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An Economic Analysis of Technical Efficiency and Constraints in Rice Farms Using Different Irrigation Systems in Tamil Nadu

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Authors' contributions

This work was carried out in collaboration between all authors. Author VB designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors TA and MB managed the analyses of the study. Author TA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Rice is the stable food in India, improvement in efficiency levels is one of the major means of sustaining the staple food production and thereby ensuring food security. This study was taken up to determine the technical efficiency and constraints faced by the farmers in rice cultivation under different irrigation systems in Tamil Nadu. It could be concluded that the mean technical efficiency was 0.76, 0.75 and 0.71 for canal, well and tank irrigation system respectively. This showed that in the study region, the efficiency of the farmers was almost same for all the three systems of irrigation.

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The results of the Garrett's ranking technique indicated that non-availability of fertilizers at the appropriate time, delay in getting subsidy for drip irrigation and fertigation systems and scarcity of irrigation water were the most important constraints in rice cultivation using canal, tank and well irrigation systems. Thus, productivity can be increased by the adoption of non-monetary inputs like timely sowing, maintaining optimum plant population, timely irrigation, efficient use of fertilizers and irrigation water, need-based plant protection measures and timely harvesting of crop.

Keywords: Rice cultivation; technical efficiency; Garrett's ranking; different irrigation systems.

1. INTRODUCTION

Rice being the most important stable food in India, improvement in efficiency levels is one of the major means of sustaining the staple food production and thereby ensuring food security. The biophysical and socio-economic constraints of the rice farmers result in low technical efficiency as well as discourage farmers to bear the risk. Changes in productivity occur due to changes in technology and changes in technical efficiency [1]. The level of efficiency of a farmer in his production process is difficult to assess unless one is sure of the prevailing conditions in which he operates. For instance, a farmer may not be allocating his resources optimally due to resource constraints or the prevailing uncertainity with regard to price/yield and perhaps due to the lack of ready assess to resources. Under such circumstances, he cannot be termed inefficient merely because he does not operate at the point where profit is maximized; profit maximization may not be his final objective. On the other hand, a farmer may be using all the inputs in required quantities, but may not be realizing the potential output due to improper management. In such cases, a comparison of output in relation to the level of inputs used reveals the true picture of efficiency. The concept of technical efficiency in rice cultivation relates to whether the rice farmers use the best available technology in their production process. The technical efficiency may also be defined as the ability of the rice farmers to produce as much output as possible with a specified level of inputs, given the existing technology. Technical efficiency can also be defined as the farm's ability to obtain the maximum output from a given set of resources [2]. A comparison of indices of technical efficiency of individual enterprises provides information on the relative as well as absolute levels of total factor productivity. For this reason, the measurement, as well as interpretation of the technical efficiency of the individual farms in the area under study, is an important exercise to do [3]. The study was taken up to determine the technical efficiency of rice cultivation under different irrigation systems (canal, well and tank) in Tamil Nadu. Moreover, the study also explores the individual farm level technical efficiency of rice cultivation under different irrigation systems. The study attempts to compare farmers' responses with respect to technical efficiency in rice production depending upon the systems of irrigation in Tamil Nadu. In addition, the present study attempts to identify the constraints associated with the farmers in rice cultivation under different irrigation systems in Tamil Nadu.

2. METHODOLOGY

2.1 Measurement of Technical Efficiency Using Stochastic Frontier Production Function Analysis

The stochastic frontier production function for estimating farm level technical efficiency [4] is specified as:

$$Y_i = f(X_i, \beta) + \varepsilon_i \quad (1)$$

Where i is the nth observations, Y_i is output, X_i denotes the actual input vector of production function and β is the vector of parameters of production function and ε is the error term that is composed of two elements, that is

$$\varepsilon_i = V_i - U_i \quad (2)$$

Where V_i is the symmetric disturbances assumed to be identical, independently and normally distributed as N (0, σ_{Vi}^2) given the stochastic structure of the frontier. The second component U_i is a one sided error term that is independent of V_i and is normally distributed as (0, σ_{Ui}^2), allowing the actual production to short fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

The farm-specific technical efficiency is defined in terms of observed output (Y_i) to the corresponding frontier output (Y_i^*) using the available technology derived which is defined as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i/u_i, X_i)}{E(Y_i/u_i = 0, X_i)}$$

$$= E\,[exp(-U_i)/\varepsilon_i] \qquad (3)$$

TE takes values within the interval (0, 1), where 1 indicates a fully efficient firm.

