Augmentation of Water Resources Potential and Cropping Intensification Through Watershed Programs

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ABSTRACT: This paper presents the biophysical impact of various interventions made under watershed development programs, in terms of the creation of additional water resources, and resultant changes in land use and cropping patterns in the Bundelkhand region of Madhya Pradesh State, India. Both primary and secondary data gathered from randomly selected watersheds and their corresponding control villages were used in this study. Analysis revealed that emphasis was given primarily to the creation of water resources potential during implementation of the programs, which led to augmentation of surface and groundwater availability for both irrigation and non-agricultural purposes. In addition, other land based interventions for soil and moisture conservation, plantation activities, and so forth, were taken up on both arable and nonarable land, which helped to improve land slope and land use, cropping pattern, agricultural productivity, and vegetation cover. *Water Environ. Res.*, **90,** 83 (2018).

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Introduction

Development initiatives in dry regions of India are being promoted, through watershed based interventions, to enhance agricultural productivity with sustainable intensification for improving livelihoods, as well as protect and improve water quality and other natural resources. As the irrigated potential in the country is estimated to be about 58% of the cropped area (MoSPI, 2016), as much as 42% of the cropped land will rely solely on rainfall for cultivation, where watershed development strategy is the most appropriate. A watershed is a natural hydrological entity that covers a specific area and the entire rainfall from its boundary passes through a specifically defined stream as runoff and is separated from adjoining areas by a naturally elevated ridgeline (Oswal, 1994). It is convenient for village-level planning as the village boundaries match the watershed boundaries in many cases. Therefore, the watershed concept enables integrated use, regulation, and treatment of water and land resources for sustainable agricultural production and livelihood security in areas dependant on rainfall for cultivation (Jensen et al., 1996).

Various land based interventions are carried out in a watershed for soil and moisture conservation in agricultural lands (contour/ field bunding and summer ploughing), drainage line treatment (loose boulder check dam, minor check dam, major check dam, and retaining walls), water resource development/management (percolation pond, farm pond, and drip and sprinkler irrigation), crop demonstrations, horticulture plantations, and afforestation activities (Palanisami and Kumar, 2002). Activities as mentioned, produce significant positive externalities on various biophysical aspects that determine productivity potentials, as well as conservation of precious soil and other natural resources, as evident from earlier studies (Chopra et al., 1990; Farrington and Lobo, 1997; Marothia, 1997; Rao, 2000; Reddy, 2000). These studies provide useful insights on the performance of numerous watersheds and examine the reasons for the success of watershed programs across different geographical regions of India. However, in the case of most of the watersheds, many authors argued that the benefits vary across different user groups, due to the varied nature of soil and water conservation interventions leading to changes in land use and the development of water resources (Batchelor et al., 2000; Calder, 2005; Gosain et al., 2006). The overall efficacy of different project interventions on resource user groups also depends on the nature of institutions, particularly the project implementing agency, user groups, and linkages and interaction with allied organizations.

In Madhya Pradesh, like other Indian states, the watershed program was conceived as a medium for rural development. The Government of Madhya Pradesh had constituted the Rajiv Gandhi Mission for Watershed Management (RGMWM) in 1994 for efficient natural resource management and all round development of local communities. The Mission is funded by the Employment Assurance Scheme (EAS), Drought Prone Area Programme (DPAP), and the Integrated Wastelands Development Programme (IWDP) of the Government of India. Up until 2008, INR 8375 million (INR: Indian Rupees) under EAS, INR 5695 million under DPAP, and INR 2529 million under IWDP have been spent covering 2.02, 1.16, and 0.48 million ha, respectively (CARD, 2008). The Ministry of Agriculture (MoA), on the other hand, treated an area of 1.15 and 1.42 million ha with an expenditure of INR2431 and INR3146 million, respectively, through the River Valley Projects and National Watershed Development Programmes for Rainfed Areas, up to the end of the tenth 'five year plan' (2002–2007) (Sharda et al., 2008). Considering the coverage of the programs, in terms of area treated and expenditure, empirical evidence on the biophysical impact of watershed development programs, in terms of shifts in land and water resources use, needs to be precisely estimated to understand the mechanism for further dissemination of these programs in other rainfed regions of the country.

