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Impact of Watershed Development Programmes on Farm-specific Technical Efficiency: A Study in Bundelkhand Region of Madhya Pradesh[§]

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Abstract

The farm-specific technical efficiency in cultivation of major crops has been quantified, and effect of various socio-economic factors has been estimated using data from a representative sample of 240 households selected from eight watersheds and eight control villages in the Bundelkhand region of Madhya Pradesh. The mean technical efficiencies of the farmers range between 0.45 and 0.76 in watersheds and 0.33 and 0.66 in control villages, which indicate that there is a scope for further increase in production by efficient use of existing inputs and technology. The socio-economic factors like education, irrigation facilities, extension contacts, marketing contacts, etc. have been observed to be the significant determinants of farm-specific technical efficiency.

Key words: Technical efficiency; watershed; socio-economic factors

JEL Classification: Q25, C25

Introduction

To enhance farm productivity, the conservation, use and sustainable management of watershed resources have been a high priority for many countries over the past several decades. In India too, there has been a significant broadening of the concept to cover integrated development of land and water resources on watershed basis under a number of special programmes. However, the observed effects have not been smooth as targeted in different areas and programmes. Therefore, it was essential to analyze the performance efficiency of watershed farmers and investigate the factors causing (in)efficiency. It would be of help to policymakers in identifying the farms' human and physical resources that might be targeted by public investments on watershed basis to improve farm efficiency.

Reviewing of literature has revealed that farmers in the developing countries fail to exploit the full potential of a technology and make allocative errors (Kalirajan and Shand, 1989; Bravo-Ureta and Evenson, 1994; Shanmugan and Palanisami, 1994; Sharma and Datta, 1997). Thus, increasing the efficiency in agricultural production assumes a greater significance in attaining potential output at the farm level. Further, the analysis of variations between the potential and actual yields on the farm, given the technology and

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resource endowment of farmers, would provide a better understanding of the yield gap. Thus, technical efficiency (TE) is an indicator of productivity differences across farms.

The study of potential sources of TE in rural economies is important from a practical as well as policy point of view. Bravo-Ureta and Pinheiro (1993) and Coelli and Battese (1996) have identified a number of variables which influence TE in agriculture. Gorton and Davidova (2004) have suggested that these variables should be classified into two major groups: (i) human capital like education, literacy, agricultural experience, training and farmer's age and (ii) structural factors, viz. family income, family size, access to credit, land tenure status, gender composition of the labour force, off-farm employment and environmental variables. The impact of agricultural extension and training, education and agricultural experience on efficiency has been evaluated and found to influence significantly in earlier studies (Kalirajan and Shand, 1985; Stefanou and Saxena, 1988). Hence, the identification of those factors, which influence the technical efficiency of farming, is very significant for policymakers.

Watershed development is considered an effective approach to raise agricultural productivity, conserve natural resources and reduce poverty, particularly in the rainfed regions. In the past, several useful studies have been conducted to assess the impact of watershed programmes (Chopra *et al.*, 1990; Farrington and Lobo, 1997; Reddy, 2000) with respect to various bio-physical and environmental indicators and have provided useful insights on the performance of numerous watersheds. The conditions for the success of the watershed programmes across different geographical regions of the country have also been examined. However, there seems to be few studies on the influence of watershed-based interventions on farm-specific technical efficiency as well as other associated factors which could be emphasized during the project implementation stage for enhancing the productivity levels. A comparative study was therefore conducted to assess the farm-specific technical efficiency prevailing in the cultivation of major crops and to identify the farmer-specific attributes which influence it in watersheds and control (untreated) areas in the Bundelkhand region of Madhya Pradesh state.

Methodology

Empirical Model

To measure farm level technical efficiency scores, the study specified the stochastic production frontier with Cobb-Douglas functional form propounded by Aigner *et al.* (1977) and Meeusen and Broeck (1977), as it is widely used in studies on estimating technical efficiency of agricultural production (Battese, 1992). The stochastic production frontier function for the individual farms and crops were specified as below.

$$\ln Y_i = \alpha + \sum_{j=1}^{5} \beta_j \ln X_{ij} + v_i - u_i$$

i=1,2,…, n

where, n is the number of farms pertaining to a particular crop; Y_i is the output in quintals of the i^{th} farm; $X_{ij}s$ are the inputs corresponding to the i^{th} farm and j^{th} inputs; v_i are normally and independently distributed random errors with zero mean and constant variance [$N(0, \sigma_v^2)$] and independent of u_i; u_i is the technical inefficiency effects, and $\beta_j s$ are the parameters pertaining to the j^{th} inputs to be estimated. The variance parameters σ_u^2 and σ_v^2 were expressed in terms of parameterization (Battese and Corra, 1977):

$$\sigma_u^2 + \sigma_v^2 = \sigma^2;\ \gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$$

and

$$\lambda = \sigma_u/\sigma_v\ (>0).$$

The parameter γ can take values from 0 to 1.