The stochastic frontier production function model [5] specified for rice crop is given below.

$$\ln(Y) = \beta_0 + \beta_1 (\ln X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + \beta_6 \ln(X_6) + \beta_7 \ln(X_7) + \beta_8 \ln(X_8) + \beta_9 \ln(X_9) + (V_i - U_i) \qquad (4)$$

Where

- Y = Yield of Paddy (Kg/ha)
- X_1 = Seed (Kg/ha.)
- X_2 = Human labour (man days/ha.)
- X_3 = Machine power (hp hrs. /ha.)
- X_4 = Farm yard manure (tonnes/ha)
- X_5 = Plant protection chemicals (Rs/ha.)
- X_6 = Nitrogen (Kg/ha.)
- X_7 = Phosphorous (Kg/ha.)
- X_8 = Potash (Kg/ha.)
- X_9 = Irrigation (ha.cm.)
- β_0 = ln β_0 = Regression Constant
- $\beta_1, \beta_2, \beta_3, \beta_4, \ldots\ldots \beta_9$ = Elasticity coefficients
- V = A random error term with normal distribution N (0, δ^2)
- U = A non-negative random variables called technical inefficiency effects associated with the technical inefficiency of production of farmers involved.

Estimation of equation (4) was accomplished by Maximum Likelihood Estimation (MLE) available in Frontier 4.1 [6] and has been used extensively by various authors in estimating technical efficiency among crop farmers.

2.2 Garrett's Ranking Technique

Garrett's ranking technique was employed to rank the factors that influenced the particular type of rice cultivation by the farmers. The order of merit given by the respondents was transmitted into the score. For converting the ranks assigned by the farmer towards the constraint in different types of rice cultivation, percent position was worked out for each rank using the formula:

$$\text{Percent position of each rank} = \frac{100(R_{ij} - 0.5)}{N_j}$$

- R_{ij} = Rank given for i^{th} constraint by j^{th} individual
- N_j = Number of constraints ranked by j^{th} individual

The percentage position of each rank then was converted into scores by referring them to table [7].

Then for each constraint, the scores of individual farmers were added together and divided by the total number of farmers, for whose scores were added. The mean scores for all the constraints were arranged in descending order and ranks were given. The important constraints in rice cultivation were identified based on the ranks of the constraints.

3. RESULTS AND DISCUSSION

3.1 Technical Efficiency in Rice Farms - Stochastic Production Frontier using MLE Method

The technical efficiency of canal, well and tank irrigated rice cultivating farmers was estimated by using the stochastic frontier production function of Cobb-Douglas form using the MLE method. The stochastic frontier function analysis attempted in this study had the rice output kg/ha as the dependent variable and independent variables included were, human labour (man days/ha.), machine power (hp hrs./ha), seed rate (Kgs/ha), FYM (tonnes/ha), PPC (Rs./ha), nitrogen (Kgs/ha), phosphorus (Kgs/ha), potassium (Kgs/ha), and irrigation (ha.cm). The Maximum Likelihood Estimates (MLE) of the parameters of Cobb-Douglas stochastic frontier function were obtained using maximum likelihood procedures through FRONTIER 4.1 package and the results are presented in Table 1.