Methodology

Study Area. The Bundelkhand region of Madhya Pradesh state was purposefully selected for carrying out the impact evaluation. The region is located in a hot and semi-humid region (23°20′ and 26°20′ N latitude and 78°20′ and 81°40′ E longitude) between the Yamuna and Narmada river and constitutes a significant part of the vast tracts of dryland farming in India. It is a hard rock area with limited or inadequate groundwater resources due to its typical geological formation. Rainfall is erratic in this region and, historically, there was a drought in every 16 years during the 19th century, which has become threefold during the last three decades of the 20th century. During the first decade of this century, the region has witnessed five drought years (Rai et al., 2014).

Forests in the Bundelkhand region are of a deciduous and thorny nature, covering about 26% of the area, and 50% of forests are scrub with less than 40% canopy which is highly prone to degradation. The topography and geology of the terrain, soil types, and the nature of precipitation favours high rates of erosion. About 47% of the total geographical area is cultivated, of which more than 60% is rainfed (NRAA, 2008), and the agriculture production is characterized with low productivity owing to lower use of fertilizers, low availability/use of high yielding varieties (HYV), and low percentage of irrigated land, leading to large-scale migration (Gupta et al., 2014). Therefore, taking up soil and water conservation measures at the watershed level will help to conserve natural resources by arresting soil loss and runoff, enhancing productivity, thereby sustaining livelihoods. Additionally, relatively low levels of commercialization of agriculture, especially with respect to use of chemical inputs, make it easier to promote sustainable farm practices through watershed programs at many places in the state (Sen et al., 2007). The RGMWM was established by the Government of Madhya Pradesh and appointed as the Nodal Agency for the implementation of all watershed programs funded by the Ministry of Rural Development (MoRD), and has emerged as a single entity implementing the largest number of microwatersheds (500–1000 ha in size) in the country.

Figure 1—Location of Bundelkhand region of India (map not to scale).

Sampling and Data Collection. Administratively, the Bundelkhand region comprises of thirteen districts; seven districts in Uttar Pradesh state (Jhansi, Lalitpur, Jalaun, Hamirpur, Mahoba, Banda, and Chitrakoot) and six districts in Madhya Pradesh state (Datia, Tikamgarh, Chhatarpur, Panna, Sagar, and Damoh) (Figure 1). Among the latter group (Madhya Pradesh state), four districts were selected based on the occurrence of differing topography and demographics. Eight microwatersheds, comprising two from each of the selected districts, were chosen randomly for detailed investigation. Without considering the size distinction, henceforth the term watershed will be used to denote each of the selected microwatersheds.

A government organization (GO) or nongovernmental organization (NGO), called a project implementing agency (PIA), ensures the implementation of the program in accordance with the guidelines of the respective sponsoring organizations (mainly MoRD and MoA under the Government of India). The selected watersheds are thereafter grouped into three categories depending upon the type of programs and implementing agencies, namely, (1) two watersheds sponsored by MoRD, implemented through RGMWM, where the PIA was a government department or a *Zilla panchayat* (a local government body at the district (*Zilla*) level) (RGMWM-GO), (2) four watersheds sponsored by MoRD, implemented through RGMWM, where the PIA were NGOs (RGMWM-NGO), and (3) two watersheds sponsored by the MoA where the PIA was Department of Agriculture (DoA-GO).

To make a comparative study, one control village from the contiguous area of each watershed, where no watershed development activities were carried out, was also selected. Fifteen farmers were chosen randomly as respondents from each watershed and control village. Thus, a total of 240 sample households were selected for detailed investigation. The household information, comprising socioeconomic characteristics and crop cultivation practices for the crop year 2009–10, were collected by face to face interviews with respondents by the first author, with the help of a structured interview schedule comprising questions on household information and farming details. Secondary information covering various land based and nonland based interventions, land use details and cropping pattern during the pre and post implementation period, water resources potential created, and so forth, were gathered from project documents and records maintained by the implementing agencies, as well as the watershed committees of the villages concerned.

Analytical Tools and Techniques. The following indicators and indices were used to evaluate the biophysical impact of watershed development programs based on 'before' (pre-project situation) and 'after' / 'now' (post-project/current situation) as well as 'within' (inside watershed)' and 'without' (control villages) approaches (Sahu, 2008; Palanisami et al., 2011).

