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Impact of watershed development programmes on productivity and efficiency of crops in Rajasthan

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ABSTRACT

Watershed development (WSD) programmes have been reckoned as an instrument to bring the second-generation Green Revolution through, increasing productivity in rainfed areas. The present study examined the productivity gains and the technical, allocative and economic efficiencies in cultivation of two major rainfed crops *i.e.*, wheat and pearl millet at farms within and outside watershed projects. It was found that implementation of WSD programmes led to significant gain in productivity of all the crops. However, farmers opted for more water intensive crops without adopting water saving technologies of irrigation, which could be counter productive. The technical efficiency for wheat was found to be more within watershed villages (0.83) than in non-watershed village (0.47). The allocative efficiency was also found to be higher within watershed (0.63) than outside watershed (0.49). Since economic efficiency is a product of the two, it was concluded that wheat farmers within watershed were economically more efficient (0.52) than their counterparts outside watershed (0.22). In case of pearl millet, no significant difference was observed in technical efficiencies between the two regions. However, farmers outside the watershed area were found to be allocatively more efficient (0.71) than their counterparts within the project (0.51). This was due to the fact that the scarcity of water makes farmers adopt a strategy that minimises risk rather than maximises production. Educational level of farmers was the most significant variable influencing technical efficiency in case of wheat. Allocative efficiency was found to be affected by farmers' access to credit, distance of the market and extension contact. Hence, it was concluded that provision of better education and training, greater credit access, providing linkages between production and marketing and providing farmers technical and market information through better extension services would lead to a greater level of economic efficiency.

Key words : Socio-economic impact, Watershed, Economic efficiency.

INTRODUCTION

Participatory watershed development programme has become a good example of the socalled community-based and community-driven approaches that have become one of the fastest growing mechanisms for channelising development assistance (Mansuri and Rao, 2004). Scaling up of watershed development programmes has been reckoned as an instrument to bring the second-generation green revolution through increase in productivity in rainfed areas (John and Reddy, 2003). Though these programmmes were initiated five decades ago, the vigor and seriousness came only after the worst drought of 1987. After 1994, participation of local communities in implenetation of these programmes was made compulsory. However, evidence of the extent to which community-based approaches have lived up to the expectations is scarce (Mansuri and Rao, 2004). The economic evaluation of participatory watershed programmes in Rajasthan highlighted the fact that apart from irrigation-induced improvement in productivity as well as net returns, there were improvements in the water table, fodder and fuelwood availability, employment on farms and reduction in the drudgery of women (Badal *et al.,* 2004). Improvement in farm-level economic efficiency is an important aspect of development impact evaluation, particularly in areas where resources are scarce and pace of technological development is low. Most of earlier studies have, however, failed to address the issue of changes in technical and allocative efficiencies at the farm level due to implementation of watershed development projects. The primary objective of this paper is to examine the effect of watershed projects on the technical, allocative and economic efficiencies at the farm level. The secondary objective is to examine the linkage between efficiency in crop production and producers socio-economic characteristics in order to provide information that could be useful in designing the efficiency enhancing development policies.

MATERIALS AND METHODS

Sampling framework:

Jaipur district of Rajasthan was purposively selected for the study as it comes under semi arid region of the state and provides a representative agro-climatic case for rainwater harvesting. Two villages namely Bapugaon and Dhaupura covered under watershed projects and a non-watershed village namely Dahami Khurd were selected to make a comparative study of efficiency

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implications of watershed development under a "with and without" framework. A total of 50 farmers were surveyed from each watershed to elicit detailed information on the cropping system, resource use pattern and socioeconomic benefits of these programmes. A brief description of the selected villages is given in Table 1.