3.2 Canal Irrigated Rice Cultivation

MLE results showed that in canal irrigated system of rice cultivation, the quantity of human labour and irrigation had significance at 1 percent level. The estimate of γ would refer to ratio of the variance of farm-specific performance of Technical efficiency (σu^2) to the total variance of output (σv^2). A high value for γ (0.99) would indicate the presence of significant inefficiency in the production of the crop. The estimate of γ would indicate that 99 percent of the difference between the observed and frontier output was mainly due to the inefficient use of resources, which were under the control of the farmers. The remaining portion i.e., 1 percent was due to factors beyond the farmers' control. The average technical efficiency was estimated at 76 percent indicating that output can be raised by 24 percent through following efficient crop management practices without actually increasing the level of application of inputs.

3.3 Tank Irrigated Rice Cultivation

MLE results showed that in tank irrigated system of rice cultivation, the application of N, P and irrigation were positively significant at 1 percent level. Human labour and seed rate were significant at 5 percent level. The estimate of γ was 0.91 which would indicate that 91 percent of the difference between the observed and frontier output was mainly due to the inefficient use of resources which were under the control of the farmers. The remaining portion 0.9, i.e., 9 percent was due to factors beyond the farmers' control. The mean technical efficiency (MTE) was only 0.71 which would imply that, on an average, the sample farmers would realize only 71 percent of their technical abilities and the remaining 29 percent accounted for the inefficiency of the farmers. Thus, the technical efficiency showed that there would be a reasonably good scope for increasing the productivity of rice with the existing level of input use in the study region by adopting better crop management practices.

3.4 Well Irrigated Rice Cultivation

The MLE results showed that in well-irrigated system of rice cultivation, the human labour was significant at 1 percent level, whereas the inputs like FYM, PPC and irrigation were significant at 5 percent level. The estimate of γ was 0.75 which would indicate that 75 per cent of the difference between the observed and frontier output was primarily due to factors which were under the control of farmers. The remaining portion of 25 percent was due to factors beyond the farmers' control. The estimated mean technical efficiency was 0.75 implying that, on an average, the sample farmers would realize only 75 percent of their technical abilities and the remaining 25 percent showed the inefficiency of the farmers.

It could be concluded that the mean technical efficiency was 0.76, 0.75 and 0.71 for canal, well and tank irrigation system respectively. This showed that in the study region, the efficiency of the farmers was almost same for all the three systems of irrigation. Thus, productivity can be increased by the adoption of non-monetary inputs like timely sowing, maintaining optimum plant population, timely irrigation, efficient use of fertilizers and irrigation water, need-based plant protection measures and timely harvesting of crop.

3.5 Distribution of Farmers according to Technical Efficiency Ratings

Distribution of sample farmers according to different technical efficiency ratings of canal, well and tank irrigation systems were presented in Table 2.

3.6 Canal Irrigated Rice Cultivation

The results showed that 11.20 percent of farmers using canal system of irrigation to cultivate rice were found to operate at technical efficiency rating of more than 0.90. About 14 percent of farmers were found to be operating at technical efficiency rating of below 0.60 percent.

3.7 Tank Irrigated Rice Cultivation

The results showed that five percent of farmers using tank system of irrigation to cultivate rice were found to operate at technical efficiency rating of more than 0.90. About 19 percent of farmers were found to be operating at technical efficiency rating of below 0.60 percent.

3.8 Well Irrigated Rice Cultivation

The results showed that five percent of the farmers using well irrigation system to cultivate rice were found to operate at technical efficiency rating of more than 0.90. About 10.00 percent of farmers were found to be operating at technical efficiency rating of below 0.60 percent.

It could be concluded that there was a variation in the level of technical efficiencies among the sample farmers who cultivated rice using different systems of irrigation. The sample farmers using canal system of irrigation for rice cultivation were technically efficient when compared to the farmers using tank and well system of irrigation for rice cultivation. This was due to the larger adoption of System of Rice Intensification technology among the sample farmers in Thanjavur district.

