Vol XLVI
No. 4

ISSN 0019-5014

OCTOBER-
DECEMBER
1991

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

Ind. Jn. of Agri. Econ.
Vol. 46, No. 4, Oct.-Dec. 1991

Flexibility and Reliability of Irrigation Systems and Their Effect on Farming - A Case of Punjab

Water for irrigation is available from either surface irrigation supplies or groundwater supplies or both. Whereas surface irrigation is mainly through canals, groundwater is exploited by means of tubewells either operated by electricity or by diesel pumps or both. Farmers use these sources either singly or in various combinations. Canal irrigation in the Punjab used to be the major source of irrigation. But its control rests with public institution and as such farmers do not have any control on the quantity and timely application of irrigation to the crops. Associated with irrigation are many inputs, the application of which is hindered as a result of inadequate amount of irrigation water and also its timely availability. Application of a package of inputs for raising productivity and thus farm income necessitated shifting of emphasis towards tubewells for exploitation of groundwater for irrigating crops as it was thought to be a more reliable and flexible source of irrigation.

Tubewells have flexibility in the sense that these can be operated at any time according to requirement, provided the energy to operate these is available to the farmers. Tubewells have high level of recurrent cost of supplying water. Economic efficiency could better be judged when farmers pay the real cost of water supply. These circumstances are rare to hold specially for canal irrigation system.

Electricity supply to farmers in the Punjab is heavily subsidised making this system also economically inefficient. It is, therefore, imperative to look into the economic efficiency of various sources of irrigation. The objectives of this paper are to (i) determine the benefit of water supply flexibility represented by various sources of irrigation and (ii) to examine the cost and use pattern of irrigation and other important inputs in relation to water supply flexibility and reliability in the case of important crops.

METHODOLOGY

The study is based on the primary data collected from farmers of areas having diverse sources of irrigation. The data were collected for three years 1982-85, for both the *kharif* and *rabi* seasons covering the main crops of wheat and paddy which accounted for 80 to 85 per cent of the cropped area during the seasons. Sixty farmers from each of the three districts of Bathinda, Patiala and Ludhiana were selected by adopting a multi-stage random sampling procedure with blocks as the first stage, village as the second and farm households as the final unit of the study. In all, the study was confined to 180 farmers selected from 12 villages drawn from four blocks of the three districts. The main criterion was to select farms adequately representing various sources of irrigation singly or in combination. It may be noted here that the plots of some farmers being irrigated through different sources were taken as different observations. The data were recorded on input use pattern, output, prices of inputs and outputs for each crop sown in the *rabi* and *kharif* seasons. Special emphasis was laid on recording the data in respect of number of irrigations, time taken for irrigation and the quantity of water used for irrigating different crops.

Classification of Farms

The farms were classified into six categories, each representing a different level of water

supply flexibility and reliability. Water supply flexibility and reliability refer to the ability of farmers to control water supply as and when desired. To estimate the gains of water supply flexibility, the performance of farmers under these categories was compared through tabular analysis. The farmers were, therefore, classified as follows (these move from lower to higher level):

Sr. No.	Farm category	Assumed degree of	
		Flexibility	Reliability
1.	Canal operated farms (C)	Low	Low
2.	Tubewell (diesel) operated farms (D)	High	Moderate
3.	Tubewell (electric) operated farms (E)	High	Moderate
4.	Tubewell diesel operated along with canal alternative (D and C)	High	Moderate
5.	Tubewell electric operated along with canal alternative (E+C)	High	Moderate
6.	Tubewell electric operated along with diesel alternative (E+D)	High	High

RESULTS AND DISCUSSION

The performance of various sources of irrigation based on aggregate data of wheat and paddy for the three years is discussed below.

