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Technical and Water Use Efficiency in Methods of Irrigation in Thane District of Maharashtra*

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Abstract

The paper has examined the nature of technological change in the irrigated crop production in the Thane district of Maharashtra by taking the cross-sectional data from 173 farms. The Cobb-Douglas production function analysis on per hectare basis has indicated that human labour (0.0613) has a significant and positive influence on output in traditional method of irrigation (TMI). In the modern method of irrigation (MMI), fertilizer (0.4612) followed by human labour (0.3180) have significant but negative influence on crop productivity. In TMI farms the quantity of water used has been excess by 27 per cent over the economic optimum while in MMI farms, it has been only marginally higher (0.38%) over economic optimum. It reveals water conservation in MMI. The average Timmer technical efficiencies have been found as 49.97 per cent in TMI and 58.37 per cent in MMI for the irrigated crop production. There has been excessive use of factors of production (human labour, bullock labour, seed, manure, fertilizer, plant protection and irrigation expenses) to the extent of 78 to 92 per cent in TMI and 30 to 37 per cent in MMI, as revealed through frontier production function analysis for frontier users. It indicates the existence of much scope in efficient use of inputs in TMI.

Introduction

Water, as an input to agriculture, is vital to economic growth and sustainable development. Its catalytic role in enhancing productivity and improving resource-use efficiency is well documented. However, water

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has become a scarce resource, owing to its multiple uses and increasing demand in crop production. The question is how to make judicious use of water. Although there are a number of price and non-price factors that have a role in improving water-use efficiency, the irrigation technology plays an important role in it. There are different methods of irrigation — each having its own advantages and limitations. This paper has examined the nature of technological change in the irrigated crop production in the Thane district of Maharashtra where drip irrigation method is practised, particularly by the farmers growing fruits and vegetables. Being in proximity to Mumbai, there is an assured market for fruits and vegetables. The rising water scarcity has forced the farmers to switch over to improved irrigation methods as to reduce the cost of production and increase crop yields.

Methodology

Sample

The sample respondents were selected using the multi-stage random sampling technique. The primary data required for the study were collected through a survey of 173 farmers from 9 villages spread across three talukas of the Thane district during the agricultural year 1997-98. The sample farms were further divided into two categories as those practising (i) traditional method of irrigation (TMI), i.e. flood/check basin irrigation, and (ii) modern method of irrigation (MMI), i.e. drip irrigation using groundwater. The distribution of sample is given in Table 1.

Analytical Tools

Production Function

Separate production functions (log linear) were estimated for measuring the change in farm productivity between the traditional and modern methods of irrigation. The functions were:

For traditional method [Eq. (1)]:

$$\text{In } Y_1 = \ln a_1 + b_{11}\ln X_{11} + b_{12}\ln X_{12} + \ldots\ldots\ldots\ldots + b_{1n}\ln X_{1n} + e_1 \quad \ldots(1)$$

Table 1. Distribution of sample farms

Particulars of well type	Traditional method of irrigation (TMI)	Modern method of irrigation (MMI)
Dugwell	104	18
Borewell	18	20
Dug-cum-borewell	8	5
Total	130	43
Average size of holding (ha)	1.52	3.52

For modern method [Eq. (2)]:

$$\ln Y_2 = \ln a_2 + b_{21}\ln X_{21} + b_{22}\ln X_{22} + \ldots\ldots\ldots\ldots + b_{2n}\ln X_{2n} + e_2 \qquad \ldots(2)$$

where,

Y_1 = Gross value of output obtained with traditional method of irrigation (Rs),

Y_2 = Gross output obtained in modern method of irrigation (Rs)

a_1 and a_2 = The intercepts of traditional and modern irrigations, respectively

bi = Output elasticity co-efficient of the ith input

X_{1n} = Independent variables in traditional method of irrigation, and

X_{2n} = Independent variables in modern method of irrigation.

Independent variables were expressed in monetary terms (Rs /ha). These were: human labour [X_1], bullock labour [X_2], seed [X_3], manure [X_4], fertilizer [X_5], plant protection chemicals [X_6], and irrigation expenses [X_7].

Marginal Productivity of Groundwater

The marginal productivity of groundwater was estimated using a gross return function of the transcendental form since it allowed for variability in marginal productivity and elasticity of water-use. It was hypothesized that the gross income would vary with groundwater used and irrigation costs. In addition, the marginal productivity of water was hypothesized to vary inversely with the level of water used and directly with the gross returns. Transcendental function by virtue of its property to accommodate the increasing, decreasing and diminishing returns to water used. The functional form was given by Equation (3):

$$Y = AX_1^{B_1}e^{C_1X_1}X_2^{B_2}e^{C_2X_2} \qquad \ldots(3)$$

where, Y = Gross returns from the farm (Rs)
X_1 = Groundwater use (lakh litres)
X_2 = Annual cost of irrigation (Rs)

Equation (3) was estimated with the following form [Eq. (4)]:

$$\ln Y = \ln A + B_1\ln X_1 + C_1X_1 + B_2\ln X_2 + C_2X_2 \qquad \ldots(4)$$

The marginal productivity of groundwater was estimated by using the expression (5):

$$MP_{GW} = [B_1/X_1 + C_1]Y \qquad \ldots(5)$$

and was estimated at the geometric mean level of gross return and groundwater used.

