farmers were about 2.33 times higher than those of conventional farmers.

Gross margins of mango growers: Drip irrigation in the study area was mainly used on mango orchards.

Table 1: *Socioeconomic charateristics of respondents using HEIs systems and CIS.*

Particulars	Sprinkler Irrigated Wheat Growers	Conventional Wheat Growers	Drip Irrigated Mango Growers	Conventional Mango Growers
Age (Years)	49.89	50.53	50.42	50.53
Family Size (No.)	8.10	7.90	7.93	8.73
Education (% of total)				
Illiterate	16.67	23.33	26.67	30.00
Under Matric	56.67	53.33	50.00	50.00
Matric and higher	26.67	23.33	23.34	20.00
Landholding Size (Acres)	33.33	14.57	49.50	32.10
Area under respective crop (Acres)	15.95	10.57	29.84	25.90

Source: *Authors' own calculations.*

We calculated the gross margins of mango growers to compare the values of drip irrigated farms with conventional farms.

Table 2: *Average cost of production of conventional and sprinkler-irrigated wheat farms.*

Activities	Sprinkler-irrigated farms	Conventional farms
	Cost/acre (Rs.)	Cost/acre (Rs.)
LandpPreparation	2699	2655
Seeds	500	550
Fertilizers	6878	6975
Chemicals	567	825
Irrigation working Cost/ Irrigation Cost (for conventional farmers)	6200	3762
Harvesting (manual cutting+ harvester+ thresher)	4807	4899
Casual Hired Labor	6857	1578
Total	28508	21244
Installation Cost (40% of total cost)	16500	N/A

Source: *Authors' own calculations.*

Table 5 shows the cost of mango production in the study areas. The total cost is divided into the cost of different activities like land preparation, fertilizers, chemicals. We did not include theh picking cost into total cost due to the contractual nature of mango orchards sale. All the farmers were found selling their orchards on contract basis in which the buyers bought the whole orchard when it was ready for picking. Therefore, the picking cost was not paid by the owners of mango orchards. The land preparation cost on conventional farms included the hoeing cost to eradicate weeds from the orchards, and for drip-irrigated orchards it was zero because of the installation of drip irrigation systems in the orchards. For weeding purpose, the farmers were recommended to use weedicides and not the method of traditional hoeing because the traditional method of removing weeds from the orchards could damage the whole system of drip sets and piping. The results showed that the average per acre cost of mango production was higher on drip irrigated farms due to higher working and installation costs. We assumed the installation cost as 40 percent of total cost because only 40 percent of total cost was paid the farmers. The rest of installation cost was paid by the government as a subsidy to encourage the use of drip irrigation.

Table 3: *Yield and revenue of conventional and sprinkler-irrigated wheat farms.*

Farm categories	Yield/ acre (monds)	Price/ mond* (Rs)	Dry stalk /acre (monds)	Price/ mond (Rs.)	Revenue (Rs.)
Conventional-irrigated farms	26.25	942	26.25	200	29977.5
Sprinkler-irrigated wheat farms	42.57	950	42.57	200	48955.5

Source: *Authors' own calculations; * 1 mond = 40 Kg*

Table 4: *Gross margins of conventional and sprinkler-irrigated wheat farms.*

Farm categories	Revenue (Rs.)	Cost (Rs)	Gross Margins (Rs.)
Conventional farms	29999.8	21246.5	8753.35
Sprinkler-irrigated farms	48955.5	28510.8	20444.7

Source: *Authors' own calculations.*

Table 6 shows the gross margins of both types of farms. It is worth noting that gross margins of drip-irrigated farms were higher than the convenetional farms even when we included the installation cost of drip irrigation system. The gross margins on drip-irrigated farms were about 31 percent higher than the conventional farms. However, when we excluded the installation cost of drip irrigation systems the gross margins of drip-irrigated farms were about 68 percent higher than those of conventional farmers.

Table 5: *Cost of production of mango orchards under conventional and drip irrigation.*

Activities	Drip-irrigated farms	Conventional farms
	Cost/acre (Rs.)	Cost/acre (Rs.)
Land preparation	0	2115
Fertilizers	19907.5	17303.5
Chemicals	3157.8	2887
Irrigation working cost	30468.7	23097.5
Casual labor	8083.33	7500
Installation cost (40% of total cost)	13366.6	N/A
Total cost with installation cost	74983.9	N/A
Total cost without installation cost	61617.3	52903

Source: *Authors' own calculations.*

Table 6: *Gross margins of mango orchards under conventional and drip irrigation.*

Particulars	Drip -irrigated farms	Conventional-irrigated farms
Revenue (Rs. /acre)	122000	88706
Total cost with installation cost (Rs./acre)	74983.9	N/A
Total cost without installation cost	61617.3	52903
Gross margins with installation cost	47016.1	N/A
Gross margins without installation cost (Rs.)	60382.7	35803

Source: *Authors' own calculations.*

Benefit-cost ratio and net present values of sprinkler and drip irrigation systems

This section provides the results of benefit-cost ratio (BCR) and net present value (NPV) of sprinkler-irrigated wheat farms and drip-irrigated mango farms (Table 7). We estimated the BCR and NPV values using discount rates of 10, 12, 15 and 18 percent. The BCR values for sprinkler irrigation systems on wheat crop were greater than 1 for all discount rates used in the analysis. The values ranged from 1.81 – 1.85. These results showed that sprinkler irrigation system on wheat crop was an economically viable option.

