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Measurement of Farm Technical Efficiency – A Case Study of Mahi Right Bank Canal Command Area, Gujarat State

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Abstract: The farm technical efficiency was measured by Timmer method and Kopp method. Data were collected during 1991-92 from randomly selected 500 farmers from 50 villages in Mahi Right Bank Canal Command area. A total number of 77 farmers growing tobacco crop was taken for the present study. Out of 77 farmers, 40 were using only canal water, and 37 were using both canal and ground water as conjunctive use. Similar results were obtained from both the methods. By proper utilization of resources and conjunctive use of water, 35.3% higher yield can be obtained; the same level of yield can be obtained at less than 32% resource use.

Key words: Tobacco, canal water, ground water.

Maximization of farm technical efficiency is an important factor in improving the productivity where the available resources are meagre. In coming years, it will be an up-hill task to feed the population which is increasing at a rate of 2% annually. Two options available to increase the agricultural production are: (a) to bring more area under cultivation, and (b) to increase production per unit area and per unit time. Land being a scarce resource, further expansion in area is possible only to a limited extent. The productivity can, however, be increased by adoption of appropriate crop management technologies, as it has been reported that considerable gap exists between the crop yield potential and the actual yield on farmers' fields. Out of 327 M ha area under cultivation in India, 160 M ha suffers from land degradation processes and salinity. One important option, therefore, is to allocate resources at optimal levels to reclaim the salt affected soils. Both the strategies can be utilized to achieve to bring more area under cultivation and increasing crop productivity from areas with low production. The extent to which innovative technology is efficiently used by the target groups will determine the success. Farmers may not be allocating their resources optimally due to resource constraints and lack of management skills. However, they can not be termed as inefficient farmers merely because they did not use the resources to a point where profit could be maximized. On the other hand, farmers may be allocating higher resources, like seeds, fertilizers, farm yard manure (FYM), etc., more than optimal level, in degraded soils, to maximize yield and profit. Such farmers cannot be termed as 'inefficient' because even if all other resources are efficiently exploited, the land itself is a crucial factor that determines the overall farm tech-

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nical efficiency. Under such circumstances, output in relation to the input used will bring out the true picture of 'farm-level efficiency', which can be defined as the maximum possible and achievable yield through the given input level. An attempt has been made here to understand the extent to which farmers in a canal command area are exploiting their resources to maximize profit in the production process.

Materials and Methods

Sampling procedure and data collection

The data for this study were collected from the farmers of the Mahi Right Bank Canal Command area in Kheda district of Gujarat state. A major part of the district is irrigated by Mahi Right Bank Canal which has 2.20 lakh hectare irrigation capacity. Based on random sampling approach, 500 farmers spread over 50 villages were selected. The tobacco crop was selected because of its salt tolerance. Tobacco was grown only in 10 selected villages. The total number of farmers growing the tobacco crop was taken for the present study. Three odd observations were deleted due to error in the data. The remaining 77 observations were used for analysis purpose. Out of 77 farmers, 40 used canal water, while 37 used both canal and ground water as conjunctive use. By survey method the input-output data for agricultural year 1990-91 were collected. The analysis was done using the following model:

$$\text{Ln } Y = \text{Ln } a + b_1 \text{Ln}X_1 + b_2 \text{Ln}X_2 + b_3 \text{Ln}X_3 + b_4 \text{Ln}X_4 + b_5 \text{Ln}X_5 + e$$

where,

Y = yield of tobacco crop (q ha^{-1}),

X_1 = expenditure on fertilisers and FYM (Rs. ha^{-1}),

X_2 = expenditure on irrigation (Rs. ha^{-1}),

X_3 = hired labour (Mandays ha^{-1}),

X_4 = family labour (Mandays ha^{-1}),

X_5 = expenditure on seeds, ploughing (Rs. ha^{-1}).

Analytical approach

Since the Cobb-Douglas production function does not distinguish between technical efficiency and allocative efficiency (Sampath, 1979) and assumes that all the farmers adopted identical technology of production with equal technical efficiency, it was decided to use Frontier production function, as many farmers in the area adopted heterogeneous technologies and had varying technical efficiency (Farewell, 1957). The approach adopted was to specify a fixed parameter frontier amenable to statistical analysis. The general form of the function is:

$$Y = f(X)\ e^{u} \quad \text{....(i)}$$

and in the Cobb-Douglas form,

$$\text{Ln } Y = \text{Ln } a + b_1 \text{Ln}X_1 + b_2 \text{Ln}X_2 + b_3 \text{Ln}X_3 + b_4 \text{Ln}X_4 + b_5 \text{Ln}X_5 + u \quad \text{....(ii)}$$

The random disturbances (u) follow a one-sided distribution (e.g., truncated normal, gamma, exponential, etc.) and to be independently and identically distributed in estimating the parameters of stochastic frontier production functions (Sidden and Yapp, 1992). In other words, Y represents the stochastic frontier production whose parameters may or may not be known to all farms (Argner *et al.*, 1977; Meeusen and Broeck, 1977). Therefore, the above frontier production function being stochastic in nature, the error term of 'u' is constituted of two independent disturbances. Maximum Likelihood Estimates (MLE) have been widely used (Banik, 1994; Kaliranjan and