Impact on Land and Water Resources. *Land Use Change*. Increases in cultivated land and reduction in wasteland and fallow land were measured over the pre-project period. Furthermore, a land levelling index (LLI) was calculated (Sharda et al., 2012) for measuring the efficiency of land levelling activity as below:

$$LLI = \frac{\text{recommended slope}}{\text{existing slope}} \quad (1)$$

where, existing land slope refers to the land slope before inception of the project, or moderated slope resulting from land leveling activities. A higher value of LLI is a measure of better moderation in land slope. The land levelling index can attain a maximum value of 1.0, which refers to a perfectly leveled field.

Creation of Water Resources Potential. Changes in surface water resources were accounted through the number of ponds/ surface water bodies constructed, surface water storage capacity, and increase in duration of water availability during the post-project period in different watersheds. Changes in groundwater status were assessed by the number of wells and depth of water, duration of water availability in wells, pumping hours, and rate of recuperation during the post-project situation compared with the pre-project situation, as well as the control villages. Increase in irrigation potential was evaluated through changes in irrigated area throughout the pre-project period across the watersheds. Changes in availability of water for non-agricultural purposes were judged by increases in the number of ponds, wells, hand pumps, and water supply system for drinking and other domestic purposes during the post-project period.

Impact on Crop Cultivation Practices. *Cropped Area and Cropping Pattern*. Changes in cropped area and cropping intensity, shifts in cropping pattern, patterns of crop diversification, and land utilization over the pre-project period were studied and measured using a crop diversification index (CDI) and cultivated land utilization index (CLUI), and computed using the formula (Sharda et al., 2012):

$$\text{CDI} = \sum_{i=1}^{n} P_i \log(1/P_i) \quad (2)$$

where, P_i is proportion of the i^{th} crop, in comparison with total cropped area, and n is the total number of crops in the watershed. The CDI can attain any value greater than zero and a higher value CDI is an indicator of better crop diversification.

$$\text{CLUI} = \sum_{i=1}^{n} a_i d_i/(A \times 365) \quad (3)$$

where, n is the total number of crops, a_i is the area occupied by i^{th} crop, d_i is the number of days that the i^{th} crop occupied in the a_i area, and A is cultivated land area. The CLUI can attain a maximum value of 1.0 and a higher value of CLUI indicates better use of cultivable land area.

Crop Productivity. The difference in productivity levels of crops and overall improvement in crop activities over the pre-project period, as well as the control areas, were calculated through a crop yield index (CYI) and the formula (Sharda et al., 2012):

$$\text{CYI} = 1/n \sum_{i=1}^{n} (y_i/Y_i) \quad (4)$$

where, n is the total number of crops in the watershed, y_i is the average yield of i^{th} crop cultivated in the watershed during the post-project period, and Y_i is the yield of i^{th} crop during the pre-project period or yield levels in the control villages.

Impact on Development of Vegetation. Overall impacts on vegetation due to watershed based interventions was measured through an induced watershed eco index (IWEI) (Sharda et al., 2012) and it was calculated as:

$$IWEI = \frac{\text{additional area brought under vegetation}}{\text{total area of the watershed}} \quad (5)$$

Results

Various need based, prioritized, and technically feasible soil and water conservation activities were undertaken in the

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Table 1—Changes in land use (% of total area) and land slope.

Watersheds	Cultivated area		Waste land / permanent fallow		Land levelling index (LLI)	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
Khakariya[a]	39.77	68.18	10.53	2.58	0.36	0.67
Manjhgunwa[a]	19.50	30.50	25.75	13.02	0.57	0.80
Kevlari[b]	57.24	58.86	-	-	0.33	0.50
Manpura[b]	49.80	57.79	3.07	3.07	0.40	0.57
Bamhori Udesha[c]	39.35	47.70	48.30	46.30	0.57	0.73
Rusolli[c]	58.76	77.87	19.74	19.44	0.50	0.57
Simrakala[c]	37.00	63.74	9.20	0	0.50	0.67
Simrakhurd[c]	54.49	68.83	24.67	10.97	0.44	0.62

