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A COMPARATIVE STUDY OF ECONOMIC EFFICIENCY OF DIFFERENT IRRIGATION SYSTEMS IN WESTERN UTTAR PRADESH

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Lift and canal irrigation systems are most prevalent in northern part of India, especially in Western Uttar Pradesh. The systems of irrigation differ with regard to the extent of control that the farmers have on the timeliness and adequacy of supply of irrigation water. Consequently, the economic benefits as well as the costs due to irrigation vary between systems of irrigation. Irrigation system coupled with better water management in crop production has increased the yield and levels of inputs. Now the question arises as to what are the sources of output growth in different irrigation systems; how much of this growth in output is due to better water management and how much of it is due to change in inputs levels ? This paper is an attempt to examine these issues with the specific objectives *(i)* to examine the effect of sources of irrigation on cropping intensity, cropping pattern, use of inputs, yield and income, *(ii)* to decompose the total change in crop production due to irrigation system into its constituent causal forces like water management and changes in inputs levels and *(iii)* to measure the returns to water management under different sources of irrigation.

These objectives are evaluated with primary cross-section data of Meerut district which has the highest percentage of the total net cultivated area under irrigation in Western Uttar Pradesh. From Meerut district, Rajpura development block having the highest percentage (90 per cent) of area under tubewell irrigation and Jani Khurd block having the highest percentage (63 per cent) of area under canal irrigation were selected as the sample blocks. Three villages from the tubewell irrigated block and one village from the canal irrigated block were selected at random. All farmers were classified into three categories, *(i)* Private tubewell (PTW), *(ii)* State tubewell (STW) and *(iii)* Canal irrigated farms based on their major source of irrigation. A sample of 40 farms was drawn at random from each category. Input-output data for the agricultural year 1980-81 were collected by personal survey method and used to analyse the objectives of the paper.

THEORETICAL FRAMEWORK

Output growth as a result of efficient irrigation system takes place in two stages. First, more output is made possible from the existing resources Second, an adjustment component of water management is evident in movement along production function. This is due to the disequilibrium caused by production relationship in the efficient irrigation system. A decomposition model which captures the effects of both stages is developed. The first stage

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will measure the contribution of better water management and the second stage will measure the contribution of changes in the levels of inputs.

The specification of crop production functions under ith and jth irrigation systems used in decomposition analysis are:

$$\left(\frac{Y}{L}\right)_i = A_i \left(\frac{N}{L}\right)_i^{a_i} \left(\frac{I}{L}\right)_i^{b_i} \left(\frac{F}{L}\right)_i^{c_i} \left(\frac{B}{L}\right)_i^{d_i} \quad \ldots\ldots (1)$$

$$\left(\frac{Y}{L}\right)_j = A_j \left(\frac{N}{L}\right)_j^{a_j} \left(\frac{I}{L}\right)_j^{b_j} \left(\frac{F}{L}\right)_j^{c_j} \left(\frac{B}{L}\right)_j^{d_j} \quad \ldots\ldots (2)$$

where, $(Y/L)_i$ and $(Y/L)_j$ are the per hectate yield in quintals for a crop under the ith and jth irrigation systems respectively, $(N/L)_i$ and $(N/L)_j$ are the per hectare human labour in man-days used in ith and jth irrigation systems respectively, $(I/L)_i$ and $(I/L)_j$ are the per hectare irrigation water in thousand gallons used under ith and jth irrigation systems respectively, $(E/L)_i$ and $(E/L)_j$ are the per hectare fertilizer (N+P+K) in kg. used under ith and jth irrigation systems respectively, $(B/L)_i$ and $(B/L)_j$ are the per hectare plough unit used under ith and jth irrigation systems respectively, A_i and A_j are the scale parameters under ith and jth irrigation systems and (a_i, b_i, c_i, d_i) and (a_j, b_j, c_j, d_j) are the slope parameters of the production function under ith and jth irrigation systems respectively.

Corresponding to the above production equations, the decomposition equation can be written as:

$$\left[\ln \frac{\left(\frac{Y}{L}\right)_j}{\left(\frac{Y}{L}\right)_i}\right] = \left[\ln \frac{A_j}{A_i}\right] + \left[(a_j - a_i) \ln \left(\frac{N}{L}\right)_i + (b_j - b_i) \ln \left(\frac{I}{L}\right)_i + (c_j - c_i) \ln \left(\frac{F}{L}\right)_i + (d_j - d_i) \ln \left(\frac{B}{L}\right)_i\right] + \left[a_j \ln \frac{(N/L)_j}{(N/L)_i} + b_j \ln \frac{(I/L)_j}{(I/L)_i} + c_j \ln \frac{(F/L)_j}{(F/L)_i} + d_i \ln \frac{(B/L)_j}{(B/L)_i}\right] \quad \ldots\ldots (3)$$

Equation (3) decomposes the total difference in per hectare yield between farms under the two types of irrigation system. The bracketed expression on the left hand of the decomposition equation is a measure of the percentage change in output with the introduction of jth irrigation system in place of ith irrigation system. The first and second bracketed expressions on the right hand side measure the contribution of better water management to total change in yield; the third bracketed expression measures the contribution of changes in the use of per hectare quantities of inputs between the two irrigation systems.