The optimum dose of groundwater was estimated by using expression (6):

$$X_1^* = (B_1 Y)/(P_{X_1} - C_1 Y) \quad \ldots(6)$$

where, P_{X_1} = Price per unit of water = (Amortized cost of irrigation for the entire farm/quantity of water used in the farm (lakh litres).

The Timmer Measure of Technical Efficiency

Timmer imposed a Cobb-Douglas type specification on the frontier and computed an output-based measure of efficiency. The approach adopted was to specify a fixed parameter frontier amenable to the statistical analysis. The general form of production function was given as Equation (7):

$$Y = f(X)\, e^u \quad \ldots(7)$$

$$U \leq 0$$

and Cobb-Douglas production function in natural logarithmic form [Eq. (8)]:

$$\ln Y = \sum_{i=1}^{n} b_i \log X_i + U_i \quad \ldots(8)$$

where, $U_1 \leq 0$

In estimating the frontier production function, Corrected Ordinary Least Squares (COLS) was chosen as the most convenient means. As a first step, OLS was applied to the C-D production function to obtain the best unbiased estimates of bi-coefficients. The constant (intercept) estimate was then corrected by shifting the function until no residual was positive and one function was zero. It was done by adding the largest error-term of the fitted model to the intercept.

The Timmer measure of technical efficiency of a farm is the ratio of the actual output to the potential output given the level of input-use on farm 'i'. It thus indicates how much extra output could be obtained if farm 'i' were to be on the frontier.

Timmer measure of technical efficiency is given by Equation (9):

$$TE = \frac{Y}{Y^*} \quad \ldots(9)$$

where,

Y^* = The maximum obtainable output given the levels of the inputs (frontier output).

The Kopp Measure of Technical Efficiency

Kopp (1981) suggested a different measure of technical efficiency in which the actual level of input used is compared to the level which would be used if farm 'i' were to be located on the frontier, given the actual output of farm 'i' and given the same ratios of input usage.

If

$$\ln Y = a + b_1 \ln X_1 + b_2 \ln X_2 + \ldots\ldots\ldots\ldots\ldots + e$$

Let

$$R_1 = \frac{X_1}{X_2}, \quad R_2 = \frac{X_3}{X_2}, \ldots\ldots R_n = \frac{X_n}{X_2}$$

where, $X_1, X_2, \ldots\ldots\ldots\ldots X_n$ denote the optimum use of inputs.

Then

$\ln X_2 = \ln X_3 \ldots\ldots\ldots$ and $\ln X_n$ can be calculated in a similar fashion.

$$\ln X_2^* = (\ln Y - A^* - b_1 \ln x_1 - b_3 \ln x_2 \ldots\ldots\ldots\ldots b_n \ln x_n)/\Sigma b_i$$

Then we may compute

$$TEi = \frac{X_2^*}{X_2} = \frac{X_1^*}{X_1} = \frac{X_3^*}{X_3} = \ldots\ldots\ldots\ldots = \frac{X_n^*}{X_n}$$

Using Kopp measure of technical efficiency, the frontier usage of input was worked out and compared with the actual usage of inputs.

Results and Discussion

Resource-use Efficiency

Coefficients of human labour (0.8645) and irrigation expenses (0.0613) (Table 2) were positive and significant on farms using traditional method of irrigation. These farms had higher proportion of vegetables in their cropping pattern than the MMI farms. However, the availability of labour, especially during the peak periods, was inadequate as perceived by the farmers. This implied that human labour was an important factor in irrigated crop production. The negative regression coefficient of bullock labour showed its excess use in the irrigated crop production due to non-availability of alternative avenues for engaging the bullocks.

Table 2. Cobb-Douglas production function estimates under different methods of irrigation

(per ha)

Sl No.	Explanatory variable	Parameter	TMI (N = 130)	MMI (N = 43)
1.	Constant	A	2.08	1.81
2.	Human labour	b_1	0.8645***	0.3180**
			(0.1420)	(0.1759)
3.	Bullock labour	b_2	-0.0212**	0.964
			(0.094)	(0.1404)
4.	Seed	b_3	0.0332	0.0226
			(0.0128)	(0.0156)
5.	Manure	b_4	0.0107	0.2199
			(0.1223)	(0.1927)
6.	Fertilizer	b_5	0.0682	0.4612***
			(0.0468)	(0.1535)
7.	Plant protection	b_6	0.0014	-0.1072**
			(0.0404)	(0.0154)
8.	Irrigation expenses	b_7	0.0613*	0.1044
			(0.0350)	(0.0931)
9.	Coefficient of multiple determination	R^2	0.92	0.95
10.	Adjusted coefficient of multiple determination	R^2	0.91	0.94
11.	Returns to scale	Σb_i	0.99	1.15
12.	Calculated 'F' value	F	198.43***	96.90***

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level
Note: Figures within the parentheses indicate standard error of respective production coefficient

Fertilizers (0.4612) followed by human labour (0.3180) (Table 2) had significant and positive influence while plant protection (-0.1072) had significant but negative influence under MMI. The farms with MMI used higher quantities of fertilizers to obtain better yields of vegetables and fruits. The negative influence of plant protection chemicals in MMI also indicated their excess use. The production elasticities of other variables were positive but their influence on productivity was not significant.