Yield in relation to Irrigation and Water Use

To assess the impact of water supply flexibility on yields, a comparison is made between yields of different farm categories, each operating under different sources of irrigation. Since the number and hours of irrigation are crude measures of the quantity of water used for irrigation, the actual quantity of water used for irrigation was, therefore, the measure adopted and it is provided in Table I. It is observed from the table that, in general, yields were higher on the farms having alternative sources of irrigation compared to farms having single source of irrigation. In the case of wheat crop, farms having diesel plus electric alternative (a highly flexible and reliable source) obtained 50 per cent higher yield compared to the canal irrigated farms and 27 per cent and 11.5 per cent higher yield compared to the diesel and electric farms respectively. These farms (D+E) applied less than half the quantity of water used by canal farms. Diesel plus electric farms and canal plus electric farms got higher yield compared to all other categories. Similarly, yields were higher under tubewell irrigation compared to canal irrigation. It shows that timeliness of irrigation is very important. Though the canal farmers applied more quantity of water to irrigate their farms and used it more frequently compared to most other categories, yet their yield was lowest compared to farms using other sources of irrigation. This could be so as canal farms did not have any choice regarding the timing of irrigation and could not apply irrigation as and when needed. They applied irrigation whenever it was available to them irrespective of the requirement of the crop. Since the payment for canal irrigation does not depend upon the amount of water used for irrigation, canal farms applied excessive irrigation leading to reduction in yield.

Analysis of fertiliser use indicated that its use also differed significantly across farm categories. Farms having alternative sources of irrigation applied higher doses of fertiliser (as indicated by fertiliser cost) compared to farms having single source of irrigation. Increase in the degree of water supply flexibility and reliability resulted in increased use of fertiliser which along with timely application of irrigation resulted in increase in yields.

TABLE I. AVERAGE YIELD OF CROP IN RELATION TO IRRIGATION AND FERTILISER USE ON PER ACRE BASIS

Parameter	Crop	Source of irrigation					
		Canal	Diesel	Electric	Canal and diesel	Canal and electric	Diesel and electric
		(C)	(D)	(E)	(C+D)	(C+E)	(D+E)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Yield (qtl.)	Wheat	10.25	12.05	13.76	12.86	14.33	15.35
	Paddy	8.14	18.08	26.76	21.40	26.84	23.72
Number of irrigations	Wheat	5.26	4.21	4.04	5.62	5.27	4.75
	Paddy	5.40	15.28	20.72	17.24	20.49	19.91
Hours of irrigation	Wheat	7.76	30.78	23.36	19.21	16.63	31.05
	Paddy	11.16	115.25	116.39	98.37	117.12	134.54
Quantity of irrigation water (cubic metre)	Wheat	2,340.67	826.40	988.60	2,145.75	2,316.21	1,025.91
	Paddy	3,313.68	3,264.48	5,022.16	4,996.92	7,889.07	4,279.41
Fertiliser cost (Rs.)	Wheat	382.34	367.36	417.33	415.84	438.22	437.90
	Paddy	131.75	384.06	535.29	397.56	573.52	422.21

Paddy is a highly water intensive crop. Though it is grown in the rainy season, its irrigation requirement is very high for most of the cropping period. The effect of water supply flexibility is expected to be more pronounced in the case of this crop compared to other crops.

Paddy requires assured and frequent irrigation. Its yield is dependent on timely availability and cost of irrigation. Canal water though cheapest is a least reliable source. The yield of paddy under canal irrigation was minimum at 8.14 quintals per acre. The highest yield of 26.84 quintals was obtained by the canal plus electric farms followed closely by the electric farms. The yield was low on the diesel farms (18.08 qtl./acre) compared to the electric (26.76 qtl./acre) and diesel plus electric farms (23.72 qtl./acre). The low yield of paddy on the diesel farms is the result of less use of irrigation and fertiliser. Diesel farms applied 3,264 cu.m of water for irrigating one acre of paddy and spent only Rs. 384 per acre on fertilisers. On the other hand, electric farms applied 5,022 cu.m of irrigation and used fertiliser worth Rs. 535 on per acre basis. Obviously, the use of water on the diesel farms is much less compared to the electric farms as the diesel farms have to pay for the entire cost of pumping whereas electric farms paid only the flat rate.

Another important aspect brought out is that there is strong complementarity between the quantity of irrigation water and fertiliser used under paddy cultivation. The higher the quantity of water used for irrigation, the higher was the expenditure on fertiliser leading to higher yields.

Production Costs and Returns

Increase in yield is a physical achievement and does not speak of the economic and commercial viability of the system of irrigation adopted. As such, the analysis was further carried to production costs and returns.