The value of inputs saved under one irrigation system over other irrigation system (SR) is treated as benefit of better irrigation system and is measured as

$$SR = \left(\frac{r}{100}\right) R_j$$

where r is the percentage change in output due to better water management. This is obtained by adding the values of the first and the second bracketed expression on the right hand side of the decomposition equation (3). $\bar{Rj}$ is the value of inputs required to produce $(Y/L)\bar{j}$ with jth irrigation system.

RESULTS AND DISCUSSION

Water Management Problems

The relative importance of various sources of irrigation with regard to water management depends upon the availability, adequacy and regularity in water supply to the crop. A comparison of water management problems between irrigation systems (Table I) revealed that PTW farms have considerably less problems of water control.

TABLE I — PROBLEMS UNDER DIFFERENT SOURCES OF IRRIGATION

(percentage of farms)

Problems	PTW	STW	Canal
Irregularity in water supply	0	100	100
Water distribution problem	0	0	35
Insufficient water	0	100	75
Inadequate drainage	0	0	25
Adverse effects on soil fertility	0	0	45

Irregularity and inadequacy in irrigation water supply were the serious problems faced by STW and canal farms. Besides this, drainage problem and deterioration in soil fertility were also reported by canal irrigated farms. Farmers, far from their supply outlets, were generally receiving less water compared to those near the canal. This type of water distribution problem is faced by 35 per cent of canal irrigated farms.

Cropping Intensity, Cropping Pattern, Use of Inputs and Returns

The problems of irregularity and inadequacy of water supply, over-irrigation and consequent drainage losses make water management imperative. Better water management leads to higher yield, increased agricultural output and higher income via additional cropping intensity, a shift to more profitable cropping pattern and higher use of farm inputs (Table II).

The intensity of cropping was maximum for PTW (172 per cent) and minimum under STW (166 per cent). Wheat crop predominated in the cropping pattern for all the irrigation systems. Sugarcane, a cash crop in the region, occupied the second place and maize and paddy occupied third and fourth places respectively in the cropping pattern for all the categories of farms. PTW farms had a more diversified cropping pattern cultivating potato (5.7 per cent) and oilseed (2.7 per cent) to maximize their returns. The area under intensive irrigated crops (wheat, sugarcane, paddy and potato) was maximum (79 per cent) on PTW farms followed by canal irrigated farms (68 per cent) and minimum under STW farms (58 per cent). Assured and

TABLE II — CROPPING INTENSITY, CROPPING PATTERN, USE OF INPUTS AND RETURNS UNDER DIFFERENT SOURCES OF IRRIGATION

Items	PTW	STW	Canal
Farm size (ha.)	2.79	2.81	2.85
Irrigated area (%)	94	87	91
Cropping intensity (%)	172	166	168
Cropping pattern (% of gross cropped area)			
Wheat	35	31	32
Sugarcane	32	24	31
Maize	8	21	14
Paddy	6	3	5
Potato	6	0	0
Oilseeds	3	0	0
Pulses	2	1	2
Other crops	8	21	16
Use of inputs (Rs./ha.)			
Human labour	502	339	435
Plough unit	518	354	400
Manures and fertilizers	757	295	541
Irrigation	330	123	153
Cost and returns (Rs./ha.)			
Cost C	5,011	2,493	3,787
Gross income	7,859	3,482	5,734
Net income	2,848	989	1,947

more dependable water supply under PTW has helped the farmers to grow intensive irrigated crops on a larger area as compared to other sources of irrigation.

A significant change in the input structure was observed on PTW farms as compared to STW and canal irrigated farms. Per hectare use of inputs was substantially higher on PTW farms as compared to canal irrigated and STW farms. Canal irrigated farms were also using more intensively farm inputs than STW farms. The high investment on inputs under PTW and canal irrigated farms was compensated by additional gross returns under these farms. The

TABLE III — PER HECTARE USE OF INPUTS AND YIELD FOR SUGARCANE AND WHEAT CROPS UNDER DIFFERENT SOURCES OF IRRIGATION

Sources of irrigation	Human labour (man-days)	Irrigation water (thousand gallons)	Fertilizer(N+P+K) (kg.)	Plough unit (pairs)	Yield (quintals)
		Sugarcane			
PTW	67	1,700	242	22	604
STW	45	571	131	20	341
Canal	88	1,110	179	27	513
		Wheat			
PTW	52	874	165	18	46
STW	42	530	85	15	25
Canal	54	707	170	16	35

net income per hectare under PTW farms was three times that of STW and two times that of canal irrigated farms. Cropwise analysis (Table III) also revealed that better water management under PTW had increased the use of inputs for all crops, which has resulted in higher yields as compared to the situations under STW and canal irrigated farms.

