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Decomposition of productivity growth in watersheds: A study in Bundelkhand region of Madhya Pradesh, India

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Total change in production and productivity are the two important dimensions of benefits of watershed development programmes along with the conservation of land and water resources. To segregate out the impact of various watershed-based interventions on crop productivity, a study was carried out in Bundelkhand region of Madhya Pradesh state of India. Data were collected from 240 farmers' selected from eight watersheds and eight control villages in the region using a multi-stage random sampling technique. Analysis of data indicated that implementation of watershed development programmes led to significant differences in productivity of major crops between watershed and non-watershed villages. Decomposition analysis of productivity difference between them indicated that the contribution of technological component was positive and higher than the contribution of input differentials. This calls for a wider coverage of watershed development programmes in order to bring all the areas under land treatment activities for improving the productivity level.

Key words: Bundelkhand region, decomposition analysis, production function, watershed programmes.

INTRODUCTION

The conservation, use and sustainable management of natural resources on watershed basis have been a high priority for many countries over the past few decades. India also accorded high priority to watershed based interventions as a strategy for improving livelihoods and sustainability in drought-prone areas. Most watershed projects are being implemented with the twin objectives of natural resource conservation and enhancing the livelihoods of the rural poor through enhancement of production levels (Sharma and Scott, 2005). Several studies (Kerr, 2001; Rao et al., 2004; Palanisami and Suresh Kumar, 2009) conducted earlier showed that introduction of watershed technologies increased the cropping intensity, production levels and shift the farming activities from less labour intensive (low income) to more labour intensive (high income) crop, along with the other benefits related to farm as well as non-farm sector (Singh and Jain, 2004; Nasurudeen and Mahesh, 2006; Kalyan Kumar, 2007; Singh and Prakash, 2010). The marked output and productivity growth in the watersheds involves many interesting issues relating to growth. How much of the growth in output is due to watershed technology alone and how much of it can be attributed to other complementary inputs such as fertilizer, irrigation, high yielding varities seeds, insecticides-pesticides, etc. It is worthwhile, therefore, to decompose the total difference in output into its' causative factors viz., differences in the levels of input use and technological efficiency.

Decomposition method was first used in Indian Agriculture by Bisaliah (1977) to evaluate the effect of technical change due to introduction of Mexican wheat in Punjab farms. Subsequently, the method was used by

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Table 1. Brief description of the selected watersheds and control villages.

Watersheds	Location	Project duration	Project cost (INR in lakhs)	Treated area (ha)	Average Rainfall (mm)	Control village
Manjhgunwa[1]	Chhatarpur	2002-06	50.50	1000 (84.70)	984.8	Bokna
Manpura[1]	Chhatarpur	2003-07	19.15	488 (59.55)	984.8	Kunwarpura
Khakriya[1]	Sagar	1997- 01	15.20	440 (36.36)	1086.7	Samnapur
Kevlari[1]	Sagar	2003-07	16.30	474 (78.48)	1086.7	Khairi
Bamhori Udesha[2]	Damoh	2002-06	30.00	500 (70.00)	1065.4	Bhatiya
Rusolli[2]	Damoh	2002-06	26.96	500 (76.03)	1065.4	Jamuniya
Simrakala[2]	Panna	2001-05	25.44	500 (80.60)	1069.6	Kumhari
Simrakhurd[2]	Panna	2001-05	23.54	500 (83.26)	1069.6	Rihuta

[1] Watersheds implemented by government organizations (GOs); [2] Watersheds implemented by non-government organizations (NGOs). INR: Indian National Rupee; Figures in parentheses indicates % of rainfed area. Source: Based on project documents of the selected watersheds.

several other workers as Kiresur et al. (1995), Kiresur and Ichangi (2011), Basavaraja et al. (2008) and Tripathy et al. (2013) to evaluate the technological gap in farm productivity. If adoption of watershed based interventions presumed to be an improved technology over control areas, then its' effects in terms of gain in productivity should have occurred in two stages. Initially, more output is made available from the existing resource base under the new production technology (in this case watershed technology). This is the efficiency component, reflected in the shift in the production function upwards and production parameters. Second, an adjustment component of technological change is evident in the movement along the new production function which follows from the efforts of the firms to adjust to disequilibrium caused by the new level of efficiency. Hence, this paper is an attempt to decompose the total change in per hectare output due to watershed development programme into the technical change and the change in the input level.