Table 1. MLE estimates of stochastic frontier function for rice cultivation under different irrigation systems

Sl. no.	Variables	Thanjavur (Canal)			Sivagangai (Tank)			Salem (Well)		
		Coefficient	Std. error	t value	Coefficient	Std. error	t value	Coefficient	Std. error	t value
A	**Frontier production function**									
1.	Constant	5.928*	0.704	8.426	4.830*	0.474	10.200	4.875*	0.637	7.654
2.	Human labour (man days/ ha.)	0.724*	0.129	5.619	0.284**	0.139	2.049	0.325*	0.049	6.680
3.	Machine power (hp. hrs/ha.)	-0.486***	0.249	-1.946	0.034 NS	0.043	0.804	0.080NS	0.084	0.949
4.	Seed rate (kgs/ha.)	0.346***	0.181	1.910	0.076**	0.027	2.850	0.029 NS	0.041	0.701
5.	Farm Yard Manure (tonnes/ha.)	-0.232***	0.136	-1.710	-0.025 NS	0.026	-0.972	0.119**	0.040	2.951
6.	PPC (Rs/ha.)	0.034 NS	0.034	0.990	0.034 NS	0.120	0.282	0.163**	0.072	2.276
7.	Nitrogen (kgs/ha.)	-0.485*	0.113	-4.273	0.262*	0.059	4.441	0.076***	0.043	1.767
8.	Phosphorous (kgs/ha.)	0.028 NS	0.038	0.736	0.178*	0.043	4.128	0.094 NS	0.073	1.284
9.	Potash (kgs./ha)	0.149***	0.081	1.829	-0.019 NS	0.062	-0.316	-0.056 NS	0.057	-0.975
10.	Irrigation (ha.cm)	0.506*	0.117	4.293	0.318*	0.045	7.080	0.152**	0.071	2.142
B.	**Diagnosis statistics**									
11.	Sigma-square (σ^2)	0.192*	0.016		0.072*	0.017		0.197*	0.065	
12.	Gamma (γ)	0.999*	0.0002		0.912*	0.064		0.752*	0.199	
13.	Log- likelihood	7.38			30.19			21.44		
14.	Mean technical efficiency	0.76			0.71			0.75		
15.	Mean technical inefficiency	0.24			0.29			0.25		
16.	Number of Observations	80			80			80		

** - 1 % level of significance ; ** - 5 % level of significance*
**** - 10 % level of significance ; NS - Non significance*

Table 2. Distribution of farmers according to technical efficiency ratings (Number of farmers)

Sl. no	Technical efficiency rating	Canal	Tank	Well
1	<60%	11(13.75)	15(18.75)	8(10.00)
2	61% - 70%	12(15.00)	20(25.00)	13(16.25)
3	71% - 80%	26(32.50)	26(32.50)	25(31.25)
4	81% - 90%	22(27.50)	15(18.75)	30(37.50)
5	>90%	9(11.20)	4(5.00)	4(5.00)
	Total	**80(100.00)**	**80(100.00)**	**80(100.00)**

(Figures in parentheses indicates percentage to total)

These results are important in that they provide detailed information to policymakers on the nature of production technologies used in farms. Thus, there was a scope to bridge the gap between the actual or realized and the potential output with the given technology by using available resources more efficiently.

3.9 Constraints Faced by the Farmers in Rice Cultivation in the Selected Districts

Garrett's ranking technique was employed to find out the constraints faced by the rice cultivating farmers using canal, tank and well irrigation systems and the results are presented in Table 3 below.

3.10 Canal Irrigated Rice Cultivation

The most important constraint in cultivation of rice using canal irrigation system was non availability of fertilizer at appropriate time followed by unremunerative price, labour scarcity in peak season, scarcity of irrigation water, inadequate supply of electricity and delay in getting subsidy for irrigation structures. Non-availability of fertilizer at appropriate time of cultivation was mainly due to poor supply of fertilizers in the inputs supply markets, cooperative societies and local fertilizer shops.