Table 1: Characteristics of sample villages

	Bapugaon	Dhaupura	Dahmi Khurd
Block	Chaksu	Jaipur	Jaipur
Population	2250	2345	1850
No. of families	177	211	164
Total geographical area (ha)	625	500	361
Project implementing agency (PIA)	CECOEDECON	Govt. of Rajasthan under EAS	-
Duration	1996-2000	1998-2001	-
Area covered (ha)	165	416	-
Budget (in Rs. Lakhs)	2.39	17.91	-
Source of funding	CECOEDECON, Panchayat Samiti and village development council	Government	-

-CECOEDECON : Centre for community economics and development consultants society
- EAS : Employment assurance scheme

Analytical techniques:

Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under a given technology. Allocative efficiency refers to the ability of choosing optimal input levels at given factor prices. Economic efficiency is the product of technical and allocative efficiencies. An economically efficient input-output combination would be both on the frontier function and the expansion path. The present study used a stochastic frontjer production function and cost decomposition method (Battesse, 1992; Kopp and Diewert, 1982) for estimating the technical, allocative and economic efficiencies within and outside watershed projects.

A firm's production function can be represented as follows:

$$\mathbf{Y_i = f(X_i ; \quad) + £_i} \qquad ...(1)$$

where, Y_i denotes output of the ith firm, X_i is vector of actual input quantities used by the ith firm, β is a vector of parameters to be estimated and ε_i is the composite error term (Mesusen and van den Broeck, 1977). ε_i is defined as:

$$£_i = \mathbf{v_i - u_j} \qquad ... (2)$$

where, v_is are assumed to be independently and identically distributed as N(0, ε_v^2) random errors, independent of u_is. The u_is are the non-negative random variables associated with technical inefficiency in production, which are assumed to be independently and identically distributed with truncations (at zero) of the normal distribution with mean σ_u^2, and variance σ_u^2 (|N (μ,σ_u^2|). The maximum likelihood estimation of equation (1) provides estimators for b and variance parameters, ($\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$. Subtracting v_i from both sides of equation (1) yields

$$\mathbf{Y_i^* = Y_i - v_i = f(X_i ; \quad) - u_j} \qquad ... (3)$$

where, Y^*_i is the observed output of the ith firm, adjusted for the stochastic noise captured by v_i. Equation (3) is the basis for computing farm level technical efficiency and analytically deriving the dual cost frontier of the production function.

The prediction of the technical efficiency (TE) of ith farm associated with the stochastic frontier production function was defined as $TE_i = \exp(-u_i)$. Assuming that the production function in equation (1) is self dual (e.g. Cobb -Douglas), the dual cost frontier can be derived algebraically and written in a general form as follows:

$$\mathbf{C_i = h(W_i, Y_i^*; \sim)} \qquad ...(4)$$

where, C_i is the minimum cost of the ith firm, associated with output Y_i*, W_i is a vector of input prices for the ith firm and a is a vector of parameters. Applying Shephard's lemma and substituting the firm's input prices and output level into the resulting system of input e demand equations gives economically efficient input vector for the ith firm, X^e_i:

$$\frac{\hat{o}\, \mathbf{C_i}}{\hat{o}\, \mathbf{W_k}} \; Z \; \mathbf{X_k^e (W_i Y_i^* ;} \; V \;) \qquad ....(5)$$

where, k = 1, 2,……...,m inputs and y is a vector of parameters. The observed, technically efficient and economically efficient costs of production of the ith firm are equal to $W'_1 X_i$, $W_i' X_i^t$ and $W_i' X_i^e$, respectively. These cost measures are used to compute technical (TE) and economic (EE) efficiency indices for the ith firm as follows:

$$\mathbf{TE_i} \; Z \; \frac{\mathbf{W_i^{'} X_i^{t}}}{\mathbf{W_i^{'} X_i}} \quad \text{... (6)}$$

$$\mathbf{EEi} \; Z \; \frac{\mathbf{W_i^{'} X_i^{e}}}{\mathbf{W_i^{'} X_t}} \quad \text{.... (7)}$$

The allocative efficiency (AE) is defined as the ratio of economic and technical efficiencies *i.e.* AEi = EE_i/E_i.