MATERIALS AND METHODS

Study domain and data sources

Bundelkhand region of Madhya Pradesh State was selected purposively for the present study due to its distinctive physical environment and its' backwardness compared to other region (Inter-Ministerial Central Team Report, 2008) where watershed development programmes assumed significantly important role for improving and sustaining soil productivity. Eight watersheds implemented under different types of government departments (GO) as well as non-governmental organizations (NGO) as project implementing agencies (PIAs) were selected from the region. To make a comparative study, one control village from the contiguous area of each selected watershed where no watershed development activities were carried out, was also chosen. A brief description of selected watersheds indicating the project details, locations and physiographic characteristics are given in Table 1. A list of households from each selected village was collected from the watershed committee/village *patwari* and fifteen households were chosen randomly as respondent from each village. Thus, a total of 240 sample households were selected from the selected villages and survey was conducted during 2010-2011 for detailed investigation. The primary data pertaining to the socio-economic characteristics of respondents along with the crop cultivation details were collected by personal interview of the respondents with the help of pre-tested comprehensive schedule particularly designed for the study. Secondary information related to project details and benchmark information were collected from documents and records maintained by the implementing agencies and watershed committees of the respective watersheds.

Analytical tools and techniques

A descriptive analysis was carried out to compare the socio-economic characteristics of sample farmers as well as productivity of major crops cultivated in the region. A Cobb-Douglas production function was fitted and estimated separately for watersheds and control areas to decompose the differences in output of three dominant crops viz., wheat, bengalgram and soybean. The general form of the function (Anupama et al., 2005; Mruthyunjaya et al., 2005; Pouchepparadjou et al., 2005) used in the analysis as shown in Equation 1.

$$\ln Y_i = \alpha + \sum_{j=1}^{5} \beta_j \ln X_{ij} + u_i \qquad (1)$$

where, Y_i is the output in kgs per hectare for i^{th} farmer, X_{ij}'s are the per hectare j^{th} input pertaining to i^{th} farmer, α and β's are the scale and slope coefficients and u_i is independent and identically distributed random errors having normal distribution [$N(0, \sigma_u^2)$]. The input variables (X_j's) included in the model were per hectare quantity of seed (X_1), fertilizer (X_2) in kgs, machine labour (X_3) in hours and human labour (X_4) in mandays. The production function specified above was estimated using the SPSS software.

The decomposition equation following Bisaliah (1977) from the above production function was specified as stated in Equation 2:

$$\text{Log}\,[Y^*/Y] = \log\,[\alpha^*/\alpha] + [(\beta_1^* - \beta_1)\log X_1 + (\beta_2^* - \beta_2)\log X_2 + (\beta_3^* - \beta_3)\log X_3 + (\beta_4^* - \beta_4)\log X_4] + [\beta_1^*\log(X_1^*/X_1) + \beta_2^*\log(X_2^*/X_2) + \beta_3^*\log(X_3^*/X_3) + \beta_4^*\log(X_4^*/X_4)] + (u^* - u) \qquad (2)$$

where, Y^* and Y are the output per hectare for the selected crops at

Table 2. Socio-economic characteristics of sample households in study villages.

Particulars	Watershed villages	Control villages
Family details		
Average family size	6.20	7.16
Labour force participation rate	47.57	43.03
Education level (average years of schooling)	5.87	3.47
Farm details		
Farm size (hectare)	1.74	1.77
Value of farm assets (INR)	76,437	70,164
Wells owned (number)	1.33	1.11
Herd size (SAU*)	3.76	3.53
SAU per hectare cultivated area	2.27	1.99

*SAU: Standard Animal Units (Patel and Kumbhare, 1980). Source: Author's calculation based on survey data.

watersheds and control villages; X_j^*'s and X_j's are the quantity of j^{th} input on watershed and control villages.

Equation (2) involves decomposing natural logarithm of the ratio of output at watershed and control areas. The first bracketed expression on the right hand side is a measure of percentage changes in output due to shift in scale parameter (α) of the production function; is attributable to neutral component of technology. The second bracketed expression, the sum of arithmetic changes in output elasticities each weighted by logarithm of input used in control villages, is a measure of change in output due to shifts in slope parameters of production function (non-neutral component of the technology). The third bracketed term refers to the gap attributable to differences in input use weighed by slope coefficients of the production function fitted for watershed areas explains the input effect. The parameters estimated from production function were used directly in the decomposition equation to compute the neutral and non-neutral effect of watershed technology as well as differences in input use effect.