Further, the variables included in the functions exhibited constant returns to scale in the traditional method of irrigation and increasing returns to scale in the modern method of irrigation.

Table 3. Distribution of sample farms according to technical efficiency levels

Particulars	TMI (N = 130)	MMI (N = 43)
High (75% and above)	18 (13.85)	-
Medium (50 to 75%)	60 (46.15)	42 (97.67)
Low (less than 50%)	52 (40.00)	1 (2.33)
Average efficiency (%)	49.97	58.37

Note: Figures within the parentheses indicate percentage total farms in each method

Water-use Efficiency and Marginal Productivity

In a well command area, the actual groundwater used was 28.50 lakh litres in MMI and 20.70 lakh litres in TMI. However, the economic optimum using transcendental production function was estimated at 28.39 lakh litres in MMI and 16.28 lakh litres in TMI. The MR (marginal revenue) to MC (marginal cost) ratio was 1.00 in MMI and 0.92 in TMI.

In the case of MMI, MR to MC ratio (1.00) had reached the economic optimum of groundwater-use. These farms were using marginally excess water over economic optimum. On the other hand, in the case of TMI, water-use was 27 per cent excess over the economic optimum.

The MMI farms had more area under irrigation than the traditional farms, may be due to their higher water-use efficiency and adopted conservation measures. In both the groups of farms, almost all the farmers grew those vegetable crops which used less water. Satyasai and Vishwanathan (1997) have made similar observations in Andhra Pradesh on different crops.

Timmer Measure of Technical Efficiency

The results of Timmer measure of technical efficiency are given in Table 3. The mean technical efficiency of 58.37 per cent on MMI farms was higher than that on TMI farms (49.97%). Only 13.85 per cent of the TMI farms had technical efficiency above 75 per cent, while none of the MMI farms had such a high technical efficiency. In most of the MMI farms, the technical efficiency ranged between 50 and 75 per cent. The proportion of TMI farms within this range was only 46 per cent, while rest of the TMI farms had technical efficiency below 50 per cent. These observations

Table 4. Actual and frontier usage of inputs in irrigated crop production under different methods

Variable	Traditional method of irrigation (TMI)			Modern method of irrigation (MMI)		
	Actual	Frontier	Per cent excess	Actual	Frontier	Per cent excess
Human labour	17987	9353	92.31	24526	17695	38.60
Bullock labour	1217	645	88.68	1537	1122	36.97
Seed	66	37	78.38	30	23	30.44
Manure	3019	1691	78.53	4852	3493	38.91
Fertilizer	4600	2576	78.57	11110	7999	38.89
Plant protection	987	543	81.77	1723	1275	35.14
Irrigation expenses	1477	768	92.32	1805	1354	33.31

indicated that there was scope in improving the technical efficiency levels on both the TMI and MMI farms through suitable modifications in input-use.

Kopp Measure of Technical Efficiency

The actual and frontier levels of factors of production for both the TMI and MMI are presented in Table 4. In general, the inputs were used excessively under TMI than MMI farms. The quantum of excessive use ranged from 78.38 to 92.32 per cent on TMI and 30.44 to 38.91 per cent on MMI farms. In other words, farmers practising TMI had a greater scope to increase their output with the existing level of inputs than the MMI practitioners. The efficiency results, by and large, were in conformity with those of Russel and Young (1983), Ali and Chowdhary (1991) and Kalirajan and Shand (1997). Alternatively, it suggested that modern methods of irrigation add to input-use efficiency.

Conclusions

The estimated farm level production response functions have been significant and a good fit has been found for both traditional and modern methods of irrigation. The Cobbs-Duglas function analysis has indicated that the human labour (0.8645) and irrigation expenses (0.0613) have a significant and positive influence while bullock labour (-0.0212) has a significant but negative influence on output on TMI farms. In case of MMI farms, fertilizer (0.4612) followed by human labour (0.3180) have a significant and positive influence while plant protection (-0.1172) has a significant but negative influence on crop productivity. The coefficient of multiple determination (R^2) (0.91 in TMI and 0.94 in MMI) was on fairly higher side.

The traditional methods of irrigation result in excess water-use, while the modern methods promote optimum utilization of water, implying that modern methods of irrigation conserve water that can be used to irrigate additional land area. The magnitude of input-use has been higher in the traditional than modern methods. This suggests a greater scope for the efficient use of inputs in the traditional method of irrigation.

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