RESULTS AND DISCUSSION

The results obtained from the present investigation are presented below:

Cropping pattern changes due to watershed projects:

Cropping pattern indicates the allocation of limited farm area under different crops, which influence the income, employment and overall living standards of farm households. With a view to assessing the changes in cropping pattern due to watershed projects, the area under different crops over a period of four years was investigated at sample household level and. results are presented in Table 2. A perusal of the Table reveals that wheat was the major crop, which occupied the greatest area in the both category of villages in *rabi* (Nov-March) season. Similarly, pearl millet was the most important crop in *kharif* (July-Nov) season under both categories of villages. Area under wheat increased by 14.2 per cent in 2003-04 as compared to that in 2000-01 in case of watershed villages. The same increased by 4.5 per cent in case of non-watershed village over the same period of time. However, area under barley declined by 11.9 per cent and 14.9 per cent, respectively, under both categories. Area under rapeseed and mustard also increased both within and outside the watershed villages. Area under pearl millet increased by 2.2 per cent in the watershed villages whereas it declined by 2 per cent in the non-watershed village. Area under maize increased by a greater proportion (34%) in the watershed village as compared to the non-watershed village (19%). Thus it can be concluded that assured availability of water has motivated farmers to go for water intensive crops. Until such cropping pattern changes are coupled with water saving irrigation technologies *i.e.*, sprinkler and drip systems of irrigation, the objective of irrigation development through watershed development cannot be achieved.

Productivity changes due to watershed projects:

A study of productivity changes on sample household was made and results are presented in Table 3. It is evident from the Table that invariably all the crops recorded an increase in yield within the watershed villages as compared to that outside watershed area. The major gain in productivity was recorded I case of wheat, mustard and rapeseed and maize. Yield of these crops increased by more than 15 per cent. This was followed by pearlmillet, groundnut, gram and barley.

Table 2 : Changes in cropping pattern on sample farms (in hectare)

Major crops	Within watershed					Outside watershed				
	2000-01	2001-02	2002-03	2003-04	% Δbetween 4 and 1	2000-01	2001-02	2002-03	2003-04	% Δbetween 4 and 1
Wheat	56.4	61.5	58.7	64.4	14.2	21.1	21.0	22.0	22.1	4.7
Barley	42.1	39.7	36.2	37.1	-11.9	12.1	10.8	11.0	10.3	-14.9
Rapeseed and mustard	17.0	18.3	19.0	19.0	11.8	7.9	8.6	8.6	8.5	7.6
Pearl millet	73.4	62.7	70.6	75.0	2.2	26.4	27.2	27.5	25.9	-1.9
Groundnut	17.9	18.7	19.4	19.4	8.4	12.1	13.2	14.1	13.6	12.4
Maize	7.1	9.1	9.9	9.5	33.8	3.2	4.0	4.3	3.8	18.8
Others	27.4	30.6	30.9	30.9	12.8	9.6	9.4	10.5	10.7	11.5
Gross cropped area	241.3	240.6	244.7	255.3	5.8	92.4	94.2	98.0	94.9	2.7

Others include gram, mungbean, guar, peas and fodder.

Table 3 : Changes in yield of major crops on sample villages (2003-04) (Qtl./ha)

Major crops	Outside of watershed projects	Within watershed projects	Gain yield (%)
Wheat	18.3	21.3	16.4
Barley	15.0	16.3	8.7
Rapeseed and mustard	8.6	10.0	16.8
Perlmillet	17.1	19.2	12.3
Groundnut	17.4	19.3	10.9
Maize	15.1	17.4	15.2
Gram	13.8	15.1	9.4

Technical, allocative and economic efficiency:

A Cobb-Douglas type of frontier production function was estimated to examine the technical, allocative and economic efficiencies. The maximum likelihood estimates of the frontier production function for wheat and pearl millet in both within and outside watershed areas are presented in Table 4. Only two crops were selected for estimation of the frontier production function as they represent the largest net sown area under *rabi* and *kharif seasons*, respectively. The variance ratio (g) for all the functions were found to be less than one indicating existence of technical inefficiencies in production of these crops.

A perusal of Table 4 reveals that the production level could be increased with the use of some of the inputs that were significant and positive. In case of wheat human labour, irrigation, fertlizer and farm yard manure could be used further to reach a higher frontier in watershed area, whereas irrigation and chemicals could be used further for increasing wheat production in the non-watershed area. Similarly, in case of pearl millet, human labour could be used further for reaching a higher frontier within watershed area, whereas human labour, machinery and seed could be used further for reaching the potential level of production in case of villages outside the watershed area.