RESULTS AND DISCUSSION

Socio-economic characteristics of the sample households

The socio-economic characteristics of the sample households in regard to the composition of their families, education and land holdings across watersheds and control villages were analyzed and presented in Table 2. The average family size in watersheds and control areas were worked out to be 6.20 and 7.16, respectively. Labour force participation rate among farmers in watershed villages was relatively higher implying that the higher cropping intensity and crop production generated new employment opportunities. The average land holding size was found marginally bigger in control areas (1.77 ha) than the watershed areas (1.74 ha). Number of wells owned per family was more in watershed villages than the control villages, which is the direct impact of different water resource development activities carried out in the watershed areas. The farmers in the control villages possessed farm assets worth higher value, the herd size and herd size per ha of cultivated area in watershed villages (3.76 units and 2.27 unit) were also comparatively bigger than that of control villages (3.53 and 1.99 unit). Improvement of grass/fodder land and development of non-arable areas with grasses might have encouraged the households to maintain more livestock in watershed villages.

Watershed based interventions undertaken and changes in productivity in watershed villages

Various soil and water conservation activities were undertaken in the sampled watersheds as per the needs and priorities of the watershed community and their technical feasibility (Table 3). Construction of different types of gully control structures like boulder checks, gully *bund*, *bori bandhan*, earthen checks, etc. were made and runoff control measures like vegetative hedges were developed to arrest erosion/ stabilize gullies. Creation of water resources potentials was undertaken through construction of water harvesting structures of different sizes and capacities, renovation/ rejuvenation of existing structures and construction of new wells. Other types of structures like percolation tanks, well recharge pit, sunken ponds, etc, were also constructed. The cumulative effect of all the above-mentioned land-based interventions was reflected through favourable changes in various bio-physical indicators/ indices like irrigation status, cropping pattern and intensity which ultimately led to increased productivity of almost all the crops grown in the region (Table 4). The highest changes were observed in case of sesame (66%) in *kharif* season and wheat (64%) during *rabi* season.

Input-output analysis in watershed and control villages and decomposition of productivity difference

A comparative analysis of productivity and input use for

Table 3. Major soil and water conservation works carried out at the selected watersheds (average per watershed).

Works	Unit	Quantity
Soil conservation works		
1. Gully control structures	Number	269 (8)
2. Staggered trenches	Number	10192 (5)
3. Continuous contour trenches	Running meter	4074(1)
4. *Bunding*	Running meter	9072(3)
Water resources development works		
1. Water harvesting structures	Number	29 (8)
2. Well construction	Number	55(2)
3. Ground water recharge structures	Number	5 (3)
Plantation works		
1. Fodder and grassland development, horticultural plantation and afforestation	Hectare	29.08 (6)
2. *Bund* plantation	Number	6467 (4)

Figures in parentheses indicate number of watersheds where the particular works have been carried out. Source: Project documents of the selected watersheds.

Table 4. Changes in productivity in the sampled watersheds due to watershed based interventions.

Crops	Pre-project yield (kg/ha)	Post-project yield (kg/ha)	% change
Rabi crops			
Wheat	885	1447	63.50
Bengalgram	720	932	29.44
Lentil	411	524	27.49
Mustard	448	631	40.85
Linseed	402	476	18.41
Kharif crops			
Soybean	652	918	40.80
Blackgram	342	395	15.50
Paddy	714	919	28.71
Pigeonpea	499	627	25.65
Sesame	213	353	65.73

Source: Pre-project yield based on project documents and post-project yield based on survey data.

the selected crops grown in the watershed and control villages was done and presented in Table 5. The results revealed that inputs were used in higher quantitites in control areas like seed in wheat, bengalgram and soybean; fertilizer and machine labour in bengalgram, whereas, human labour usages were significantly higher in the watershed areas in bengalgram and soybean. However, with respect to the yield, the differences were found to be significantly higher at watershed areas for all the crops indicating direct effect of watershed based interventions in the study region.

The decomposition analysis was used to estimate the contribution of various sources to the productivity difference between watershed beneficiaries and non-beneficiaries in the region. The analysis showed that per hectare output in watershed villages over control villages were 14, 44 and 30% higher in case of wheat, gram and soybean, respectively (Table 6). Decomposition of causative factors which influenced the differences indicated that the effect of watershed technology contributed mostly which accounted for 11.05, 37.62 and 35.19% in wheat, bengalgram and soybean, respectively. This implies that with the present level of resource use by the farmers at control areas output could be increased by about 11, 38 and 35%, if watershed programme implemented thereof.