Economic Evaluation for Irrigation Systems

Indirectly estimated Cobb-Douglas type production functions (Table IV) for sugarcane and wheat crops grown under different sources of irrigation, derived from profit function formulation, were used for decomposing the total difference in yield between sources of irrigation into their constituent forces, *i.e.,* better water management and changes in the level of inputs. The results of the decomposition analysis for sugarcane and wheat are presented in Table V.

TABLE IV — INDIRECT ESTIMATES OF COBB-DOUGLAS PRODUCTION FUNCTION FOR SUGARCANE AND WHEAT UNDER DIFFERENT SOURCES OF IRRIGATION

Items	Parameter	Sugarcane			Wheat		
		PTW	STW	Canal	PTW	STW	Canal
Constant	A	150.3	88.6	75.8	7.05	4.13	3.50
Human labour (N/L)	a	0.0515	0.0675	0.0723	0.0884	0.1385	0.1273
Irrigation water (I/L)	b	0.0588	0.0268	0.0217	0.0396	0.0677	0.0370
Fertilizers (F/L)	c	0.1220	0.1210	0.1023	0.1948	0.2139	0.2742
Plough unit (B/L)	d	0.0192	0.1109	0.2739	0.0859	0.0493	0.0379

TABLE V — DECOMPOSITION ANALYSIS OF TOTAL CHANGE IN PRODUCTION BETWEEN IRRIGATION SYSTEMS

Items	Sugarcane			Wheat		
	PTW vs. STW	PTW vs. canal	Canal vs. STW	PTW vs. STW	PTW vs. canal	Canal vs. STW
Observed changes in yield (%)	57.1	16.5	40.7	60.8	27.7	33.1
Sources of change						
1. Water management	40.3	11.3	22.4	44.8	28.6	10.0
2. Changes in inputs						
Human labour	2.0	1.1	4.4	1.9	-0.5	3.5
Irrigation	6.4	2.5	1.4	2.0	0.8	1.0
Fertilizer	7.5	3.7	3.2	12.9	-0.6	19.0
Plough unit	0.2	0.4	8.9	1.5	0.8	0.3
All Inputs	16.1	7.7	17.9	18.3	0.5	23.8
Estimated changes in yield (%)	56.4	19.0	39.3	63.1	29.2	33.9

Better water management in terms of assured, timely and adequate water supply led to an improvement in the productivity of land and inputs on PTW farms as compared to STW and canal irrigated farms. Water management under PTW farms accounted for about 40 per cent more output for sugarcane and 45 per cent more output for wheat as compared to the

relatively inefficiently managed STW. The contribution of water management on PTW farms as compared to canal farms in terms of output growth was 11 per cent for sugarcane and 29 per cent for wheat. Water management under canal farms led to about 10 to 22 per cent higher yield for all crops as compared to the output on STW. Fertilizer and irrigation water inputs are identified as important determinants in increasing the yield for both the crops in all the irrigation systems.

The foregoing results established that water management under PTW has contributed a major share in output growth. Water management contribution varies with the irrigation systems. Now the question arises, how much additional returns and cost are incurred to the difference in the levels of water management influenced by irrigation systems. Net benefit and benefit-cost ratio were computed for different groups of irrigation systems to judge the economics of water management (Table VI).

TABLE VI — BENEFIT-COST ANALYSIS OF WATER MANAGEMENT

Items	PTW vs. STW	PTW vs. canal	Canal vs. STW
		Sugarcane	
Additional benefits (Rs./ha.)	1,214	342	633
Additional cost (Rs./ha.)	356	279	77
Net benefits (Rs./ha.)	858	63	556
Benefit-cost ratio	3.41	1.23	8.22
		Wheat	
Additional benefits (Rs./ha.)	926	592	201
Additional cost (Rs./ha.)	70	88	22
Net benefits (Rs./ha.)	856	504	179
Benefit-cost ratio	13.23	6.73	9.14

Water management under PTW over STW farms had increased the benefits by Rs.926 per hectare for wheat and by Rs.1,214 per hectare for sugarcane. The benefit-cost ratio of water management was as high as 13.23 for wheat and 3.41 for sugarcane. Water management under private tubewells over the canal irrigation system had generated additional benefits per hectare of Rs.342 for sugarcane and of Rs.592 for wheat crop. Better water management under private tubewell farms had raised irrigation costs by Rs.88 per hectare for wheat and by Rs.279 per hectare for sugarcane. These benefits and cost estimates of better water management gave a positive value of net benefit per hectare of Rs.504 for wheat and Rs.63 for sugarcane. The benefit-cost ratio of water management was also greater than one. Water management under canal irrigated farms over STW farms had also generated additional benefits of Rs.201 per hectare for wheat and of Rs.633 per hectare for sugarcane and the benefit-cost ratio was also greater than one for both the crops.

CONCLUSIONS

Substantial positive contribution of better water management to the crop output growth demonstrates the importance of PTW over canal and STW irri-

gated farms in increasing the yield and income to the farmers. PTW irrigation system was a low cost venture compared to the benefits derived from it. The horizontal expansion of irrigation specially through PTW will enhance agricultural production and farmer's income at a rapid rate.