Table 4 : Stochastic frontier production functions for wheat and pearl millet within and outside watershed areas in Jaipur

Variable	Within watershed		Outside watershed	
	Wheat	Pearl millet	Wheat	Pearl millet
Constant	3.614	2.093	3.357	2.236
	(0.906)	(9.601)	(11.270)	(1.230)
Machinery	0.158	0.446	-0.229	1.116**
	(0.149)	(2.669)	(2.036)	(0.188)
Human labour	0.854**	0.982*	1.403	0.550*
	(0.158)	(0.439)	(1.210)	(0.228)
Seed	0.0519	-0.166	-0.064	0.166*
	(0.046)	(2.209)	(0.696)	(0.077)
Irrigation	0.018*	-0.006	0.019*	----
	(0.008)	(0.327)	(0.008)	
Fertiliser	0.030**	0.010	0.715	-0.808
	(0.007)	(0.631)	(0.501)	(0.465)
Farm yard	0.780*	-0.204	-0.358	-0.238
manure	(0.060)	(0.582)	(0.299)	(0.290)
Chemicals	0.012	-0.061	0.161**	0.311
	(0.009)	(0.071)	(0.064)	(0.178)
γ	0.922	0.831	0.904	0.811
σ^2_v	0.005	0.216	0.143	0.292
σ^2_u	0.059	1.062	1.345	1.251
Log likelihood	-22.26	-57.94	-58.39	-61 .92

Figures in parentheses are standard errors

** and * indicates significance of values at P=0.01 and 0.05, respectively.

Farm-specific technical, allocative and economic efficiencies were estimated for the sample households and are presented in Table 5. It is apparent from the Table that there were considerable differences in efficiency levels within and outside watersheds in case of wheat, whereas the same were narrower in case of pearl millet. The mean technical efficiency for wheat was found to be 0.83 within watershed areas, whereas the same was estimated to be 0.47 in the village outside the watershed projects. This indicates that with availability of water, farmers become conscious of the optimum level of use of other inputs as well and provide better management to the crop. The allocative efficiency was also found to be higher for wheat within watershed areas indicating farmers efforts to provide the least cost combination of inputs.

The overall economic efficiency for wheat was found to be 0.52 within watershed whereas the same was a dismal 0.22 outside the watershed projects. This reflects on a challenge for extension workers to make farmers aware of economic way of wheat production both within and outside watershed areas.

In case of pearl millet the technical efficiency was found to be 0.52 within watershed, whereas the same was estimated to be 0.49 outside watershed areas. This indicates that there was not much difference in the management of inputs by farmers under these two conditions. However, allocative efficiency of farmers outside watershed was found to be much higher. As it has been observed that farmers outside watershed areas face scarcity of water and are much concerned about risk management, they try to allocate the resources in a way that minimises the total cost. Therefore, the overall economic efficiency outside the watershed was higher in case of pearl millet (0.35) as compared to that within the watershed villages (0.26).

Factors influencing technical and allocative efficiency:

The results of the estimated frontier production function indicated that not all the inefficiencies were due to random variables; rather there were inefficient farm management practices leading to inefficiencies. Different farm-specific socio-economic variables, which define management practices, were used as explanatory variable to explain the technical and allocative efficiencies. Since economic efficiency is a product of technical and

Table 5 : Efficiency measures for wheat and pearl millet in watershed villages

Crop	Particulars	Within watersked			Outside watershed		
		TE	AE	EE	TE	AE	EE
Wheat	Mean	0.83*	0.63*	0.52*	0.47*	0.49*	0.22*
	S.D.	0.10	0.27	0.24	0.28	0.19	0.14
	Minimum	0.58	0.34	0.23	0.13	0.29	0.20
	Maximum	0.97	0.97	0.92	0.88	0.76	0.52
Pearl millet	Mean	0.52	0.51*	0.26*	0.49	0.71*	0.35*
	S.D.	0.16	0.18	0.12	0.18	0.21	0.16
	Minimum	0.22	0.16	0.18	0.11	0.16	0.23
	Maximum	0.89	0.90	0.47	0.88	0.96	0.62

* indicates significance of value at P=0.01

allocative efficiencies, it was assumed that if either of the two, technical and allocative efficiencies are significantly affected by any of these socio-economic variables, it will also influence the economic efficiency. A linear regression was performed and results are presented in Table 6. A dummy variable was included in the model to distinguish between watershed and non-watershed conditions.