The independent variables ($X_{ij}s$) included in the model were seed (in kg per ha), agrochemicals (DAP equivalent of fertilizers, manures and plant protection chemicals in kg per ha), labour input (mandays equivalent of human and bullock labour per ha), machinery input (pump hour equivalent use of tractor for ploughing, pump for irrigation, harvester and thresher for harvesting and threshing of produce, etc.) and miscellaneous expenses (cost of marketing, transportation, etc. in rupees per ha) corresponding to the i^{th} farm.

Due to the inherent advantages of one-stage procedure over the two-stage procedures (estimating a stochastic production frontier at the first stage, then a separate two-limit tobit equations for TE are estimated as a function of various attributes of the farms/ farmers in the sample), an inefficiency model was fitted and estimated simultaneously with the estimation of parameters of stochastic production frontier. The model specified was:

$$TI = u_i = \delta_0 + \sum_{j=1}^{7} \delta_j Z_{ij} \qquad \ldots(2)$$

where, Z_{ij} is the vector of farm and farmer-specific characteristics, which include age (in years) and education (years of schooling) of household-head, farm size (in ha), number of irrigation structures owned or accessed, extension contacts (number of times visited/ contacted agricultural development offices/ officials during preceding year for which data were collected), marketing contacts as linkages with marketing agencies, credit access, etc. (used as dummy; 1 for yes, 0, otherwise) and an watershed dummy (which assumes a value 1, if the farmer belongs to watershed area, 0, otherwise).

The parameters of the stochastic frontier production function model were estimated by the maximum likelihood estimation (MLE) method using FRONTIER Version 4.1 (Coelli, 1996).

Data

Eight watersheds implemented under different types of institutional arrangements and eight control villages from a contiguous area of the selected watersheds were chosen from the Bundelkhand region of Madhya Pradesh state for this study. Fifteen farmers were selected randomly as respondents from each watershed and control villages, respectively. Thus, a total of 240 sample households were selected for detailed investigations. Six major crops, namely wheat, gram (chickpea) and lentil during *rabi* season and soybean, urad (blackgram) and paddy during *kharif* season cultivated in the region, were selected. The crop-specific input-output data for the crop year 2009-10 and farmers' socio-economic information were collected by personal interview of the respondents with the help of a comprehensive schedule specifically designed for the study.

Results and Discussion

Watershed-based Interventions

Different types of treatment activities were carried out in the watersheds in the study area. These included soil and moisture conservation measures in agricultural lands, drainage line treatment, water resource development/ management, crop demonstration, horticultural plantations and afforestation as per the needs and priorities of the community. The development of surface and ground water resources is critical in improving land productivity in the rainfed areas. Therefore, development of water resources received prime attention in all the watersheds, and 33 to 52 per cent of the total project expenditure was allocated for creation of additional water storage capacity through the construction and rejuvenation of ponds, *dabri*, construction of gully control structures as *nala bunds*, stop dams, percolation tanks, etc. which also influence the groundwater recharge of the nearby wells. These resulted in increase in the net and gross irrigated area; irrigation intensity as well as gross irrigated area as a proportion of gross cropped area (13-37%). Contrary to this, farmers of the adjoining control villages revealed that the water-table in the wells had declined due to continuous pumping of water. These positive externalities are supported by the earlier studies (Sikka *et al.*, 2000; Palanisami and Suresh Kumar, 2009) revealing that conservation and water harvesting measures produced significant positive impact in creating irrigation potential.

The gully control measures undertaken in the area helped in improving the topography of land. Levelling, terracing and *bunding* activities undertaken by the farmers under the technical guidance of project authorities also helped in reducing the general slope of the fields and improving the fertility of land by retaining organic content of soil. A cumulative effect of all the land-based interventions and development of surface and groundwater resources resulted in significant changes in productivity levels of all the major crops in the watersheds over the pre-project situation as well as over the control areas.

