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AN ECONOMIC ANALYSIS OF GROUNDWATER DEVELOPMENT *VIS-À-VIS* RESOURCE USE EFFICIENCY IN TANK COMMAND AREAS

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Abstract: *In the study area, the majority of farmers (75 per cent) are cultivating rice in tank command areas. Among the rice growers 27 per cent of them have raised rice with tank water alone while the rest applied both tank water and well water. The analysis was done for two situations i) tank water alone and ii) tank cum well water application. The total cost of rice cultivation was Rs.16016.00 per hectare using only tank water and the total cost of rice cultivation was Rs.24628.00 per hectare in tank cum well water situation. The Mean Technical Efficiency (MTE) was calculated to be 0.3996 for tank water using farmers. It indicated that the technical efficiency of rice farmers were only 39.96 per cent and yield of rice could be increased by 60.04 per cent more by adopting a technically efficient plan without any increase in cost. The Mean Technical Efficiency (MTE) was calculated to be 0.6248 for tank cum well water users. It indicated that technical efficiency of rice farmers was only 62.48 per cent and yield of rice could be increased by 37.52 per cent more by adopting a technically efficient plan without any increase in cost.*

Key words: Technical Inefficiency, Tank Command Areas, Tank Water Irrigation, Irrigation.

Introduction

The important factor in agricultural development in India is going to be efficient use of available water resources for crop production. The increasing need for crop production due to growing population led to the rapid expansion of irrigation throughout the world. The major sources of irrigation in India are tanks, canals and wells. The tanks have existed in India from time immemorial, and have been an important source of irrigation, particularly, in South India where it accounts for about one-third of the rice irrigated area. (Palanisami *et al.,* 2001). The recent estimate places the actual number of tanks in Tamil Nadu at 34,000, the remaining 5,000 plus has just disappeared over the past 15 years, so because of a variety of reasons during the 1980's, for example, the area irrigated by tanks in Tamil Nadu as a proportion of total irrigated declined from 33 per cent to 26 per cent; and the share of well-irrigated areas has increased from 34 per cent to 41 per cent (PRADAN, 1996). The groundwater in agriculture production give enhanced yields as alone or if combined with tank water as supplementary irrigation, which was less than 6 Million Hectares in 1959-60, went up to 18 Million hectares in 1999-2000. Also, the share of ground water in total irrigated area increased from 30 per cent in 1960-61 to 58.77 per cent 1999-2000. The area under ground-water is increasing progressively as this is the most reliable and cost-effective source of irrigation. (Joshi, 2002). Though there are several studies on tank irrigation and its problems, studies on groundwater development and resource use efficiency of rice in tank command areas are limited. However, in this paper we attempt to study the resource use efficiency in rice cultivation and returns to supplemental irrigation in tank command areas. In particular, we employ the stochastic frontier production techniques to measure technical efficiency of rice.

Methodology

The measurement of efficiency was the main motivation for the study of frontier. The technical efficiency literature begins with Farrell (1957), employed a deterministic approach in which he estimated a cost frontier by using linear programming (LP), requiring all observations to lie on or above the frontier. Aigner and Chu (1968) translated Farrell's cost frontier into a production frontier, since outlier observations under a deterministic approach seriously affect the problem, by using a probabilistic frontier function. Then, Timmer's (1971) approach yields a frontier, which is probabilistic rather than deterministic or stochastic. Later Aigner *et al.,* (1977) developed a stochastic frontier model and key feature of the model was that the disturbance term is composed of two parts, one symmetric and the other 'one-sided'.

A (linear) stochastic frontier model is specified as $Y=f(X_1, X2 \ldots Xn) + (v \pm u)$; v is the symmetric error component causing the deterministic part of the production frontier $f(X_1, X_2 \ldots X_n)$ to vary across the firms. Technical efficiency relative to the stochastic production frontier is captured by the one-sided error component (± depending on whether one specifies a production or cost frontier), $u \geq 0$.

Direct estimates of the stochastic production function frontier model may be obtained by maximum likelihood estimator (MLE) method. In this study MLE method is used to estimate (as was used by Olsen *et al.,* (1980): and Banik Arindam (1994)). Measurement of technical efficiency has been attempted across crops such as Rice (e.g. Kalirajan & Shand 1994; Mythili & Shanmugam 2000); tea (e.g. Hazarika & Subramanian 1999); rice, groundnut and cotton (Shanmugam 2003); and coffee, orange, banana and pepper (e.g. Venkatesh *et al*., 2005).

