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Resource-use Efficiency of Paddy Cultivation in Peechi Command Area of Thrissur District of Kerala: An Economic Analysis

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Abstract

This study undertaken in the Peechi Command Area of Thrissur district in the Kerala state, has examined the resource productivity and allocative as well as the technical efficiency of paddy production. The study has used the primary data collected from 71 rice farmers of the command area using the stratified random sampling. The cost of cultivation of paddy in the command area has been found as Rs 21603/ha, resulting in a BC ratio of 1.34. The elasticity coefficients for chemical fertilizers, farmyard manure and human labour have been observed significant and positive. The allocative efficiency has indicated that marginal return per one rupee increase under these heads would be Rs 2.83, Rs 1.57 and Rs 1.17, respectively. The average technical efficiency of the paddy farmers in the command area has been found as 66.8 per cent. Education of the farmer and supplementary irrigation provided during the water-stress days have been identified as the factors which could enhance the technical efficiency. The study has called for an equitable distribution of canal water and enhanced extension services for resource management in the area.

Introduction

Rice is the major food crop of the Kerala state. It was cultivated in 3.49 lakh hectares with a production of 7.7 lakh tonnes in 1999-2000. In the Kerala state, paddy is mainly cultivated during three seasons: *Virippu*

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(Autumn), *Mundakan* (Winter) and *Punja* (Summer) with *Mundakan* being the predominant paddy-growing season. The area under rice is gradually shrinking due to the conversion of marginal lands to non-agricultural purposes and for cultivation of high-value horticultural crops. The area under rice was 8.74 lakh hectares in 1970-71, but it fell down to 3.49 lakh hectares in 1999-00 with the corresponding decline in production from 12.92 lakh tonnes to 7.70 lakh tonnes. The extent of decline in the area under paddy has not affected production to that magnitude due to increase in its productivity. The productivity of paddy in the state increased from 1477 kg/ ha in 1970-71 to 1954 kg/ ha in 2000-01. With total production of 7.7 lakh tonnes of paddy, Kerala meets only 35 per cent of its total rice requirement. Thus, the state suffers from the supply-induced regional food-insecurity. Since expansion of the area under paddy is not an option for the land-constrained state, it is imperative to meet the food security by improving the production through enhancing the productivity of the paddy crop. To achieve this objective, it is essential to enhance the resource-use efficiency and technical efficiency for rice cultivation. Various irrigation projects were implemented in the state to enhance the productivity of paddy in the water-deficient areas. Peechi Irrigation Project is one such projects implemented to meet the water requirement of paddy cultivation in the Thrissur district of Kerala state. It is a large irrigation project implemented in 1951 with a total proposed command area of 17256 ha. This paper has studied the price and technical efficiencies of paddy cultivation in the Peechi Command Area. An attempt has also been made to understand the technical efficiency of paddy farmers and the factors determining it.

It is difficult to estimate the efficiency of the farmers without the knowledge of the conditions under which the production is performed. To achieve maximum profit in a resource-constrained production environment, the farmers have to be price-responsive. The efficiency associated with allocation of inputs according to the prevailing market price is called allocative efficiency of the farmers. Even if the farmers are allocatively efficient, they may not be realising the technically feasible maximum production due to inefficient management of the resources. In such cases, a comparison of output in relation to the level of inputs-used will reveal the true picture of efficiency. This is referred to as technical efficiency. Efficiency is an important concept in production economics when resources are constrained and opportunities of adopting better technologies are competitive (Gaddi *et al*., 2002). Efficiency studies help in understanding the current performance and opportunities to improve the production performance of the crops under consideration. Efficiency studies have showed that it is possible to raise the productivity of the crop without actually raising the input application (Ali and Choudhury, 1991; Umesh and Bisalaiah , 1991 and Gaddi *et al.*, 2001). The corrective steps undertaken to mitigate the reasons for the low efficiency of the farmers will help in long-term to achieve higher productivity.

Methodology

To assess the allocative and technical efficiencies of paddy cultivators of the Peechi Command Area, a primary survey was undertaken using the stratified random sampling with stratification based on the length of the canal. The project has two main canals, the Right Bank Canal (RBC) and the Left Bank Canal (LBC). The RBC was purposively selected as it was irrigating more area. The RBC was divided into three approximately equal parts, based on the length of the canal. From each portion one distributory was selected in the second stage. In the third stage, each selected distributory was divided into three portions, based on the distance and from each portion, 10 farmers were selected randomly. Thus, from each distributory the sample size constituted 30 farmers, constituting 90 farmers altogether. However, only 71 farmers were found to have cultivated paddy as the main crop. Hence, data collected from 71 paddy cultivators, comprising 12 from the head reach, 29 from the middle reach and 30 from the tail reach were used for the study.