Footnote: a, b, and c indicate watershed programs implemented by RGMWM-GO, DoA-GO, and RGMWM-NGO, respectively; pre and post indicates pre-project and post-project period, respectively.

sampled watersheds (Appendix 1). Construction of different types of gully control structures, like boulder checks, gully bunds (embankments constructed across water channels/gullies for reducing the velocity of runoff, increasing water percolation, and improving soil moisture regime), earthen checks, and so forth, were constructed and runoff control measures, like vegetative hedges, were established to stabilize gullies. Water resources potentials were created through the construction and rejuvenation of farm ponds and open wells, *dabri* (a natural depression in the agricultural field used as small pond/reservoir), small check dams, percolation tanks and so forth. Horticultural plantations, afforestation, and fodder development activities were also undertaken at farm fields/boundaries as well as nonarable land. Furthermore, wasteland was also reclaimed to bring about additional areas under vegetation. Considering the fact that livestock is an integral part of rainfed farming, various fodder production activities were also undertaken. The cumulative effect of the above mentioned land based interventions led to favourable changes in the values of various biophysical indices. The results are grouped into three headings, namely, impact on land and water resources, impact on cropping pattern and productivity, and the development of vegetation, and are presented in the following sections.

Impact of Watershed Development Programs on Land and Water Resources. *Changes in Land Use and Land Slope.* Table 1 indicates changes in land use pattern attributable to watershed based interventions in the selected villages. It is worth noting that the area under wasteland and fallow (permanent) decreases considerably in all the watershed categories, because of various types of land treatment measures, except the Kevlari watershed (DoA-GO) and Manpura watershed (DoA-GO) where there were nil or negligible areas under wasteland to reclaim. The areas under wasteland/permanent fallow decreased by 50% and a similar increase in area under pasture land/forest was reported. However, the cultivable area remained the same as in the pre-project period implying that reclaimed wastelands were converted into pasture land for community grazing, especially for landless farmers who generally obtain a noticeable amount of their income from livestock rearing. Furthermore, in different watersheds, around 3 to 38% of the current fallow (cultivable waste) was brought under cultivated land due to better availability of moisture and improved production practices.

Construction of various gully control structures, farm ponds, open wells, percolation tanks, plantations on bunds, and so forth, helped indirectly to improve upon both arable and nonarable land. Apart from field bunding by the project authorities (under the program components), few farmers adopted levelling, terracing, and *bunding* activities at their own expense, which helped to reduce the general slope of the fields. Prior to the watershed interventions, the LLI ranged between 0.33 and 0.57, which improved to a range of 0.50 and 0.80 after the project interventions. The highest incremental value of LLI, indicating a better moderation of land slope due to various land

Table 2—Development of surface water resources.

Watersheds	Additional number of water harvesting structures		Duration of water availability (up to calendar month)	
	Ponds/ tanks	*Nala* bund / stop dam / *dabri* / percolation tank	*Pre*	*Post*
Khakariya[a]	90P[#]	14	November	February
Manjhgunwa[a]	4	43	November	April
Kevlari[b]	2	5	November	February
Manpura[b]	1	15	November	March
Bamhori Udesha[c]	-	5	December	April
Rusolli[c]	2	8	November	February
Simrakala[c]	5	16	December	April
Simrakhurd[c]	5	13	November	March

Footnote: a, b, c as defined in footnote of Table 1; # micro/small sized pond.

Table 3—Groundwater resources development and water availability.

Watersheds	Open wells (no.)		Depth of water (meter)		Pumping hours		Time of recuperation (hour)		Bore wells (no.)	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Khakariya[a]	20	106	3.0	4.5 (3.5)	0.50	2.50 (2.00)	24	12 (18)	NA	5
Manjhgunwa[a]	165	255	1.0	2.2 (1.5)	1.50	2.50 (1.50)	24	15 (18)	5	17
Kevlari[b]	95	155	2.5	3.5 (2.0)	0.50	2.50 (1.50)	24	18 (24)	NA	1
Manpura[b]	52	104	1.25	2.25 (1.75)	0.75	1.50 (0.75)	36	18 (24)	NA	3
Bamhori Udesha[c]	18	64	1.8	3.0 (2.2)	0.75	1.75 (1.50)	36	18 (24)	3	4
Rusolli[c]	5	30	3	4.2 (3.2)	1.00	3.00 (2.50)	30	18 (24)	11	11
Simrakala[c]	50	80	2.5	3.6 (3.1)	1.25	2.50 (2.25)	36	18 (24)	15	15
Simrakhurd[c]	50	130	2.4	3.4 (3.0)	1.00	2.25 (2.25)	48	20 (24)	8	8