Inputs vary in their use among different farm categories. Production costs have been split into two types. Production cost I is the sum of *(i)* cost of seed, *(ii)* irrigation expenditure, *(iii)* fertiliser cost, *(iv)* wage cost, *(v)* bullock labour cost, *(vi)* tractor and other machinery cost (at market rate of hiring), and *(vii)* expenditure on agricultural chemicals. Production cost II includes all production cost I but irrigation expenditure. Based on the two types of

production costs, two types of net returns, namely, net return I and net return II were calculated. Net return II is thought to be a better indicator of economic efficiency of the farm compared to net return I. Table II shows that there are large differences in the production cost of different farm categories. A part of these differences arises because of the difference in irrigation expenditure.

TABLE II. PER ACRE RETURNS AND PRODUCTION COST UNDER CROP CULTIVATION

(Rs.)

Parameter	Crop	Source of irrigation					
		Canal	Diesel	Electric	Canal and diesel	Canal and electric	Diesel and electric
		(C)	(D)	(E)	(C+D)	(C+E)	(D+E)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gross returns	Wheat	1,611.05	1,941.94	2,116.05	2,096.12	2,266.44	2,438.76
	Paddy	1,178.93	2,518.34	3,365.07	2,946.80	3,410.80	3,203.30
Production cost I	Wheat	1,425.16	1,435.60	1,341.08	1,509.54	1,405.90	1,392.69
	Paddy	457.79	1,928.15	1,934.67	1,939.35	2,117.20	1,727.81
Production cost II	Wheat	1,409.25	1,310.25	1,288.33	1,418.50	1,357.73	1,308.93
	Paddy	446.04	1,468.18	1,873.76	1,497.52	2,036.80	1,473.05
Irrigation expenditure	Wheat	15.91	124.97	52.75	91.04	48.17	87.76
	Paddy	11.75	459.97	60.91	441.68	80.40	254.76
Net returns I	Wheat	185.89	506.34	774.97	586.58	860.54	1,046.07
	Paddy	721.14	590.19	1,430.40	1,007.45	1,293.60	1,475.49
Net returns II	Wheat	201.80	631.31	827.72	677.62	908.71	1,129.83
	Paddy	732.89	1,050.16	1,491.31	1,449.28	1,374.00	1,730.25

There was a clear association between the level of flexibility and reliability as represented by various sources of irrigation and net returns. These returns, which can be called return to fixed factors, were the highest on the farms having diesel plus electric alternative (Rs. 1,129.83) followed by canal plus electric farms (Rs. 908.71 per acre) from wheat crop. Differences in net returns can be attributed to the difference in input use. Canal farms got the lowest returns with the highest investment in production compared with all other categories except canal plus diesel alternative. When diesel farms were supplemented by electric alternative, there was decrease in the production cost and increase in per acre net returns. Similarly, returns were much higher on the canal plus electric farm alternative compared with the canal or electric farms alone.

It is clear from Table II that timely application of irrigation and in proper quantities resulted in increased output with the same and even lesser use of inputs. Thus it can be inferred that farms having different sources of irrigation operated at different production frontiers. The higher the degree of flexibility, the higher the production frontier of the farm category.

As regards paddy crop, wide variations in the production cost were noted and consequently in net returns mainly due to the variation in irrigation expenditure. The difference in the production cost I and II gives irrigation expenditure on per acre basis. It is interesting to note that diesel farms incurred seven times more expenditure on irrigation compared to the electric farms but used 35 per cent less water than electric farms. Such distortions in subsidy on irrigation water have very serious repercussions on production and income distribution in various farm categories.

Table II showed that net returns in paddy crop were the highest on the diesel plus electric

operated tubewell farms followed by electric operated tubewell farms. Thus diesel plus electric farms turned out to be the best source of irrigation for paddy production though the productivity of this source was much less than the productivity of electric as well as canal plus electric farms.

Average Returns and Average Cost

Average returns per rupee invested along with the level of total output indicate economic efficiency under different sources of irrigation. The calculation of average cost and average returns is based on production cost II. It can be observed from Table III that the sources of irrigation representing various levels of flexibility and reliability had direct bearing on the average returns per rupee invested. In the case of wheat crop the highest returns were obtained on the farms with diesel plus electric alternative source of irrigation, *i.e.*, Re. 1.86 per rupee of investment. Higher reliability is associated with higher yield as regards both the crops. With the increase in the degree of control over water supply, there appears to be an upward shift in the production function leading to a downward shift in the average cost curve.