It can be seen from the Table that there were significant differences between technical and allocative efficiencies, as indicated by dummy variable distinguishing the regions within and outside watershed projects for wheat between two conditions confirming the earlier results. However, there were no significant differences between the two efficiencies within and outside watershed in case of pearl millet.

Table 6 : Socio-economic factors influencing efficiency in crop production

Variables	TE	AE	TE	AE
Constant	0.0141	1.850	0.623	0.659
	(0.229)	(0.279)	(0.232)	(0.262)
Age	0.002	-0.002	0.002	-0.001
	(0.002}	(0.002)	(0.002)	(0.002)
Education	0.007*	0.004	0.001	0.005
	(0.003)	(0.005)	(0.004)	(0.005)
Category	0.059	-0.025	-0.032	0.039
	(0.037)	(0.033)	(0.028)	(0.031)
Operational holding	-0.047**	-0.008	-0.072*	0.002
	(0.006)	(0.007)	(0.006)	(0.007)
Family size	0.009**	-0.001	-0.001	-0.003
	(0.003)	(0.004)	(0.003)	(0.004)
Extension contact	-0.037	0.016	0.011	0.094*
	(0.038)	(0.047)	(0.039)	(0.044)
Credit access	0.061	0.071 **	0.035	0.076*
	(0.038)	(0.005)	(0.039)	(0.044)
Market distance	0.002	-0.047**	-0.006	-0.025*
	(0.007)	(0.009)	(0.007)	(0.008)
Dummy	0.340**	0.175*	-0.024	0.178
	(0.061)	(0.075)	(0.062)	(0.070)
Adjusted R^2	0.54	0.30	0.08	0.29
F value	12.54**	5.16**	0.78	3.71 **

Figures in parentheses indicate standard error
* and ** indicates significance of values at P=0.01 and 0.05, respectively

Education and family size were found to be significant positive variables for explaining TE in wheat. Operational holding was negatively related to the TE indicating small farms were technically more efficient.

In case of allocative efficiency in wheat, credit access and market distance were found to be significant variables. The allocative efficiency in case of pearl millet was being significantly influenced by extension contact, credit access and market distance. Thus, creating market infrastructure, linking production with marketing and providing better extension services would have positive impact on allocative efficiency in production of crops.

Conclusion:

The study revealed that WSD programmes lead to significant gains in yield of almost all the crops. I was found that technical and allocative efficiencies in cultivation of wheat and pearl millet varied significantly within and outside watershed projects. The technical efficiency for wheat was found to be more within watershed villages (0.83) than in nonwatershed village (0.47). The allocative efficiency was also found to be higher within watershed (0.63) than outside watershed (0.49). Since economic efficiency is a product of the two, it was concluded that wheat farmers within watershed were economically more efficient (0.52) than their counterparts outside watershed (0.22). This indicates that as more water becomes available to farmers, they try to arrive at optimum combination of inputs, both technically and allocatively, to maximize their production and returns. In case of pearl millet, no significant difference was observed in technical efficiencies between the two regions. However, farmers outside the watershed area were found to be allocatively more efficient (0.71) than their counterparts within the project (0.51). This was due to the fact that the scarcity of water makes farmers adopt a strategy that minimises risk rather than maximises production.

Explanation of technical and allocative efficiencies with the help of different farm-specific socio-economic and institutional factors was attempted with the help of a linear regression. It was found that education of the farmers was the most significant variable influencing technical efficiency in case of wheat. Thus, technical efficiency could be increased by providing education and training of farmers in optimum use of inputs. Allocative efficiency was found to be affected by farmers' access to credit, distance of the market and extension contact. Hence, it was concluded that provision of greater credit facilities, providing linkages between production and marketing and providing farmers technical and market information through better extension services would further enhance the positive impact of participatory watershed development projects on rainfed agriculture.

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