Analytical Framework

Resource Productivity

The production function approach was used to find out the productivity of resources used in paddy cultivation. For this purpose, the Cobb-Douglas production function was employed. The single most advantage of this production function has been that the input coefficients constituted the respective elasticities. The function was modified to include dummy variables. The modified form of Cobb-Douglas production function is by Eq. (1):

$$Y = a\, X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} e^{(b_9 D_1 + b_{10} D_2 + \mu)} \qquad \ldots(1)$$

where,

Y = Total returns from paddy cultivation (Rs)

X_1 = Area under paddy cultivation (ha)

X_2 = Value of seed (Rs)

X_3 = Tractor charges (Rs)

X_4 = Cost on human labour used in paddy cultivation (Rs)

X_5 = Cost on chemical fertilizers (Rs)

X_6 = Cost on farm yard manure (FYM) (Rs)

X_7 = Cost on plant protection chemicals (PPC) (Rs)

X_8 = Amount of water applied (ha cm)

D_1 = Dummy of water stress days (value 1 was given if water stress days were present, 0, otherwise)*

D_2 = Availability of supplementary irrigation (value 1 was given if supplementary irrigation was given and 0, otherwise)

μ = Random-error

This Cobb-Douglas function was estimated using ordinary least square (OLS) approach after converting it into loglinear form. The estimable form of the equation is given below:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + b_9 D_1 + b_{10} D_2 + \mu \quad \ldots(2)$$

The coefficients were tested for statistical significance by using 't' test.

Where profit maximization was the objective of the rational farmer, it was imperative that he allocated his resources consistent with their respective marginal contributions in monetary terms. The degree to which it was accomplished was measured by allocative efficiency. If the marginal contribution of one unit of input was greater than the price of the input in question, then the farmer was said to be allocating the resources efficiently and there was further scope for allocating more unit of that particular input. If the marginal contribution was negative, then the farmers were said to be using the input excessively so that the fixed resources were no longer responsive to the variable input- applied.

Allocative efficiency (AE) was determined by calculating the ratio of the marginal value product (MVP) to the marginal factor cost (MFC), i.e.

$$AE = MVP/ MFC \quad \ldots(3)$$

$$MVP = MPP_i \times P_y$$

where,

MVP = Marginal value product

MPP_i = Marginal physical product of the i^{th} input

P_y = Price of output

$$MPP_i = b_i\, Y/ X_i \quad \ldots(4)$$

where,

b_i = Elasticity coefficient of the ith independent variable

Y = Geometric mean of the output, and

X_i = Geometric mean of the ith input

Technical Efficiency

The technical efficiency evaluated the farm's ability to obtain the maximum possible output from a given level of resources. The Cobb-Douglas production function did not distinguish between technical and allocative efficiencies (Sampath, 1979). It ignored the problem of technical efficiency by assuming that all the techniques of production were identical across farms and each farmer was technically efficient, which many a times was not true. The concept of frontier production function introduced by Farrel (1957) distinguished technical and allocative efficiencies. Timmer (1971) operationalized the concept by imposing Cobb-Douglas type on the frontier and evolved an output-based measure of efficiency. The approach adopted here was to specify a fixed parameter frontier amenable to statistical analysis. This takes a general form as:

$$Y = f(X)\, e^{(\mu)} \qquad \ldots(5)$$

where,

Y = Output (dependent variable)

X = Vector of inputs (independent variables)

μ = Error-term

This function in loglinear form would be:

$$\ln Y = \ln a + \Sigma\, b_i \ln X_i + \mu \qquad \ldots(6)$$

Equation (6) was estimated by the Corrected Ordinary Least Square (COLS) regression. As a first step, the OLS was applied to the equation to get the best linear unbiased estimates, b_i coefficients. The intercept estimate 'a' was then corrected by shifting the function until no residual was positive and one became zero. The new production function with the shift into the intercept was the frontier function and it gave the maximum output obtainable for given level of input and it would be of the form:

$$\ln Y^* = a + \Sigma\, b_i \ln X_i + \mu$$
$$\mu \leq 0 \qquad \ldots(7)$$

The Timmer measure of technical efficiency would be the ratio of the actual output to the potential output on the production function given the level of input-use on farm i.

$$\text{Timer measure} = Y_i / Y_i^* \leq 1 \qquad \ldots(8)$$

where,

Y_i = Actual output of the ith farm, and

Y_i^* = Maximum output obtainable by the ith farm at given level of input.