Footnote: a, b, c as defined in footnote of Table 1; figures in parentheses indicate the situation at control villages of respective watersheds; NA: data not available.

based activities, was observed in the RGMWM-GO developed watersheds.

Development of Water Resource Potentials. *Development of Surface Water Resources*. Construction of farm ponds, renovation of existing farm ponds, construction of *nala bunds*, stop dams, *dabri*, and percolation tanks has enhanced available storage capacity in different watersheds for rejuvenating surface water bodies and replenishing groundwater. As an indicator of increased water availability in water harvesting structures, duration of water availability was recorded, as shown in Table 2. Availability of water for longer periods resulted in an increased irrigated area and irrigation intensity. Furthermore, it ensured availability of drinking water for domestic/stray animals during the summer season.

Development of Groundwater Potential. Based on the available records and group discussions with farmers of respective watersheds, it can be stated that, because of watershed interventions, the number of wells and availability of water has increased over the years (Table 3). This is mainly due to the construction of groundwater augmenting structures such as gully control measures, percolation tanks, and recharge structures. The groundwater table has improved over the pre-project periods and also within control villages. Incremental changes to the groundwater table (from the bottom) ranged between 1 and 1.5 m in different watersheds and within the control villages, the gap was found to an extent of 0.4 to 1.5 m. Average duration of pumping hours before a well goes dry, and time it takes to recuperate to the previous level, were also collected and it was found that watershed treatment activities augmented the average pumping hours by 0.75 to 2 hours over the pre-project period - substantially higher than within the control villages. It is also significant to note that not only higher groundwater recuperation rates in the vicinity of newly constructed structures were reported but also time to fill to average depth decreased by 18 to 28 hours in the pre-project situation. However, due to differences in size of wells/storage capacity, this impact could not be compared across the watershed villages.

Increase in Irrigation Potential. The impact of watershed treatment activities on irrigated area was analysed and results are shown in Table 4. Watershed interventions helped in increasing the availability of irrigation water during both *kharif* (July to October) as well as *rabi* (October to March) season, and thereby a significant increase in the net and gross irrigated area was recorded. The gross irrigated area as a proportion of gross cropped area, which had been 17 to 34% during the pre-project period, increased to 30 to 71% in the post-project period in different categories of watersheds. An in-depth analysis across project categories revealed that highest increase in net irrigated area and gross irrigated area was observed in the case of RGMWM-GO implemented watersheds, followed by RGMWM-NGO and DoA-GO implemented watershed villages.

Changes in Availability of Water for Non-Agricultural Purposes. Though changes in basic amenities are not directly targeted in watershed programs, obviously increases in water availability for non-agricultural purposes is one of the important expected outcomes. In most of the watershed villages, hand pumps and wells are a common source of drinking water, which would become dry during summer months before inception of the watershed programs. The respondents in the study area reported an increase in water availability in wells and hand pumps, because of the adoption of various types of conservation measures. It is evident from Table 5 that the number of wells and pumps has increased during the post-project period in all the

Table 4—Impact of watershed treatment activities on irrigation status.

Watershed categories	Average geographical area (ha)	Net irrigated area (ha)		Gross irrigated area (ha)	
		Pre	*Post*	*Pre*	*Post*
RGMWM-GO	720	64.25	216.50	98.25 (33.88)	366.00 (71.07)
DoA-GO	481	84.26	149.70	84.26 (24.36)	185.70 (44.59)
RGMWM-NGO	500	45.56	112.65	54.32 (17.19)	142.00 (30.22)

Footnote: Figures in parentheses indicate gross irrigated area as percentage of gross cropped area.

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Table 5—Changes in number of water sources for non-agricultural uses.