Data Model and Variables used in the Study

The study area was Sivaganga District, which is situated in southern region of Tamil Nadu has more number of tanks purposefully selected for sampling. Multi-stage Stratified Random sampling was employed. (Stage I) Sivaganga Taluk was chosen and four tanks of Public Works Department (PWD) management and two of under Panchayat Union (PU) maintenance (Stage II). So, six villages are benefited by the chosen tanks, namely Namanur, Kovanur, Panaiur, Mudikondon, Valuthani and Salur. Twenty farmers from each of the mentioned villages were randomly selected for sampling (Stage III). On the total 120 respondents were interviewed. Rice was the major cereal crop in this district. Therefore, rice crop was chosen for further analysis. The survey was conducted during the year 2002-2003. Cobb-Douglas production function was used to estimate the resource use efficiency.

$$Y = bo\ X1^{b1} X2^{b2} X3^{b3} X4^{b4} X5^{b5} U$$

Where, Y = Rice yield in quintals per hectare

X_1 = Area under rice in hectare

X_2 = Fertilizer applied (NPK kgs/ hectare)

X_3 = Labour man days/ hectare

X_4 = Expenditure on bullock, machinery power, seeds and pesticides (Rs/ hectare)

X_5 = Irrigation (hectare cm.,)

b_o = Intercept

b_i = 1,2,3,4, and 5 are production elasticity.

U = Error term

Result and Discussion

The total sampling size was 120 and around 100 were cultivating rice in tank command areas. The rest of them having other crops and hence resource use efficiency has been restricted for rice crop alone. Among the rice growers, 27 per cent of farmers have raised rice with tank water alone while the rest applied both tank and well water. The Cobb-Douglas production function was estimated as specified for rice growers with tank water alone as well as tank water plus well water and the results are presented in Table 1.

Table 1: Cobb-Douglas Production Function for Farms using Tank Water alone and Tank cum Well Water

Particulars	Estimated partial regression co-efficient	
	Tank water	Tank cum well water
Constant	5.4868 (10.2229)	5.6996 (6.2736)
Area under rice (ha.)	6.0359* (1.3542)	2.5984* (0.6899)
Fertilizer (NPK kg/ha.)	0.1090 (0.0398)	0.0934 (0.0189)
Labour man-days (ha.)	0.2045 (0.1731)	0.1324 (0.173)
Other expenditure (Rs/ha.)	0.0019 (0.0007)	0.0007** (0.0003)
Quantum of water used in tank irrigation (ha cm.,)	0.0393* (0.0454)	0.0289 (0.130)
Quantum of water used in well irrigation (ha cm.,)	NA	0.2762* (0.0906)
N	27	73
R^2	0.897*	0.778*

Figures in parentheses indicate standard errors
** Significant at 5 % and ** 1% level of probability*
Other expenditure is expenditure on bullock, machine power, seeds and pesticides

Rice growers using tank water alone, the coefficient of multiple determinations was 0.897 which indicated that 89 per cent of variation in rice yield has been attributed by the independent variables included in the function and the function was significant at one per cent probability level. Among the independent variables included in the production function area under rice, and quantity of tank water for irrigation had significantly influenced rice yield at one per cent probability level. The partial regression coefficients revealed that elasticity of production for area under rice was 6.039 and 0.0393 for tank water application respectively.

The production function estimated for rice growers applying both tank water and well water revealed that 77.80 per cent variation in rice yield was explained by independent variables included in the function and it was a significant at one per cent probability level. Among the explanatory variables included, the area under rice cultivation and well water application significantly influenced the rice yield at one per cent probability level while the other expenditures significantly influenced the rice yield at five per cent probability level. This showed that the availability of well water had encouraged the farmers to spend more on seed, pesticides and machineries. The estimated partial regression coefficients showed the elasticity of production due to land; well water application and other expenditures were respectively 2.598, 0.276 and 0.0007.

The elasticity of production indicated that quantum of tank water, quantum of well water and other expenditures spent on seed, pesticides and machineries were less than one and were operating in the second zone of production. On the other hand, the elasticity of production for area under rice was more than one for both tank water users and tank and well water users. This showed that there is scope for increasing rice production through expansion of area in Sivaganga district provided the water is made available either *in-sittu* conditions or water application deliberately and crop management methods.

Resource use Efficiency of Rice Growers

Resource use efficiency of rice growers have been worked out for the resources which had significantly influenced the rice yield (Table 2). The ratio of Value of Marginal Product (VMP) of resource to their price indicated that for rice growers using only tank water for irrigation, the land resource is over utilized whereas there is scope for further increase in use quantum of tank water. The ratio of VMP of resources to their price estimated for farmers using tank cum well also indicated the over utilization of land and other expenditures which money spent on seed, pesticides and machineries whereas underutilization of well water.