The average yield of paddy from each reach of the command was estimated from which the potential yield was found out. The ratio of the average yield to the average technical efficiency gave the potential yield of paddy. The average technical efficiency was the mean of the technical efficiency of all farmers.

Potential yield = Average Yield / Average technical efficiency …(9)

Factors Contributing to the Technical Efficiency

The factors contributing to the technical efficiency were studied using the logit model. From the literature it was observed that technical efficiency of about 70-80 per cent was designated as technically efficient and hence in this study the farmers with technical efficiency of more than 75 per cent were considered as 'technically efficient' and those below this value, as 'technically inefficient'. Technically efficient groups were given the value 1 and technically inefficient group was given the value 0. The probability P that a farmer reached technically efficient status was in a slower rate as the independent variable(s) increased or decreased and the probability that a farmer reached a technically inefficient status was slower rate as the independent variable(s) decreased or increased. In such cases, the logit model would be used for the specification of the relationship. The logit model takes the general form:

$$Y_i = X_i b + \mu_i \qquad \ldots(10)$$

The dependent variable Y_i took the value 1 if the farmer was technically efficient, zero otherwise; X_i was a matrix of regressors with N observations and K estimable coefficients, b was a K×1 vector of parameters; and μ_i was the ith identically and independently distributed random disturbance with zero mean (Polson and Spensor, 1991). While the linear probability model was computationally and conceptually easier than the other two, its specification created estimation problems with the application of ordinary least square (OLS) (Amemiya, 1981; Lee and Stewart, 1983; and Capps and Crammer, 1985) and many a times violated the basic tenets of probability (Mingche, 1977). An inherent deficiency of the model was the heteroscedastic disturbance term. Though the heteroscedastic problems could be overcome through monotonic transformation, its efficiency by 'Weighted Least Square' also depended on conditions applied. These deficiencies could be overcome through the use of monotonic transformation estimated through likelihood approach (logit or probit specification), which guarantees that predictions lie between the intervals 0 and 1 (Capps and Crammer, 1985).

The logit model is specified as Eq. (11):

$$Ti = f\,(Z_i) = \frac{e^{zi}}{1 + e^{zi}} \quad \text{for } -\infty < Z_i < \infty \text{ and } Z_i = X_i' \qquad \ldots(11)$$

where,

$f\,(Z_i)$ is the logistic density function for logit model.

Let P_i be the probability that a farmer is technically efficient. As per the above logistic function, we have

P (C/X) = The probability of an individual farmer is technically efficient.

$$= \frac{1}{1 + e^{-zi}}$$

$$1 - P\,(C/X) = 1 - \frac{1}{1 - e^{-zi}}$$

= The probability of an farmer is technically inefficient

$$\text{The Odd's ratio} = [\{P\,(C/X)\} \,/\, \{1-P\,(C/X)\}] = e^{Zi} \qquad \ldots(12)$$

Taking logarithm on both sides, we get Eq. (13):

$$\ln\,[\{P\,(C/X)\} \,/\, \{1-P\,(C/X)\}] = Z_i = X_i'\,\beta + E \qquad \ldots(13)$$

where, β = Vector of response coefficients

E = Vector of random disturbance

The specific logit model estimated to predict the 'odds' of a farmer becoming technically efficient to inefficient is:

$$\ln\,[\{P\,(C/X)\} \,/\, \{1-P\,(C/X)\}] = \alpha + \Sigma\, \beta_i X_i + \mu$$

where,

X_i= Vector of explanatory variables.

In the present study the variables included were:

X_1= Age of the farmer (years)
X_2= Educational status (years)
X_3= Canal distance (m)
X_4= Dummy for water-stress days
X_5 = Dummy for supplementary irrigation

Results and Discussion

The input utilized in paddy cultivation in the command area is given in Table 1. Since only variable cost was important in the short-run in influencing the decision-making of the farmers, only these were considered for deriving the profit. The total variable cost in cultivation of paddy amounted to Rs 21,603 per hectare resulting in a total per hectare income of Rs 28, 999 giving a BC ratio of 1.34. Among the inputs, the maximum share was accounted for by human labour (62.47%), followed by FYM (11.67%). This district had one of the highest wage rates, Rs 125 for a male labour per 8-hour work and Rs 100 for the females. Unlike many other states, the farmers in the Kerala state applied more amount of farmyard manure in the cultivation of food crops. In the Peechi Command Area also, the expenditure on FYM was Rs 2522/ha (11.67%), and on chemical fertilizer was Rs 1937/ha (8.97%). Other inputs like seeds, tractor and PPC accounted for 4.54, 11.14 and 1.21 per cent of the total expenditure, respectively. The total return was Rs 28,999 per ha, including both the main product and by product.