	Open wells		Bore wells#		Ponds#		Hand pumps	
Watersheds	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Khakariya[a]	10	15	-	5	3	3	2	13
Manjhgunwa[a]	15	27	5	8	1	5	-	5
Kevlari[b]	12	23	-	3	1	3	-	1
Manpura[b]	10	13	-	3	-	1	-	4
Bamhori Udesha[c]	5	13	-	3	2	2	-	30
Rusolli[c]	5	17	-	-	1	3	2	15
Simrakala[c]	3	20	-	-	3	8	-	14
Simrakhurd[c]	10	17	-	-	3	6	3	15

Footnote: a, b, c as defined in footnote of Table 1; # water used for both agricultural and domestic purposes.

selected watershed villages. Apart from irrigation, people in rural India use pond water for various non-agricultural purposes, and it was reported that the number of ponds, and the period for which water was available in ponds increased, indicating better availability of water for non-agricultural use.

Impact on Cropping Pattern and Productivity. *Changes in Cropped Area and Cropping Pattern*. Analysis of observations relating to cropping pattern during the pre and post-project period indicates that there is an increase in net cropped area, gross cropped area, and thereby higher cropping intensity in all the watersheds (Table 6). Though the rainfall pattern in the region favours the *kharif* cropping system, the farmers generally leave their fields fallow during *kharif* and cultivate the main *rabi* crop using the residual moisture. However, during the post-project period a considerable rise in *kharif* cropped area (19 to 250%) was recorded in all the watershed villages. Increases in gross cropped area ranged between 20 and 78% in watersheds under the different categories. The results also showed that the highest change in gross cropped area and cropping intensity was in case of the RGMWM-GO implemented watersheds followed by the RGMWM-NGO and DoA-GO implemented watersheds.

This clearly indicates project interventions resulted in better availability of irrigation water and improved cultivation practices, and the introduction of new crops, particularly vegetables, helped farmers to diversify their cropping patterns and realise more income. In addition to this, some new crops were also introduced in the watershed area for better economic returns. This was well elucidated by improvement in the CDI in watersheds under the different categories. The highest increment was observed in the case of the DoA-GO implemented watersheds, as compared to other categories, and this may be attributable to this department's priorities in improving farm production systems and adoption of better agronomic practices. A cumulative effect of various land based interventions and agriculture improvements in the selected watersheds has enhanced the CLUI. The change in CLUI was found to be highest in RGMWM-GO watersheds, followed by RGMWM-NGO and DoA-GO implemented watersheds.

Table 7 presents changes in cropping pattern and it is evident that during both pre and post-project periods, cropping pattern was dominated by pulses (leguminous crops; black gram, green gram, and lentil), followed by cereals (paddy and wheat) and oilseeds (soybean) in all the selected watersheds. However, the share of pulses declined substantially during the post-project period due to a significant rise in area under oilseeds, the better remunerative crops (particularly soybean) during the post-project period. The increase in area under oilseeds was found to be highest in the RGMWM-GO implemented watersheds than the other watershed categories.

Changes in Crop Productivity. A comparison of major crop productivity between the watershed villages and the control villages was made and the results are presented in Table 8. It is evident from the results that invariably all the crops recorded an increase in yield, with varying rates in different watersheds. The average gain in productivity recorded was 33 to 47% for different crops (except wheat, where it ranged between 10 and 11%) due to soil and water based interventions and introduction of better agronomic practices. The CYI was calculated indicating the extent of aggregate increase in crop productivity throughout the control villages. The estimated indices were found to be considerably higher than 1 in the selected watersheds (Table 8). The index was found to be highest in the RGMWM-NGO implemented watersheds (1.38), followed by

Table 6—Changes in cropped area, cropping intensity, crop diversification, and land utilization.

	Gross cropped area (ha)		Cropping intensity (%)		Crop diversification index (CDI)		Cultivated land utilization index (CLUI)	
Watershed categories	Pre	Post	Pre	Post	Pre	Post	Pre	Post
RGMWM-GO	290.00	515.00	72.05	130.25	1.81	2.35	0.27	0.40
DoA-GO	345.95	416.50	116.36	139.69	1.51	2.27	0.39	0.44
RGMWM-NGO	315.97	469.87	97.82	143.87	1.57	2.14	0.35	0.45

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Table 7—Shift in cropping pattern (in terms of % of gross cropped area).