3.11 Tank Irrigated Rice Cultivation

The most important constraint in cultivation of rice using tank irrigation system was scarcity of irrigation water followed by inadequate supply of electricity, non availability of fertilizer at appropriate time, unremunerative price, labour scarcity in peak seasons and delay in getting subsidy for irrigation schemes.

3.12 Well Irrigated Rice Cultivation

The most important constraint in cultivation of rice using well irrigation system was delay in getting subsidy for irrigation schemes followed by inadequate supply of electricity, scarcity of irrigation water, non availability of fertilizer at appropriate time, labour scarcity in peak seasons, and unremunerative price. Most of the sample farmers in Salem district cultivated rice under well irrigation system, for which, the Government of Tamil Nadu provided subsidy of 100 percent to small and marginal farmers and 75 percent to all other farmers for establishing drip irrigation and fertigation system and installment of these structures.

The results on the analysis of constraints in rice cultivation by the sample farmers in the study area using Garrett's ranking technique indicated that non-availability of fertilizers at appropriate time, delay in getting subsidy for drip irrigation and fertigation systems and scarcity of irrigation water were the most important constraints in rice cultivation using canal, tank and well irrigation systems in Thanjavur, Sivagangai and Salem districts respectively.

While comparing the results with the previous studies [8], it was found that the mean technical efficiency was 0.75, 0.85 and 0.77 for TPR, DSR (I) and DSR (R) respectively indicating that in the study region DSR (irrigated) farmers were more efficient than farmers cultivating rice in the other methods of cultivation. About 22.5 percent of TPR farmers and 7.5 percent of rainfed rice farmers were found to be operating at technical efficiency rating of below 0.60 which indicated that there was tremendous scope for increasing the efficiency of TPR and rainfed rice farms in the study area. The results on the analysis of constraints in rice cultivation by the sample

Table 3. Constraint analysis in rice cultivation under different irrigation systems of the selected districts using garrett's ranking technique

Sl. no	Constraints	Canal (Thanjavur)		Tank (Sivagangai)		Well (Salem)	
		Score	Rank	Score	Rank	Score	Rank
1	Scarcity of irrigation water	46	IV	54	III	77	**I**
2	Non availability fertilizer at appropriate time	77	**I**	46	IV	54	III
3	Labour scarcity in peak season	54	III	36	V	36	V
4	Unremunerative price	63	II	23	VI	46	IV
5	Inadequate supply of electricity	36	V	63	II	63	II
6	Delay in getting subsidy for irrigation structures	23	VI	77	**I**	23	VI

farmers in the study area using Garrett ranking technique indicated that low net return, weed infestation and crop failure were the most important constraints in rice cultivation for TPR, DSR (I), and DSR (R) respectively.

4. CONCLUSIONS

The technical efficiency of the farmers was almost same for all the three systems of irrigation, and it was apparent that the resources used in rice cultivation in the study area leave ample scope for improvement for all the selected respondents. Thus, productivity can be increased by adoption of non-monetary inputs like timely sowing, maintaining optimum plant population, timely irrigation, efficient use of fertilizers and irrigation water, need based plant protection measures and timely harvesting of the crop. By a better organization of resources, a considerable amount of resources (i.e. inputs including land) can be saved without affecting the achievement of the current level of production of rice. Thus, the importance of productivity management in rice cultivation in terms of improving technical efficiency of the farmers by proper management and judicious utilization of the resources is a matter of prime concerned today. The results Garrett's ranking technique indicated that non-availability of fertilizers at appropriate time, delay in getting subsidy for drip irrigation and fertigation systems and scarcity of irrigation water were the most important constraints in rice cultivation using canal, tank and well irrigation systems in Thanjavur, Sivagangai and Salem districts respectively. Hence, the government should ensure necessary actions to regularize the availability of subsidy to the eligible farmers in an appropriate time. Provision of timely and adequate inputs and infrastructure supported by mechanization, credit availability and proper guidance through services may help to raise the technical efficiency of farms under all the systems of irrigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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