Table 7: *The BCR and NPV values for sprinkler and drip Irrigation systems.*

	Discount rate	Sprinkler irrigation systems	Drip irrigated systems
BCR	10	1.85	1.93
	12	1.84	1.92
	15	1.82	1.92
	18	1.81	1.91
NPV (Rs.)	10	266527.7	501927.4
	12	232214.8	439097.3
	15	192523.4	366338.5
	18	162867.1	311891.7

Source: *Authors' own calculations.*

The NPV values were also positive for various discount rates used in the analysis. These values ranged from Rs. 162876 – Rs. 266527. The NPV estimates also confirmed that sprinkler irrigation system on wheat crop is highly profitable and economically viable option.

The BCR values estimated for drip irrigation systems on mango orchards were also higher than 1. The values ranged from 1.91 – 1.93 for various discount rates used in the analysis. These results showed that drip irrigation on mango orchards was economically feasible option. The same was confirmed from NPV values for drip irrigation systems on mango orchards. These values were all positive and ranged from Rs. 311891 – Rs. 501927. Our results of BCR and NPV proved that high efficiency irrigation systems (sprinklers and drip systems) were economically feasible options.

Water productivity of hei and conventional farmers

Water productivity (WP) is an important measure indicating the water saving capacity of HEIs compared with the conventional irrigated farms. The WP result of both the modern and conventional farmers is shown in Table 8.

Table 8: *Water productivity of HEIs and CIS farms.*

Farm Category	Water Productivity (kg/m^3)
Sprinkler-irrigated wheat farms	0.51
Conventional wheat farms	0.37
Drip-irrigated mango farms	0.93
Conventional Mango Farms	0.57

Source: *Authors' own calculations.*

The water productivity on sprinkler irrigated wheat farms was 0.51 kg/m^3 which was much higher than

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those of conventional wheat farmers who had a water productivity of 0.37 kg/m^3 only. In case of drip irrigation which is more efficient than sprinkler irrigation, the water productivity on drip irrigated mango orchards was 0.93 kg/m^3. On the other hand, the conventional mango growers had water productivity of 0.57 kg/m^3 only. Our results show that HEIs have significant potential to increase water productivity in Punjab province of Pakistan.

Conclusions and Recommendations

Pakistan is a water scarce country, and its agriculture sector needs irrigation water to feed the rapidly growing population. Also, in the developing countries, the water demand for non-agricultural uses is expected to grow more than its agricultural uses (Rosegrant and Ringler, 2000). Therefore, a shift to water-saving technologies is needed to maintain the balance in the use of this precious resource in its competitive uses.

High-efficiency irrigation systems, e.g. the drip irrigation and sprinkler irrigation provide numerous other benefits along with the huge water saving potential. The low adoption of these technologies in Pakistan might be due to several limiting factors. Farmers in Pakistan are reluctant to adopt the technology because they might perceive it as an expensive technology that offer water savings only. However, the inefficient water pricing system fails to induce the farmers to adopt the modern water saving technologies for the sole purpose of water saving. This study was designed with an aim to investigate the economic perspective of HEIs so that farmers could be incentivized through the economic benefits the HEIs.

Based on the findings of this study, it was concluded that high efficiency irrigation systems provide substantial increases in yield, water productivity, and the gross margins at wheat and mango farms. However, in Pakistan, most of the farmers are small farmers with an average landholding ranging from 2.5 - 5 acres. Therefore, the HEIs may not be affordable for small farmers. The results of our study showed that most of the farmers using HEIs were large farmers. The large subsidies (up to 60 percent of total cost of HEIs) offered by the government for installation of HEIs may not be enough to encourage the small farmers to adopt HEIs partly due to lack of awareness about the economic benefits of HEIs. In addition, the low education status of conventional growers found in this study could also be a limiting factor in the adoption of HEIs.

The economic analysis of HEIs using BCR and NPV measures confirmed the economic feasibility of high-efficiency irrigation technologies in the study area. The policy makers could use the findings of this study to educate the farmers about the economic benefits of adopting HEIs.