Table 2: Resource use Efficiency of Rice Growers

A. Tank water alone			
	VMP	Px	VMP/Px
Land	273.80	1500*	0.18
Tank Irrigation	32.17	4	8.04
B. Tank cum well water			
Land	122.47	1500*	0.08
Well Irrigation	159.92	15	10.66
Other expenditures	829.42	912.0	0.91

* *Rental value of land was taken as the price*
*Marginal product=Elasticity*Average product. VMP valued at output price of rice*

Maximum Likelihood Estimator Method for Production Function for Farms using Tank Water alone and Tank cum Well Water

It could be seen from the Table 3 that the estimated discrepancy parameter (θ) was 0.9703 and 0.9521 for only tank water and tank cum well water application respectively. This implied that deviation in the output from the frontier yield was mainly due to technical inefficiency at the farmers' level. The Mean Technical Efficiency was 0.3996 and 0.6248 respectively for tank water alone and tank cum well water applying farms. This implied that yield was 60 per cent less than the maximum possible output in tank water using rice growers and 38 per cent in tank cum well water using rice growers respectively. The low technical efficiency was due to inadequate water during crop period in the former category. Besides uncertainty in rainfall and poor filling of tanks had led to these problems.

Table 3: Maximum Likelihood Estimator Method for Production Function for Farms Using Tank Water alone and Tank cum Well Water

Particulars	Estimated partial regression coefficients	
	Only tank water for irrigation	Tank cum well water for irrigation
Constant	6.5177(7.1483)	6.2553 (4.7527)
Area under paddy (ha.)	4.9367* (1.1734)	2.6494** (1.1245)
Fertilizer (NPK kg/ha.)	0.1035 (0.0246)	0.0604* (0.0156)
Labour man days/ha.	0.1126** (0.0578)	0.0232**(0.0093)
Other expenditure (Rs/ha.)	0.0009 (0.0007)	0.0013* (0.0005)
Quantum of water used in tank irrigation (ha cm.,)	0.0429* (0.0129)	0.0304 (0.0689)
Quantum of water used in well irrigation (ha cm.,)	NA	0.6742* (0.1603)
σ^2_u	1.7776	0.6788
σ^2_v	0.0544	0.0342
$\lambda=\sigma_u / \sigma_v$	5.7153	4.4559
$\theta=\sigma^2_u/ (\sigma^2_u +\sigma^2_v)$	0.9703	0.9521
MTE=1- $\sigma u\sqrt{2/\pi}$	0.3996	0.6248

Figures in parentheses indicate standard errors
** 1% level of significant level and ** 5% level of significant level*
Other expenditure is amount of expenditure spent on bullock power, machine power, seeds and pesticides

Technical Efficiencies of Rice Growers

The distribution of rice growing farmers based on the technical efficiency is furnished in Table 4. In majority,15 rice growers (55.6 per cent) are using tank water alone were operating at 50-60 per cent technical efficiency level, on the contrary, 38 rice growers (52.1 per cent) in tank cum well water situation, were operating at 70-80 per cent technical efficiency, and 80-90 per cent technical efficiency attained by 15.1 per cent of farmers. We conclude that is very large scope to improve the technical efficiency of rice farmers in both the situation, because water resources are underutilized.

Table 4: Technical Efficiencies of Rice Producing Farmers

#	Technical efficiency of Rice growers	Only tank water using farmers (in numbers)	Tank cum well water using farmers (in numbers)
1	<40	2 (7.4)	-
2	40-50	8 (29.6)	-
3	50-60	15 (55.6)	4 (5.5)
4	60-70	2 (7.4)	20 (27.4)
5	70-80	-	38 (52.1)
6	80-90	-	11 (15.1)
7	90-100	-	-
	Total	27 (100.0)	73 (100.0)

Figures in parentheses indicate percentage

Returns to Supplemental Irrigation

The supplemental irrigation became necessary when the tank water was not available for the entire rice growing period. When the rice growers could not supplement well water with tank water, they had to either harvest reduced yields or in several cases they had to abandon their entire standing crops. Thus, all the expenses incurred for the crop cultivation could not be recovered. The demand for supplemental irrigation depends upon the variety and duration of the crop and the yield depends on the number of supplemental irrigation provided. In the tanks chosen for the present study, the rainfall received during the year 2002-2003 was less than the normal rainfall and hence water required for tank filling was less than full capacity. Therefore, supplemental irrigation with well water played a vital role in obtaining increased rice yield.