Input-output Pattern and Farm-specific Socio-economic Characteristics

A detailed description of inputs and output variables included in the stochastic production frontier and farm-specific variables included in the technical inefficiency functions is presented in Table 1. The mean and standard deviations of the variables were calculated separately for the watershed and control villages for

Table 1. Description of variables used in the stochastic frontier and technical inefficiency functions

Variable	Symbol	Parameters	Watershed villages						Control villages					
			Wheat (109)	Gram (111)	Lentil (93)	Urad (96)	Paddy (52)	Soybean (61)	Wheat (107)	Gram (110)	Lentil (92)	Urad (95)	Paddy (51)	Soybean (59)
Output variable														
Output (q/ ha)	Y		12.49	10.55	7.07	6.73	12.10	8.37	11.29	7.72	5.14	4.85	8.63	6.10
			(3.11)	(2.84)	(2.00)	(2.54)	(2.66)	(3.96)	(3.19)	(3.18)	(2.02)	(2.50)	(4.18)	(1.78)
Input variable														
Seed (kg/ha)	X_1	β_1	85.53	77.98	22.64	31.30	98.56	49.59	89.96	82.88	24.59	28.84	93.37	55.93
			(16.58)	(17.53)	(6.27)	(6.43)	(20.34)	(11.38)	(16.58)	(17.49)	(6.28)	(6.46)	(21.00)	(13.72)
Agrochemicals (kg/ha)	X_2	β_2	76.29	75.89	41.41	37.31	87.04	72.95	75.99	81.19	46.01	36.23	90.73	71.75
			(20.50)	(21.66)	(16.67)	(11.10)	(37.14)	(18.63)	(19.36)	(21.28)	(16.84)	(11.51)	(35.42)	(18.43)
Labour (mandays/ha)	X_3	β_3	32.00	31.62	27.61	27.35	35.93	28.60	32.40	28.66	26.19	25.86	38.30	26.65
			(6.85)	(6.83)	(6.15)	(5.95)	(6.96)	(5.68)	(6.46)	(6.85)	(6.16)	(5.98)	(6.96)	(5.77)
Machinery input (hours/ ha)	X_4	β_4	35.54	32.32	31.03	23.92	37.20	36.95	35.70	35.26	32.57	24.38	35.81	34.71
			(9.86)	(10.06)	(11.05)	(8.92)	(12.91)	(9.39)	(9.87)	(10.08)	(11.16)	(8.97)	(13.03)	(9.64)
Miscellaneous expenses (₹/ha)	X_5	β_5	532.39	477.30	442.10	528.65	533.85	654.10	486.73	435.36	440.38	577.61	443.82	528.39
			(246.28)	(227.68)	(146.06)	(236.19)	(254.91)	(390.22)	(249.63)	(230.53)	(145.90)	(237.38)	(275.65)	(380.07)
Inefficiency variables														
Age of the house-hold head (years)	Z_1	δ_1				44.56						46.58		
						(11.31)						(11.23)		
Education level of the household head (years of schooling)	Z_2	δ_2				5.88						4.48		
						(3.54)						(3.25)		
Farm size (ha)	Z_3	δ_3				1.74						1.77		
						(2.76)						(2.88)		
Irrigation structures owned or accessed (No.)	Z_4	δ_4				1.89						1.58		
						(1.96)						(1.55)		
Extension contacts (number of times visited agricultural development offices)	Z_5	δ_5				3.01						2.70		
						(2.33)						(2.08)		
Marketing contacts (dummy)	Z_6	δ_6				0.22						0.25		
						(0.41)						(0.43)		
Watershed (dummy)	Z_7	δ_7				1.00						-		
						(0.00)								

Note: Figures within the brackets indicate standard deviations of means and under crops it indicate the number of observations in each case

Source: Based on survey data

Table 2. Likelihood ratio test for comparison of functional forms of u_i and presence of inefficiency effects

Crop	Test for distribution of u_i			Test for presence of inefficiency effects		
	Truncated normal log-likelihood	Half normal	Test statistic (d.f.=1)	Restricted model log-likelihood	Unrestricted model	Test statistic (d.f.=7)
Wheat	94.85	38.56	112.58***	94.85	-21.53	232.76***
Gram	51.16	-0.60	103.50***	51.16	-75.00	252.32***
Lentil	0.93	-13.81	29.48***	0.93	-74.35	150.56***
Urad	13.27	-18.94	64.42***	13.27	-63.41	153.36***
Paddy	-18.24	-18.26	0.06	63.37	-42.13	211.00***
Soybean	33.89	18.59	30.61***	33.89	-9.45	86.68***

Note: *** Significant at 1 per cent level
Source: Based on survey data

each of the crops. The average per hectare output for all the crops was found to be higher in the watershed than the control villages, which is a direct manifestation of land treatments and productivity enhancement activities carried out as a part of the watershed development programme. The input-use level did not vary much between the two areas; however, the magnitudes of farm-specific socio-economic factors were higher in the watershed areas.