	Pulses		Cereals		Oilseed	
Watershed categories	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
RGMWM-GO	63.17	38.65	28.31	31.43	7.35	25.87
DoA-GO	50.56	31.81	42.85	40.88	6.12	26.11
RGMWM-NGO	55.58	41.51	38.78	40.66	5.26	16.30

the DoA-GO (1.33) and RGMWM-GO implemented watersheds (1.32).

Impact of Watershed Development Programs on Vegetation. Measures like afforestation and plantation activities in nonarable and arable lands, in conjunction with the mechanical measures, were implemented to help with soil moisture conservation and the establishment of vegetation, to provide additional green biomass cover in the watersheds. It is evident from the result that an additional 133 to 199 ha area was brought under vegetation cover in different watershed categories, through changes in cropped area and other agroforestry interventions (Table 9). The IWEI, which indicates the additional green cover as a fraction of total area of watershed, was estimated to be 0.27 to 0.30 in different watershed categories, implying that an additional 27 to 30% area was covered with green biomass cover.

Discussion

Watershed development activities result in significantly positive impacts on various biophysical indices, such as investment on soil and water conservation measures, soil and water erosion, expansion in cropped area, changes in cropping pattern, cropping intensity, and production and productivity of crops (Sikka et al., 2000; Ramaswamy and Palanisami, 2002). Different kinds of activities were carried out in the study watersheds including soil and moisture conservation measures in agricultural lands, drainage line treatment, water resource development/management, crop demonstration, horticulture plantation and afforestation measures to ensure availability of drinking water, fuel wood and fodder, and raising of farm income and employment opportunities for landless laborers through improvements in agricultural production and other income generating activities. The evaluation showed that in all the selected watersheds, cultivated area increased, though at varying intensities. The average area sown more than once has increased over the pre-project period, and also the current fallow (cultivable waste) were brought under cultivation with different crops, especially during the *kharif* season, resulting in increased cropping intensity during the pre-project situation. Most importantly, the area under waste land has decreased considerably and was brought under pasture and/or afforestation activities, though any discernible trend among the different categories of watersheds could not be established.

Development of surface water and groundwater resources is critical to improve land productivity in rainfed areas and it was reported from watershed documents that the development of water resources received prime attention, with 33 to 52% of the program budget allocated to these activities. The program interventions created additional water storage capacity through the construction and rejuvenation of ponds, *dabri*, construction of gully control structures as *nala bunds*, stop dams, percolation tanks, and so forth. This also influenced groundwater recharge to the nearby wells, enhancing the duration of pumping hours and reducing recuperation time in all the watershed villages.

The results also indicate that the average, net and gross, irrigated area and gross irrigated area as a proportion of gross cropped area registered a considerable increase over the pre-project period in all the watersheds. This categorically shows that watershed development activities have the potential to increase the water resources of the region and expand the irrigated area. In contrast to this, farmers of adjoining control villages revealed that the water table in wells had declined, due to continuous and injudicious withdrawal of water for water guzzling crops. Such kinds of positive externalities due to

Table 8—Changes in productivity of major crops in watershed villages compared with control villages (in quintal per ha).

	RGMWM-GO watersheds		DoA-GO watersheds		RGMWM-NGO watersheds	
Crops	*Watershed villages*	*Control villages*	*Watershed villages*	*Control villages*	*Watershed villages*	*Control villages*
***Rabi* crops**						
Wheat	12.96	11.71	12.88	11.58	12.04	10.91
Bengalgram	11.31	8.44	10.36	7.42	10.32	7.51
Lentil	7.75	5.74	7.57	5.56		
***Kharif* crops**						
Soybean	8.29	6.04	7.88	5.91	9.82	6.71
Blackgram	7.37	5.38	7.32	5.30	6.12	4.17
Paddy	11.09	7.84	12.42	8.89	12.35	8.73
CYI	1.32		1.33		1.38	

* *one quintal = 100 kilograms, CYI = crop yield index.*

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Table 9—Additional vegetation cover (in ha) and induced watershed eco index (IWEI).