Author's Contribution

A. Razzaq and A.H. Qureshi: Conceptualization
A. Razzaq, A.H. Qureshi, I. Javed and A. Rehman: Data collection
A. Razzaq, A. H. Qureshi and I. Javed: Formal analysis and methodology
A. Razzaq: Writing original draft
I. Javed, A. Rehman, R. Saqib and M.N. Iqbal: Writing review and editing:

References

Ali, S. 2000. Productivity growth in Pakistan's agriculture 1960-1996. Ph.D. dissertation, Dep. Econ. Simon Fraser Univ. Canada.
Au, T. and Au, T.P. 1983. Engineering economics for capital investment analysis. Boston, MA: Allyn and Bacon.
Bhattarai, M. and Narayanamoorthy, A., 2003. Impact of irrigation on rural poverty in India: an aggregate panel-data analysis. Water Policy. 5(5-6), pp. 443-458. https://doi.org/10.2166/wp.2003.0028
Dhawan, B.D. 1988. Role of irrigation in raising intensity of cropping. J. India. Sch. Polit. Econ. 3(4), pp. 632-671.
Eyhorn, F., Mäder, P. and Ramakrishnan, M. 2005. The impact of organic cotton farming on the livelihoods of smallholders. Evidence from the Maikaal bioRe project in central India. Res. Inst. Org. Agric. FiBL, Frick, Switzerland.
GOP, 2014. Pakistan Economic Survey 2013–14. Ministry of Finance, Government of Pakistan, Islamabad, Pakistan.
Hanjra, M.A. and Qureshi, M.E. 2010. Global water crisis and future food security in an era of climate change. Food Policy, 35(5), pp. 365-377. https://doi.org/10.1016/j.foodpol.2010.05.006
Hansona, B.R., Schwankl, L.J., Schulbach, K.F. and Pettygrove, G.S. 1997. A comparison of furrow,

surface drip, and subsurface drip irrigation on lettuce yield and applied water. Agric. Water Manage. 33(2-3), pp. 139-157. https://doi.org/10.1016/S0378-3774(96)01289-9

Haq, N. 1990. Evaluation of modern irrigation techniques for sandy loam soil having low slope. Unpublished M.Sc. thesis, Department of Irrigation and Drainage, Univ. Agric. Faisalabad, Pak.

Howe, C.W. 1972. Benefit-cost analysis for water system planning. In Water Resources Monograph Series (Vol. 2). Am. Geophys. Union.

Humphreys, L., Fawcett, B.R.A.D., O'Neill, C. and Muirhead, W. 2005. Maize under sprinkler, drip and furrow irrigation. IREC Farmers' Newsletter, 170, pp. 35-38.

INCID. 1994. Drip irrigation in India. Indian National Committee on Irrigation and Drainage, Ministry of Water Resources, Government of India, New Delhi, India.

Narayanamoorthy, A. 1996. Impact of drip irrigation on consumption of water and electricity. Asian Econ. Rev. 38(3), pp. 350-364.

Narayanamoorthy, A. 2001. Impact of drip irrigation on sugarcane cultivation in Maharashtra. Agro-Economic Research Centre, Gokhale Inst. Polit. Econ. Pune, June.

Narayanamoorthy A. 2008. Economics of drip irrigated cotton: a synthesis of four case studies. Proceedings of the 7th Annual Partners Meet, International Water Management Institute (IWMI) TATA Water Policy Res. Prog., ICRISAT. 2008 Apr: 2-4.

Postel, S., Polak, P., Gonzales and J. Keller. 2001. Drip irrigation for small farmers: A new initiative to alleviate hunger and poverty. Water Int. 26(1), pp. 3-13. https://doi.org/10.1080/02508060108686882

Qureshi, A.S., Shah, T. and Akhtar, M., 2003. The groundwater economy of Pakistan (Vol. 64). IWMI.

Raza, A., Khanzada, S.D., Ahmad, S. and Afzal, M. 2012. Improving water use efficiency for wheat production in Pakistan. Pakistan Journal of Agriculture: Agric. Eng. Vet. Sci. (Pakistan), 28 (1): 27-39

Rosegrant, M.W. and Ringler, C. 2000. Impact on food security and rural development of transferring water out of agriculture. Water Policy, 1(6), pp. 567-586. https://doi.org/10.1016/S1366-7017(99)00018-5

Sharma, S.K. 1984. Principles and practices of irrigation engineering. Oxford and IBH Publication Co., New York.

Sinden, J. A. and D. J. Thampapillai. 1995. Introduction to benefit-cost analysis. Longman, Melbourne, Australia. Reprinted in 1999.

Sivanappan, R.K. 1977. Sprinkler irrigation. Oxford and IBH Pub-Co. Pvt. Ltd, New Dehli, India.

Srivastava, S.K., Kumar, R. and Singh, R.P., 2009. Extent of Groundwater Extraction and Irrigation Efficiency on Farms under Different Water-market Regimes in Central Uttar Pradesh. Agric. Econ. Res. Rev. 22(1).

Tejero, I.G., V.H.D., Zuazo, J.A.J. Bocanegra and J.L.M. Fernández. 2011. Improved water-use efficiency by deficit-irrigation programmes: Implications for saving water in citrus orchards. Sci. Hortic. 128(3), pp. 274-282. https://doi.org/10.1016/j.scienta.2011.01.035

Vaidyanathan, A., A. Krishnakumar, A. Rajagopal and D. Varatharajan. 1994. Impact of irrigation on productivity of land. J. India. Sch. Polit. Econ. 6(4), pp. 601-645.

Watto, M.A. and A.W. Mugera. 2015. Econometric estimation of groundwater irrigation efficiency of cotton cultivation farms in Pakistan. Journal of Hydrology: Reg. Stud. 4, pp. 193-211.