Mean Irrigation Water Applied by Different Rice Growers

The quantum tank water used for irrigation by rice growers was 25.70 ha cm. and 23.24 ha cm. of tank water and 50.95 ha cm of well water used in tank cum well water using rice growers. They applied 50.95 ha cm. of well water over and above the tank water. Generally, farmers using tank water alone cultivated semi-dry rice varieties like PMK1, PMK2, MDU5, IR20, IR36, ADT36, ADT39, ADT43 and CO43.

Mean Irrigation Water Used By Sellers and Buyers

From table 5, farmers sold 19.67 ha cm. of tank water and 53.53 ha cm. of well water respectively to rice crop. On the other hand the well water buyers applied 16.94 ha cm. of tank water and 43.78 ha cm. of well water to rice crop and own users were applied 21.86 ha cm. of tank water and 53.44 ha cm of well water to rice crop. The total water applied by well water buyers were 60.72 ha cm less than the well water sellers.

Table 5: Mean Irrigation Water used by Sellers and Buyers

Groundwater users	Number of farmers	Tank water (ha.cm.)	Well water (ha.cm.)	Total (ha.cm.)
Sellers	16	19.67	53.53	73.20
Buyers	18	16.94	43.78	60.72
Own users	39	21.86	53.44	42.77

Source: Field survey data using questionnaire, 2003

Comparison of Well Owners with Non-Well Owners

It could be seen from the Table 6 that the rice yield obtained with supplemental irrigation (5003 kg) was more than farmers using only tank water (3511 kg). Availability of well water for supplementing tank water enhanced the use of other inputs like fertilizers, labour man-days and plant protection chemicals.

Table 6: Comparison of Well Owners with Non-Well Owners

Variables	Tank cum well water	Well water
Total water applied (ha/cm,)	74.19	2.7
Lobour man-days/ha	197.3	170.7
Fertilizer (NPK kg/ha)	282	217
Other expenditure (Rs/ha)	5742	4865
Rice yield (kg/ ha)	5003	3511
Rice yield (kg/ha cm.,)	67.54	136.62

Source: Field survey data using questionnaire, 2003

Rice yield per unit quantity of water was the highest at 136.62 kg per ha cm. for farmers using only tank water. Whereas it was lower at 67.54 kg per ha cm. for farmers supplementing tank water with well water.

Average Returns to Supplemental Irrigation

It could be seen from the Table 8 that without supplemental irrigation yield of rice obtained as low as 2437 kg per hectare. As the number of supplemental irrigation increased the rice yield up to 10-12 supplemental irrigations and then declined. Likewise the average net return from rice cultivation has increased until 10-12 supplemental irrigations. The estimates of returns per supplemental irrigation applied were the highest for 10-12 supplemental irrigation.

Table 7: Average Returns to the Supplemental Irrigation

#	Number of supplemental irrigations	Well water Applied (ha cm.,)	Rice yield (kg/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Average return per irrigation (Rs)
1	0	-	2438	12,188	2,737	-
2	2-4	8-16	3250	14,200	3,750	338
3	4-6	16-32	3737	16,489	4,929	438
4	6-8	32-48	4062	18,500	6,380	520
5	8-10	48-54	4875	21,457	7,806	563
6	10-12	54-60	5688	23,789	9,268	594
7	12-14	61-76	5119	24,700	9,911	552

Source: Field survey data using questionnaire, 2003

Conclusion

Area under rice occupied 75 per cent of Gross Cropped Area in tank command areas. Only 27 farmers irrigated by tank water for rice cultivation while the rest used well water as supplemental irrigation. Inadequate tank water cause increase in groundwater market where in there were 16 water sellers, 18 buyers and 39 own users of well water for crop cultivation. The yield was significantly influenced by area and tank water irrigation in the tank water alone situation and the yield was significantly influenced by area, well water and expenditure on bullock, machine power, seeds and plant protection chemicals in tank cum well water using farms. In farms using only tank water, among the variables land and tank irrigation, significantly influenced the rice yield, area under rice was over utilized while the tank irrigation was underutilized. The variables, other expenditures and area under rice were under utilized in farms using tank cum well water situation while, well irrigation was over utilized. The technical efficiency analysis showed that 60 per cent less than maximum possible output was achieved in tank water alone using farms and 38 per cent less than maximum possible output in tank cum well water using farms. Grouping of farmers based on efficiency showed 55.6 per cent of farmers operated at 50-60 per cent efficiency level in tank water alone situation. On the other hand, 52 per cent of farmer's efficiency operated at the efficiency between 70 and 80 per cent category. Average returns increased up to 10-12 supplemental well irrigation and decreased thereafter. Average returns increased from Rs.337.67 to Rs.593.73 using supplemental irrigation.

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