Shand, 1994). The results obtained by MLE are quite close to the Ordinary Least Square (OLS) estimates (Greene, 1980) and identical (Koutsoyannis, 1983; Johnston, 1988). However, the resultant set of inputs (x_j) were assumed to be independent of the disturbances. The first step was to apply OLS to equation (ii), to provide the best linear unbiased estimate of the coefficients. The intercept estimated was then corrected by shifting the function until no residual was positive and one was zero. This can be done by adding largest positive estimated residual recorded by sample farm to the intercept. Greene (1980) has shown that a consistent, though biased estimate of 'a', which imposed sign uniformity on the residuals, can be generated by this procedure.

Two different methods were employed to measure the technical efficiency.

Timmer measure of technical efficiency

The Timmer measure of technical efficiency is the ratio of actual output to the potential output on the frontier production function, given the level of input use on the i^{th} farm (Timer, 1971). It, thus, indicates how much extra output can be obtained if i^{th} farm was on the frontier.

As the revised residuals ($e_i < 0$) are defined as:

$$e_i = LQ_i - LQ^*_i \quad i = 1, 2, ...$$

$$\text{Timmer } TE_i = Q_i / Q^*_i < 1.$$

Kopp measure of technical efficiency

Kopp (1981) suggested an alternative method of measuring technical efficiency (TE_i) by comparing the actual level of inputs used to the level which could be used if the i^{th} farm was located on the frontier and obtained efficient level of output and given the same ratios of input usage. This level of input to realize the same output (Y) was calculated as:

$$\text{Ln } Y = a^* + b_1 LnX_1 + b_2 LnX_2 + b_3 LnX_3 + b_4 LnX_4 + b_5 LnX_5 + e$$

$$\text{Let } R_1 = X_1 \backslash X_n,\ R_2 = X_2 \backslash X_n,\ R_3 = X_3 \backslash X_n, ...\ R_{n-1} = X_{n-1} \backslash X_n$$

$$\text{or} \quad = X_1 \backslash X_2, = X_3 \backslash X_2, = X_4 \backslash X_2, R_n = X_n \backslash X_2$$

and let X_1^*, X_2^*,......X_n^* denote the optimum use of inputs on i^{th} farm for Q level of output. Then

$$\text{Ln } X_2^* = [LnQ - a^* - b_1 Ln(R_1) - b_3 Ln(R_3) - b_4 Ln(R_4) - b_5 Ln(R_5)]/bj$$

In a similar manner, X_1^*, X_3^*, X_4^*, X_5^* frontier values can be calculated indicating corresponding inputs used.

One can then compute:

$$TE_i = X_1^* \backslash X1 = X_2^* \backslash X2 = X_3^* \backslash X3 = X_4^* \backslash X4 = X_5^* \backslash X5$$

Results and Discussion

The estimated 'average' Cobb-Douglas production function took the following form:

$$LnQ = -4.0005 + \underset{(0.0678)}{0.2950^{***}} LnX_1 + \underset{(0.0744)}{0.4135^{***}} Ln\ X_2 + \underset{(0.0344)}{0.0961^{**}} LnX_3 + \underset{(0.0600)}{0.2580^{***}} LnX_4 + \underset{(0.0761)}{0.1109^{*}} LnX_5$$

***Significant at 1%; **Significant at 5%; *Significant at 10%.

$R^2 = 0.7388 \quad R^{-2} = 0.7204 \quad N = 77$

The largest positive estimated residual recorded by a sample farm was 0.4358. So the appropriate change in the frontier production function was:

$$LnQ^* = -3.5647 + 0.2950LnX_1 + 0.4135LnX_2 + 0.0961LnX_3 + 0.2580\ LnX_4 + 0.1109\ LnX_5$$

Table 1. Measures of technical efficiency

Number	Rank Kopp	Rank Timmer	Number	Rank Kopp	Rank Timmer	Number	Rank Kopp	Rank Timmer
1.	1.00	1.00	27	0.77	0.75	53	0.62	0.62
2.	0.95	0.97	28	0.76	0.75	54	0.61	0.61
3.	0.94	0.96	28	0.76	0.74	55	0.60	0.60
4.	0.94	0.93	30	0.75	0.74	55	0.60	0.59
5.	0.92	0.93	31	0.74	0.73	57	0.58	0.59
6.	0.90	0.91	31	0.74	0.72	57	0.58	0.58
7.	0.89	0.90	33	0.73	0.72	57	0.58	0.58
8.	0.88	0.88	33	0.73	0.70	60	0.57	0.57
9.	0.88	0.87	35	0.72	0.70	61	0.56	0.56
10.	0.87	0.87	36	0.71	0.70	62	0.54	0.55
10.	0.87	0.86	36	0.71	0.69	63	0.51	0.55
12.	0.85	0.85	38	0.70	0.68	64	0.50	0.54
12.	0.85	0.85	38	0.70	0.68	64	0.50	0.52
12.	0.85	0.85	40	0.69	0.67	66	0.49	0.51
15	0.84	0.83	41	0.68	0.67	67	0.49	0.50
15	0.84	0.83	41	0.68	0.67	67	0.49	0.50
15	0.84	0.82	41	0.68	0.66	69	0.48	0.49
18	0.83	0.81	41	0.68	0.66	69	0.48	0.46
18	0.83	0.80	45	0.67	0.66	71	0.44	0.45
18	0.83	0.80	46	0.66	0.64	74	0.41	0.43
23	0.82	0.80	46	0.66	0.63	75	0.38	0.43
24	0.79	0.79	50	0.64	0.63	75	0.38	0.38
24	0.79	0.75	51	0.63	0.63	77	0.29	0.37
26	0.78	0.75	51	0.63	0.63			