Particulars	RGMWM-GO watersheds	DoA-GO watersheds	RGMWM-NGO watersheds
Average geographical area (ha)	720	481	500
Additional area brought under vegetation (ha)	199	133	134
Induced watershed eco index (IWEI)	0.30	0.28	0.27

watershed interventions are supported by earlier studies (Madhu et al., 2004; Palanisami and Kumar, 2009; Sikka et al., 2000, 2001), revealing the positive impact of conservation in terms of groundwater recharge, increased perenniality of water in the streams, rise in water table in wells, sediment trapping behind the conservation measures/ structures, stabilization of gully beds, and so forth.

The impact analysis of watershed based interventions also reveals that a sizeable fallow area was brought back into cultivation, during both *kharif* and *rabi* season, resulting in an expansion of cropped area in all the watershed villages. Estimates of CDI and CLUI showed higher crop diversification and additional area under cultivation in all the watersheds. These findings corroborate the results of an earlier study by Sharda et al. (2005) which found that watershed programs improved the CDI and CLUI considerably, due to soil and water conservation, as well as better agronomic practices.

The results also indicated an increase in crop yields throughout control villages in all the project categories. The CYI, which represents a combined index of yield of all the crops on a farm, has also shown improvement when calculated with the farmers' actual yield of various crops and the yield of control villages. The CYI was higher in the case of RGMWM-NGO implemented watersheds than other watershed categories. Among the various indices discussed above, CLUI, which is direct manifestation of better soil and moisture availability, was correlated with number of structures and share of program budget within a particular category (soil conservation and water resources development). However, no distinct trend was found because the type and size of structures were different, and the period of interventions was not similar for all the watersheds.

Planting of trees in private farm lands and on bunds, and fodder and grassland development were also popular as one of the major components of watershed based interventions in the study area. Increased availability of soil moisture induced natural vegetation growth apart from additional cropped area and improved environment. The IWEI ranged between 0.27 and 0.30 in different watersheds, implying that an additional 27% to 30% green cover was developed through crops and various agroforestry interventions as mentioned above. Similar results were reported from earlier studies (Sikka et al., 2014; Singh et al., 2013), where the index ranged between 0.14 and 0.41. Thus, it is proved that watershed based interventions can generate sufficient positive externalities, with respect to various bio-physical and environmental indicators like land and water resources, cropping intensity and productivity, and vegetation cover.

Conclusion

The present study indicates that various land based treatments have significantly increased irrigated area, through the augmentation of surface water and groundwater resources that ultimately favour crop diversification and led to an increase in crops yield in the Bundelkhand region of Madhya Pradesh State, India. It can, therefore, be suggested that watershed development programs be extended to similar and untreated areas, to mitigate the effects of drought induced shocks and enhance farm income. However, regular monitoring of biophysical and environmental parameters should be done in order to increase the credibility and acceptability of the program initiatives. Furthermore, appropriate water saving technologies need to be introduced and encouraged, for long term sustainability of the impact of watershed programs.

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Appendix 1—Soil and water conservation works undertaken at the selected watersheds.

		Watersheds							
Works	**Unit**	**Khakariya[a]**	**Manjhgunwa[a]**	**Kevlari[b]**	**Manpura[b]**	**Bamhori Udesha[c]**	**Rusolli[c]**	**Simrakala[c]**	**Simrakhurd[c]**
Soil conservation works									
1. Gully control structures	No.	101	176	125	425	133	24	587	577
2. Staggered trenches	No.	4612	11056	48	-	-	-	6969	6969
3. Continuous contour trenches	Rm.	-	4074	-	-	-	-	-	-
4. Field bunding	Rm.	-	5372	-	-	12150	9694	-	-
Water resources development works									
1. Water harvesting structures	No.	103	49	7	17	5	10	18	21
2. Construction of wells	No.	-	-	-	-	-	-	30	80
3. Groundwater recharge structures	No.	2	-	-	11	-	-	3	-
Plantation works									
1. Fodder and grassland development, horticultural plantation, and afforestation	Ha	35	27	-	-	10	1.5	41.50	59.50
2. Bund plantation	No.	-	14171	2500	7195	2000	-	-	-

Footnote: Ha: hectare; Rm.: linear meter.