The resource productivity of input used in the cultivation of paddy in the command area is given in Table 2. This table indicated that the areas under paddy, human labour, fertilizer and dummy variables for supplementary irrigation in the case of water-stress days were statistically significant. The area under paddy cultivation had an elasticity of 0.65, indicating that one per cent increase in the land area would bring 0.65 per cent increase in the production. The human labour and fertilizers applied in the cultivation had significant positive elasticity coefficients of 0.55 and 0.17, indicating that at current level these resources were under-applied. There were some farmers who suffered water stress during the critical stages of plant growth. The water-stress days had a depressing influence on the yield as indicated by the negative coefficient (-0.13), though it was statistically non-significant. It

Table 1. Input utilization in paddy cultivation

Inputs	Value (Rs/ha)	Percentage
Seeds	981	4.54
Tractor	2406	11.14
Human labour	13495	62.47
Chemical fertilizers	1937	8.97
Farm yard manure	2522	11.67
Plant protection chemicals	262	1.21
Total variable	21603	
Total returns	28999	
B:C ratio	1.34	

was well understood that the water-stress at the critical stages of plant growth would have negative effect on the yield of paddy. The water-stress was observed mainly in the tail reach of the command area at the panicle initiation stage of the plant. Some farmers were able to give supplementary irrigation in these areas to mitigate the bad effect of the water-stress. The dummy variable included to capture this indicated significant positive influence on the yield of paddy (0.24). The amount of water applied in the cultivation of paddy did not have a significant influence. This might be because paddy being a water-intensive crop and farmers, especially those in the head reach of the canal command, often flooded the field with excess amount of water. Hence, the variations in the amount of water applied might not yield a statistically significant coefficient. The elasticity coefficient for the seed used for the cultivation of paddy was -0.13, but it was statistically non-significant, indicating that a marginal increase in the amount of this input would not raise the total value of output realized. The elasticity coefficients of other inputs like FYM and PPCs were statistically non-significant, indicating that at the current level they were applied at the physically optimum level. The coefficient of multiple determination was 0.86, indicating that 86 per cent of the total variation in the return of paddy cultivation was explained by the regression analysis. The computed F value for the regression analysis was statistically significant at 1 per cent level.

The allocative efficiency in paddy cultivation is reported in Table 3. The allocative efficiency indicated the price response of the farmers. The allocative efficiency of 1 indicated that the farmers were price efficient in allocating that particular resource in paddy cultivation. The allocative

Table 2. Resource productivity in paddy cultivation in Peechi Command Area

Variables	Coefficient	Standard error
Intercept	5.16	3.38
Area	0.65*	0.03
Seed	-0.13	0.72
Tractor	-0.01	0.16
Human labour	0.55*	0.03
Fertilizers	0.17*	0.017
Farm yard manure	-0.006	0.36
Plant protection chemicals	0.01	0.52
Water applied	0.05	1.42
Dummy for water-stress days	-0.13	1.22
Dummy for supplementary irrigation	0.24*	0.02
R^2	0.863	

* Indicates significance at 1 per cent level

efficiency of more than 1 indicated the under-utilization of that particular resource and scope in increase in its application till the ratio reached 1. The results indicated that the MVP/MFC ratio was highest in the case of land (3.04), followed by fertilizers (2.83) and plant protection chemicals (1.57). This indicated that bringing in more land under paddy cultivation would bring out the economies of scale and would result in higher productivity. However, the average landholding under paddy in the state has been very low and highly fragmented. These have prevented the mechanization of paddy cultivation in the state. The result for fertilizer application indicated that an increase of one rupee in fertilizer application would yield a return of Rs 2.83. This showed that the fertilizer application should be enhanced in the paddy cultivation in the command area to reap higher benefits. Though the elasticity for human labour was very high (0.55), the MVP/MFC was only 1.17. This was because of the high wage rate prevailing in the state. The PPC had an MVP/MFC ratio of 1.57, indicating that farmer would gain Rs 0.57 if they applied an additional unit of PPC worth Re 1.

The production function analysis gave statistically non-significant value to the amount of seed applied, but the allocative efficiency ratio indicated that an additional expenditure of one rupee on this account would reduce the revenue by Rs 3.77. Hence, to be economically efficient, the farmers had to reduce the amount of seed applied. Similarly, the FYM also gave a negative ratio (-0.16), indicating that an increase of one-rupee in the farmyard manure applied at the current price level would reduce the return by Re 0.16. The negative return for the farmyard manure was contrary to the expectation. This could be explained taking into account the management of the manure. Application of high amount of FYM at the time of transplanting produced an impact on the carbon-nitrogen ratio of the soil and delayed the establishment of the crop after transplanting. This would result in low crop yield. In this region, the majority of the farmers were applying the FYM at the time of transplantation of paddy seedlings and probably this might have resulted in the negative coefficient.