Model Specification Tests

For choosing the appropriate distribution of inefficiency (u_i), a generalized likelihood-ratio (LR) test was used which compared the half normal and truncated normal distribution. For this purpose, the null hypothesis [(H_o): ln (H_o) = ln (H_1)] was tested against the alternate hypothesis [(H_1): ln (H_o) < ln (H_1)], where ln (H_o) and ln (H_1) are the log-likelihood functions of half normal and truncated normal distributions of u_i, respectively.

The test statistic was significant for all crops, except paddy (Table 2). However, by virtue of a higher value of log-likelihood function, truncated normal distribution was preferred. Moreover, the half-normal distribution has mode at zero, implying that a high proportion of the farms being examined may belong to the efficient category, while truncated normal distribution allows a wider range of distributional shapes, including non-zero modes (Coelli *et al.*, 1998).

It may be mentioned here that the specified model can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, it was necessary to test the hypotheses that inefficiency is absent and is not stochastic. The presence of technical inefficiencies was confirmed by using the generalized likelihood ratio test, and the test statistic was found to be significant for all the crops. Therefore, the null hypothesis of no inefficiency (H_0: $\gamma = 0$) was strongly rejected and it could be inferred that u_i followed an asymptotic distribution ($0< \gamma <1$) and there was existence of stochastic frontier.

Parameter Estimates of Stochastic Production Frontier

The maximum likelihood estimates of stochastic production frontier for Cobb-Douglas form under truncated-normal distribution of u_i have been presented in Table 3. The variables having positive significant coefficients were: seed in lentil, urad and soybean; labour in wheat and urad; machinery in wheat and urad; and miscellaneous expenses in gram, lentil, paddy and soybean. Application of these inputs in these crops implied that there was potential of increasing the production through raising their input levels. The effect of some inputs was found negative also, for example, seed in wheat, labour in lentil, machinery in soybean, and miscellaneous expenses in wheat; it indicated their over-use in the production of these crops. The coefficients associated with the use of agrochemicals were not found significant in any of the selected crops. The results also showed decreasing returns to scale for all the crops which implied that the quantities of some inputs exceeded the scale efficient point for the prevailing technology.

Determinants of Technical Inefficiency

The estimated coefficients in the explanatory variables in technical inefficiency model are of interest and have important implications. Table 3 indicates the association between various farm-specific socio-economic characteristics and inefficiency effects. The results revealed that the age of household-head exerted a negative influence on the inefficiency in case of wheat and positive in case of paddy, which indicated that older farmers were more efficient in wheat cultivation and less efficient in paddy, cultivation. This conforms to the findings of Coelli and Battese (1996) who had reported from a study of two villages in India that elder farmers were more efficient. However, the results contradict Singh (2008) who has reported a positive relationship between age and technical inefficiency of the wheat farmers in Haryana and has argued that as age advances, farmers become more risk averters and hesitate to adopt new technologies, making the production process inefficient.

The coefficient of education was negative and statistically significant for all the crops, except paddy, which implied that inefficiency declined as the level of education increased. The education increases the ability to perceive, interpret and respond to new events and enhances farmers' managerial skills, including efficient use of agricultural inputs. Farm-size exerted a positive influence on the technical inefficiency in wheat cultivation, indicating that small farms had higher technical efficiency which may be attributed to their motivated family labour.

A perusal of Table 3 also revealed a negative and significant association between the number of irrigations/conservation structures owned or accessed for cultivation and inefficiency effects in all the crops (except urad), which implied that as the irrigation facility increased, the inefficiency reduced. The coefficient of extension contacts was negative for all crops and was found significant (except paddy), indicating that farmers who established contact with extension agencies were less inefficient (or more efficient). This observation highlights the role of extension services in improving the technical efficiency of farmers and points towards strengthening of extension services. The effect of marketing contacts captured by a dummy, was found negative and significant in paddy and soybean, implying better marketing facilities could decrease inefficiency in cultivation of these crops. This calls for the extended efforts of the implementing agencies of watershed programmes in establishing forward and backward linkages with the marketing agencies to improve the level of production efficiency. To segregate the effect of watershed development programmes, a 'watershed dummy' was introduced whose effect was found to be negative and statistically significant for all crops which implied that watershed farmers were less inefficient (more efficient) than their counterparts in the control villages.