Where Q^* denotes the maximum value of output obtainable for given input levels.

It was observed that farmers were operating at constant returns to scale as the sum of elasticities of input (i.e., $b_I = 1.1735$) did not differ significantly from unity. The regression coefficients have positive and significant effects on the yield of tobacco crop at different levels of significance. The value of adjusted coefficient of determination (0.7204) indicated the adequacy of the model used for the present study.

The values of Timmer and Kopp technical efficiencies for each farm are shown in Table 1. If the sum of the elasticities of inputs under study indicates constant returns to scale (i.e., equal to 1), both the Timmer and Kopp technical efficiency will be identical. The sum of elasticities of inputs used for tobacco crop was a little more than one, and Timmer measure were slightly less than Kopp measure. However, it is noted that ranking of technical efficiency measured by Timmer and Kopp are more or less the same. As per Timmer measure

Table 2. Actual and frontier usage method of allocation of input and output in Tobacco crop in the canal command area of Mahi Right Bank Canal, Gujarat

Input/output	Actual usage	Frontier usage	Excess use (%)
Fertilizers and FYM (Rs.)	693.55	460.62	33.6
Irrigation charges (Rs.)	392.55	257.77	34.3
Hired labour (Mandays)	24.43	17.43	28.6
Family labour (Mandays)	15.46	10.62	31.3
Other expenses (Rs.)	917.12	639.41	30.3
Yield (q ha^{-1}) at existing level	8.75		
Yield (q ha^{-1}) at technically efficient level	13.53		
Excess output (%)	54.60		

of technical efficiency, nearly 30% farmers were more than 80% efficient; 41% of the farmers were between 80 and 60% better or efficient. However, 29% farmers were at an efficiency level below 60%. Similarly, as per Kopp measure of technical efficiency, nearly 30% farmers were more than 80% efficient; 43% farmers were between 80 and 60% and the remaining farmers operated at below 60% technical efficiency. The majority of farmers (14 out of 23) having higher technical efficiency (0.8) were using canal and ground water plus less amount of fertilizers, and remaining used higher dose of fertilisers and canal water only. The farmers (22 out of 33) having technical efficiency between 0.8 and 0.6 are using more ground water with canal water and remaining farmers were under higher dose of fertilizers and canal water only. The main reason of low technical efficiency (0.6 and 0.8) of farmer is use of more ground water which is saline in nature and/or having marginal waterlogging problem during monsoon period. Twenty out of 22 farmers having technical efficiency (<0.6) were using only canal water.

The efficiency of production was measured by maximum output attainable by each farmer. According to Timmer measure of technical efficiency, 13.53 q ha^{-1} tobacco crop can be produced at the existing level of inputs if it is technically efficient (Table 2). The results showed that farmers are excessively using various inputs (28.6 to 34.3) and actual yield of tobacco was 8.75 q ha^{-1}. If field level technical efficiency could be enhanced by appropriate use of inputs, it was technically feasible to get yield of 13.53 q ha^{-1}, an increase of 54.6% over the actual. If the existing level of tobacco yield (8.75 q ha^{-1}) is maintained, nearly 32% of input used can be saved. The farmers resorted to higher allocation primarily for inputs like hired and family labour, fertilisers and FYM, especially because of soil salinity and waterlogging. To minimize the menace of salts, farmers generally would resort to increased input use of FYM. It was also observed that farmers having technical efficiency below 60% could increase the tobacco yield by simply resorting to a strategic cyclic use of canal and saline ground water (Gajja and Sharma, 1994). Farmers having technical efficiency between 80 and 60% in the study area were largely using more saline ground waters which led to low productivity. It is proposed that the farmers may be educated about the ill-effects of saline water use alone and encouraged to adopt a strategy of conjunctive use of canal water and saline ground water. Such a strategy will not only lead to a saving of excess inputs but will also help to cope with soil salinity and waterlogging problems and lead to higher production per unit of area and time.

Conclusions

This study shows that technical efficiency measured through Timmer method and Kopp method yield more or less similar results. Proper utilisation of resources in tobacco cultivation in the Mahi Right Bank Canal Command area can enhance productivity. At least 54.6% more yield can be obtained through proper resource utilization. If the present level of yield is maintained, then about 32% of the present resources can be conserved. What is urgently required, therefore, is to take up appropriate transfer of technology programmes, whereby the farmers are motivated to adopt a strategic mix of saline ground water and canal water.

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