Water use efficiency was calculated by dividing gross returns per acre by the quantity of water used for irrigating an acre. Table III further shows that the average returns for wheat crop for one cu.m of water were the highest (Rs. 2.38) on the diesel plus electric farms, followed closely by the diesel operated tubewell farms. The average cost of using a given quantity of water for irrigation showed great divergence. (Diesel farms paid Rs. 151.22 per thousand cu.m of water whereas canal farms paid only Rs. 6.80 per thousand cu.m of water used for irrigating wheat crop.) This was so because water use efficiency was influenced mainly by two factors: *(a)* pricing of irrigation input and *(b)* water supply flexibility. Farmers who operated diesel pumps had to incur the entire cost. On the other hand, canal farms and electric farms paid fixed charges. Canal farms had to pay only nominal charges whereas electricity is highly subsidised. As could be expected, water use efficiency was the highest under diesel irrigation and the lowest under canal irrigation.

TABLE III. AVERAGE COST AND RETURNS TO INVESTMENT AND IRRIGATION UNDER CROP

Parameter	Crop	Source of irrigation					
		Canal	Diesel	Electric	Canal and diesel	Canal and electric	Diesel and electric
		(C)	(D)	(E)	(C+D)	(C+E)	(D+E)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Yield (qtl.)	Wheat	10.25	12.05	13.76	12.86	14.33	15.35
	Paddy	8.14	18.08	26.76	21.40	26.84	23.72
Average returns per rupee investment in production (Rs.)	Wheat	1.14	1.48	1.64	1.47	1.66	1.86
	Paddy	2.64	1.71	1.79	1.96	1.61	2.17
Average returns/per unit (cu.m) of water (Rs.)	Wheat	0.69	2.35	2.14	0.98	0.98	2.38
	Paddy	0.36	0.77	0.67	0.57	0.43	0.75
Average cost/1,000 cu.m of water	Wheat	6.80	151.22	53.35	42.42	20.80	85.54
	Paddy	3.54	140.90	12.12	88.35	10.18	59.53

In the case of paddy there were large differences in irrigation cost; as such the comparison of average cost and average returns are not undertaken. Thus we are unable to say anything about the economic efficiency of paddy cultivation under different sources of irrigaiton. Water use efficiency however was the highest on the diesel farms (0.77), followed closely by the diesel plus electric farms (0.75) and the minimum under canal irrigation. It followed the same trend in the case of wheat.

The data for water use efficiency clearly showed that pricing of irrigation is not the sole determinant of water use efficiency; flexibility of water supply is an equally important factor.

CONCLUSIONS

The present study has investigated the effects of water supply flexibility, reliability and pricing of irrigation water on wheat and paddy cultivation. It was observed that there were significant differences in the inputs used and outputs produced on the farms using different sources of irrigation. The effect of pricing of irrigation as an input was stronger in the *kharif* season because paddy was the main crop of the *kharif* season and its water requirements were very high. However, for wheat during the *rabi* season, water supply flexibility was more important than pricing of irrigation water in affecting the performance of various sources of irrigation. There was significant increase in the productivity due to increased use of inputs resulting from either complementary effect of irrigation or lower level of input use with the increase in the degree of control over water. Among the single source of irrigation, the performance of farms using electric tubewell was much better compared to diesel and canal farms. There was wider scope for increasing productivity under canal irrigated land provided this source was made more reliable by efficient management of canal system. The main disadvantage of diesel tubewell was that they generally had high recurrent cost per acre of land and per unit of irrigation water compared to farms irrigated through electric tubewells and canal. This may be justified by the high degree of flexibility under tubewell irrigation compared to canal irrigation. But there were wide differences in irrigation costs of diesel and electric tubewells with the same degree of water supply flexibility (pricing problem).

From the social point of view, the decision to replace the diesel tubewell by electric tubewell should take into account the cost of maintaining electric tubewell and the subsidy on electricity used for irrigation vis-a-vis the gain in total production. Also rational pricing of irrigation input would make farmers use other inputs rationally because of the complementarity of these inputs with irrigation.

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Received September 1990. Revision accepted April 1991.

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