Technical Efficiency Estimates and Distribution of Farms

The TE of individual farm was estimated from the pooled sample and then dis-aggregated for the farmers at watersheds and control villages. A summary of mean, maximum and minimum levels of TE for major crops are presented in Table 4. The results show that there were significant differences in the efficiency between the two areas for all crops. The mean TE for different crops ranged between 0.45 and 0.92 for watershed farmers and 0.33 and 0.66 for control areas farmers. Thus, output could be increased by 8 to 55 per cent in watershed areas and by 34 to 67 per cent in control areas simply through efficient use of the existing inputs and technology. The crop-specific analysis indicated that the variation in TE was relatively low in the case of paddy in watershed farmers where the maximum and minimum levels of TE were 0.97 and 0.84, respectively, with mean TE of 0.92. Likewise, a lower variation in TE in control villages was found in soybean, where it ranged between 0.53 and 0.16 with the mean TE of 0.33. The results also revealed highest average TE in paddy cultivation. This could be attributed to the fact that in the Bundelkhand region farmers used to cultivate up-land paddy without any intensive cultivation practices and obtained almost same level of yield.

Table 3. Maximum likelihood estimates of parameters of the stochastic frontier and inefficiency model

Variable	Para-meters	Crop					
		Wheat (216)	Gram (221)	Lentil (185)	Urad (191)	Paddy (103)	Soybean (120)
Constant	α	1.080***	1.903***	1.174***	0.210	1.516**	2.374***
		(0.403)	(0.499)	(0.476)	(0.559)	(0.778)	(0.836)
Seed (kg/ha)	β_1	-0.141**	0.080	0.314***	0.143*	-0.114	0.289**
		(0.069)	(0.094)	(0.072)	(0.099)	(0.149)	(0.130)
Agrochemicals (kg/ha)	β_2	0.052	0.031	0.057	0.063	0.010	-0.103
		(0.056)	(0.085)	(0.061)	(0.080)	(0.097)	(0.110)
Labour (mandays/ha)	β_3	0.531***	-0.035	-0.298***	0.279***	0.066	-0.067
		(0.057)	(0.061)	(0.120)	(0.111)	(0.166)	(0.120)
Machinery input (hours/ha)	β_4	0.410***	0.032	0.043	0.229***	0.109	-0.233***
		(0.046)	(0.062)	(0.068)	(0.045)	(0.097)	(0.081)
Miscellaneous expenses (₹/ha)	β_5	-0.162***	0.062**	0.118**	-0.024	0.144**	0.143***
		(0.031)	(0.032)	(0.061)	(0.051)	(0.070)	(0.052)
Inefficiency model							
Constant	δ_0	1.039***	1.317***	1.252***	1.522***	-0.252	1.561***
		(0.099)	(0.107)	(0.183)	(0.138)	(0.770)	(0.106)
Age of household-head (years)	δ_1	-0.002**	-0.009	0.001	-0.001	0.015*	0.000
		(0.001)	(0.002)	(0.003)	(0.002)	(0.012)	(0.002)
Education level of household-head (years of schooling)	δ_2	-0.021*** (0.005)	-0.045*** (0.008)	-0.070*** (0.014)	-0.040*** (0.009)	0.043 (0.039)	-0.013** (0.007)
Farm size (ha)	δ_3	0.019***	-0.016	-0.005	-0.098***	0.001	0.003
		(0.006)	(0.016)	(0.019)	(0.012)	(0.062)	(0.007)
Irrigation structure owned or accessed (No.)	δ_4	-0.083*** (0.015)	-0.052** (0.022)	-0.055* (0.037)	-0.013 (0.023)	-0.281** (0.137)	-0.093*** (0.018)
Extension contacts (number of times visited agriculture development offices)	δ_5	-0.047*** (0.008)	-0.055*** (0.013)	-0.038** (0.021)	-0.055*** (0.014)	0.049 (0.072)	-0.038*** (0.018)
Marketing contacts (dummy)	δ_6	-0.011	0.001	-0.070	-0.016	-0.410*	-0.069***
		(0.033)	(0.48)	(0.077)	(0.049)	(0.272)	(0.044)
Watershed (dummy)	δ_7	-0.077***	-0.354***	-0.544***	-0.340***	-2.187***	-0.210***
		(0.024)	(0.039)	(0.087)	(0.046)	(1.329)	(0.044)
Variance parameter							
	σ^2	0.025***	0.054***	0.101***	0.059***	0.250***	0.034***
		(0.002)	(0.006)	(0.017)	(0.006)	(0.092)	(0.004)
	γ	0.480**	0.999***	0.909***	0.764***	0.816***	0.999***
		(0.219)	(0.001)	(0.058)	(0.088)	(0.074)	(0.332)
	λ	0.54	232	2.19	7.44	1.41	92
log-likelihood function		94.85	51.15	0.93	13.27	-18.24	33.89
Mean technical efficiency		61.14	58.14	64.19	52.30	78.84	39.01
Returns to scale		0.638	0.062	0.134	0.651	0.144	0.199