The further segregation of influence of watershed technology indicated that the contribution of the neutral technological component in the productivity difference was positive (118.04%) whereas the non-neutral technological component contributed negatively (-80.42%) to the total difference in the output in case of bengalgram. The positive neutral technological component signifies that with the present level of input used in the control areas, the farmers could have increased the productivity level by 118% on implementation of watershed development programmes provided that the efficiency levels of input use were held constant. But the reduction in net efficiency level of various inputs together narrowed down the productivity gap on adoption of watershed programmes, as signified by the negative non-neutral technological component. Contrarily, neutral technological component contributed negatively in the productivity difference in case of wheat and soybean, while, efficiency level of input use

Table 5. Input-output analysis for the selected crops in the study area (per hectare).

S/No.	Input/ Output	Watershed area			Control area		
		Wheat	Bengalgram	Soybean	Wheat	Bengalgram	Soybean
1.	Seed (kg)	85.70	77.98	49.59	89.96**	82.88**	55.93***
2.	Fertilizer (kg)	76.51	75.89	74.30	75.99	81.19**	71.75
3.	Machine labour (hours)	36.06	32.29	36.78	35.70	35.26**	34.71
4.	Human labour (mandays)	33.74	30.62**	28.60**	32.40	28.66	26.65
5.	Output (kg)	1336**	1058***	837***	1129	772	610

***, ** and *: Mean differences significant at 1, 5 and 10%, respectively. Source: Author's calculation based on survey data.

Table 6. Decomposition of output growth between watershed and control areas.

	Sources of output difference	Per cent contribution		
		Wheat	Bengalgram	Soybean
A.	Technical change	11.05	37.62	35.19
I.	*Neutral technological difference*	-25.56	118.04	-315.39
II.	*Non-neutral technological difference*	36.61	-80.42	350.58
B.	Due to difference in input use level	1.91	-1.31	-8.76
1.	*Seed*	0.47	0.36	-12.42
2.	*Fertilizer*	-0.01	-0.92	2.11
3.	*Machine labour*	0.14	-2.29	-0.39
4.	*Human labour*	1.31	1.53	1.94
C.	Total estimated difference in productivity	12.96	36.30	26.43
D.	Total observed difference in productivity	13.84	43.77	30.25

Source: Author's calculation based on survey data.

contributed significantly in broadening the gap in output between watershed and control villages.

The total contribution of differences in the levels of input use to the productivity gap were negative in case of bengalgram (-1.32%) and soybean (-8.76%) and negligible in wheat (1.91%). These indicate that productivity on the farms in control areas could be increased by only 2% in wheat and it would actually decline by 1 and 9% in bengalgram and soybean, if the per hectare input use levels on these farms increased to the same level as on the watershed farms. The results support the earlier researches (Hugar and Patil, 2007; Kiresur et al., 2011 and Priyanka et al., 2013) where contributions of complementary inputs on technology adoption were reported to be negligible or even negative. There was a slight discrepancy between the observed and the estimated differences in productivities in farms of watershed and control areas which was attributed to the random error term and the variables that could not be included in the model.

Conclusion

The ex-post socio-economic impact of watershed based developmental programmes was assessed by 'with' and 'without' (control) approach by observing differences in input and output between treated areas (watersheds) and contiguous non-treated area (control) with similar economic, social or agro-climatic conditions. The analysis revealed that most of the inputs were used at significantly higher rate in control villages, however, the gross output of all the crops were significantly higher at watershed villages. The decomposition analysis carried out to dis-aggregate the effect of various factors which caused differences in output between watershed beneficiaries and non-beneficiaries. The study also revealed that watershed-based intervention in terms of various types of soil and water conservation activities contributed mostly to the variation and the cumulative contribution of differences in the levels of input use to the productivity gap were negligible or even negative for the selected crops. This indicates that with no additional or even with lower inputs, the existing level of production could be increased to a great extent by the implementation of watershed development programmes. This shows the vital contribution of integrated watershed management interventions in mitigating the effects of drought-induced shocks on livelihoods. Therefore, the implementation of watershed development programme needs to be extended to all the un-treated villages for all-round development of people in marginalized areas.

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