Table 3. Allocative efficiency in paddy cultivation in Pecchi Command Area

Variables	Coefficient	MVP	MFC	MVP/MFC
Land	0.65	17651	5791	3.04
Seeds	-0.13	-3.77	1	-3.77
Tractor	-0.01	-0.15	1	-0.15
Labour	0.55	1.17	1	1.17
Fertilizers	0.17	2.83	1	2.83
Farm yard manure	-0.006	-0.16	1	-0.16
Plant protection chemicals	0.01	1.57	1	1.57

Table 4. Technical efficiency distribution of paddy farmers in Peechi Command Area

Efficiency ranges (per cent)	Frequency	Percentage
< 50	10	14.08
51-60	14	19.72
61-75	26	36.62
76-90	19	26.76
> 90	2	2.82
Total farmers	71	100
Mean technical efficiency = 66.18		

The frontier production function studies the efficiency in a relative basis. In this approach, efficiency of farmers in a particular area is related with the best farmer in that group. The technical efficiency of paddy farmers in the command area, given in Table 4, had an average value of 66.18 per cent. The technical efficiency of the farmers increased as one moved from head reach to tail reach. The technical efficiencies of the head, middle and tail reach farmers were 57.9, 64.7 and 71.1 per cent, respectively. Even though the tail reach farmers were facing constraints in the availability of water, they were managing the resources in a more efficient way.

The majority of the farmers in the command area had the technical efficiency ranging from 50 to 90 per cent. Nearly 37 per cent farmers belonged to the technical efficiency range of 60-75 per cent and 27 per cent farmers were in the range of 76-90 per cent. There were only two farmers in the technical efficiency range of 91-100 per cent. This indicated that there was scope for improvement in the yield of paddy in the command area of the dam by improving the technical efficiency alone, without improvement in the application of inputs. This was also indicated by the potential yield of paddy cultivation in the command area, which was projected to be Rs 43813/ha. It was Rs 44265, Rs 47605 and Rs 40096 per ha for the head, middle and tail reaches, respectively. Thus, the highest potential yield was in middle reach and the lowest, in the tail reach. The lowest potential yield in the tail reach was mainly because of the low water availability in that region.

The factors influencing the technical efficiency obtained through logit regression are given in Table 5. The education of the farmer had a significant influence on the efficiency of paddy cultivation in the state. The efficiency was reduced by the presence of water-stress days. The water-stress arose mainly due to the inadequate storage of irrigation water in the dam and low conveyance efficiency. The dummy variable for supplementary irrigation improved the efficiency of the farmers. Even though the tail reaches were

Table 5. Determinants of technical efficiency of paddy farmers obtained through logit model

Variables	Coefficient	Standard error
Constant	-2.2434	1.9509
Age of the farmer (years)	0.019	0.0237
Education level of the farmer	0.054	0.0264
Canal distance (m)	0.00000947	0.0000179
Water-stress days	-2.8234	1.2301
Dummy for suppl. irrigation	1.3914	0.8284

affected by the water-stress, they were able to supplement irrigation from some other sources. Other independent variables like age of the farmer and canal distance did not have any statistically significant influence on the technical efficiency of paddy farmers. Odds ratio for the logit estimation was 0.11.

Conclusions

The paddy cultivation in the Peechi Command Area of Thrissur district in the Kerala state during the second crop season has yielded an average return of Rs 28, 999/ha with the BC ratio of 1.34. Human labour and farmyard manure have accounted for the highest share in the total cost of cultivation of Rs 21, 603/ ha (63.47 and 11.67%, respectively). The elasticity coefficients for area under paddy cultivation, human labour, fertilizer and supplementary irrigation provided are 0.65, 0.55, 0.17 and 0.24, respectively. The allocative efficiency analysis has indicated that an additional one rupee spent on fertilizer, plant protection chemicals and human labour would enhance the total returns by Rs 2.83, Rs 1.57 and Rs 1.17, respectively. The MVP: MFC ratio for seed has been found as -3.77, indicating overapplication of seed rate. The average technical efficiency of the farmers has been observed as 66.18 per cent. The education level of the farmers and the supplementary irrigation provided have depicted statistically significant positive influence whereas the presence of water-stress has negative influence on the technical efficiency of rice farmers. The study has called for an equitable distribution of canal water and enhanced extension services for resource management in the area.

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