Notes: Figures within the brackets indicate standard errors of coefficients and under crops these indicate number of observations in each case.

***, ** and *: Significant at 1 per cent, 5 per cent and 10 per cent levels, respectively.

Source: Based on survey data

Table 4. A comparison of TE among the farmers at watershed and control villages

Crop	Watershed villages				Control villages			
	Mean	S.D.	Maximum	Minimum	Mean	S.D.	Maximum	Minimum
Wheat	0.65	0.16	0.98	0.36	0.57	0.14	0.92	0.33
Gram	0.67	0.17	1.00	0.37	0.49	0.19	1.00	0.16
Lentil	0.76	0.16	0.97	0.38	0.52	0.18	0.89	0.16
Urad	0.61	0.17	0.98	0.34	0.44	0.18	0.98	0.18
Paddy	0.92	0.03	0.97	0.84	0.66	0.18	0.94	0.20
Soybean	0.45	0.18	1.00	0.20	0.33	0.08	0.53	0.16

Note: Difference in mean TE between watershed and control villages was significant at 1 per cent level for all crops.
Source: Based on survey data

Table 5. Distribution of farms into different TE categories at watershed and control villages

Crop	Watershed villages				Control villages			
	Low	Medium	Moderately high	High	Low	Medium	Moderately high	High
Wheat	0	17	51	32	0	32	49	19
Gram	0	16	44	40	15	45	23	17
Lentil	0	7	24	69	12	34	38	16
Urad	0	31	42	27	24	46	20	10
Paddy	0	0	0	100	6	12	29	53
Soybean	15	58	16	11	39	59	2	0

Source: Based on survey data

Following Bhattacharya (2008), farms were distributed into four technical efficiency categories as: low (0 to 0.30), medium (0.31 to 0.50), moderately high (0.51 to 0.70) and high (above 0.70) (Table 5). The frequencies of occurrence of farmers indicated that only 17 per cent, 16 per cent, 8 per cent and 31 per cent of the farmers had TE below 0.50 for wheat, gram, lentil and urad cultivation, respectively in the watershed areas; while in the control areas the corresponding figures were quite high at 32 per cent, 60 per cent, 46 per cent and 73 per cent, respectively. Further, the analysis revealed that about 32 per cent, 40 per cent, 69 per cent, 27 per cent and 100 per cent of the watershed farmers were operating close to the frontier with the TE of more than 70 per cent in wheat, gram, lentil, urad and paddy, respectively. The corresponding figures for farmers in the control areas were only 19 per cent, 17 per cent, 16 per cent, 9 per cent and 53 per cent. In the case of soybean cultivation, most of the farmers remained below TE of 0.50 in both watersheds (73%) as well as control villages (98%).

The results indicate that farmers in watershed areas were operating with medium-to-high level of technical efficiency for most of the crops, and in control areas were operating with medium level of TE. But, in the case of soybean, farmers were found to have medium level of TE in watersheds and low-to-medium level of TE in control areas. Therefore, it emerges from the study that there is sufficient potential of increasing the level of production using existing level of inputs and technology.

Conclusions

The study has assessed the technical efficiency of cultivation of major crops in the watersheds and control villages of Bundelkhand region of Madhya Pradesh. On an average, the watershed farmers have been found to be more efficient than their counterparts at control villages, which justify the efforts being made to improve the productivity by land treatment and creation of water resources. The average technical efficiency of most of the crops has been found to be medium to high, whereas in soybean cultivation, it is low to medium. The shortfall in the realized productivity from the frontier has largely been due to technical inefficiency and within the control of individual farmers at both the areas. Thus, farmers have substantial scope to improve their production with the existing levels of input-use and technology.

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