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Impact of integrated watershed interventions on bio-physical indicators in Garhkundar-Dabar watershed in drought prone Bundelkhand region, India

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Abstract
Bio-physical changes were estimated in Garhkundar-Dabar watershed, Tikamgarh district of Bundelkhand region in Central India, recently transformed by National Research Centre for Agroforestry, Jhansi through integrated watershed development interventions. The study revealed that the values for land leveling, critical area, gully stabilization and cultivated land utilization index are 0.57, 0.80, 50 and 0.74, respectively. Critical area index shows that 80 per cent of critical area is benefitted through IWD interventions. Water storage capacity utilization index, irrigability, crop productivity, diversification and conserved water productivity index recorded 368.36, 1.25, 0.92, 0.85 and 0.65, respectively. This is due to the fact that almost 8 times of created surface water storage capacity was harvested in watershed. Increase in crop diversification index (18.53 %) is mainly due to agroforestry interventions. Crop fertilization and induced watershed eco-index registered 0.57 and 0.41, respectively indicating a shift towards balanced fertilization and improved ecosystem.

Key words: Agroforestry, Bio-physical indicators, Crop diversification, Integrated watershed development interventions, Land utilization, Water productivity

Abbreviations: CAI: Critical Area Index, **CDI:** Crop Diversification Index, **CFI:** Crop Fertilization Index, **CPI:** Crop Productivity Index, **CWPI:** Conserved Water Productivity Index, **GSI:** Gully Stabilization Index, **II:** Irrigability Index, **IWD:** Integrated Watershed Development, **IWEI:** Induced Watershed Eco-Index, **IWMP:** Integrated Watershed Management Programme, **LLI:** Land Levelling Index, SE**:** Storage Efficiency, **WSCUI:** Water Storage Capacity Utilization Index

Introduction

Better ecosystem services, particularly water availability and producing food and fodder to increasing human and animal population are important concern in general in semi-arid tropics. Low agricultural productivity of rainfed agriculture is not only a cause of poverty but also a cause for severe environmental degradation. Out of total cultivable land (142 million ha) in India, 60 per cent area is under rainfed condition. Agricultural productivity of these areas oscillates between 0.5 and 2.0 ton ha^{-1} with average of one ton production per ha. Rest of 40% irrigated land significantly contributes in satisfying 55 % of total food requirement of the country (GOI, 2012). Thus, achieving food security of the country in future is largely dependent on rainfed agriculture through watershed management (Sharda *et al*., 2005; Wani *et al*., 2009, 2012).

The Bundelkhand region is amongst the most degraded ecosystems characterized by undulating and rugged topography, highly eroded and dissected land, poor soil fertility and low water holding capacity, scarce ground water resources, erratic distribution of rainfall, lack of assured irrigation facilities, heavy biotic pressure on forests, inadequate vegetation cover and frequent crop failures, resulting in scarcity of food, fodder and fuel (NRCAF, 2012*)*. Watershed interventions programmes in India has long history of development, however, only few have attempted to quantify the impact of IWD interventions on various bio-physical and socio-economic indicators (Dogra *et al.,* 2005; Sharda *et al*., 2005 and 2012; Sanchej *et al.,* 2007). Objective of the paper is to present the impacts of IWD interventions on bio-physical indicators in Garhkundar-Dabar watershed.

Materials and Methods

***Garhkundar-Dabar Watershed*:** The Garhkundar-Dabar watershed is located at 25^0 27' N latitude, 78^0 53'E longitude, and about 200-280 m above mean sea level in Tikamgarh district of Madhya Pradesh, India. It is a part of Betwa river catchment of Yamuna sub-basin (Fig. 1). The geographical area of Garhkundar-Dabar watershed is 842 ha predominated by degraded forest. The climate is tropical semi-arid with temperature ranging between 2°C during December and January and 45°C during May and June. Long term weather data shows that annual average rainfall in study region is 877 mm (standard deviation, ó = 251 mm) with about 85% falling between June to September. It has been observed that in a cycle of five years, three are normal, one is drought and one is excess rainfall year (Singh *et al.,* 2002) though there was continuous acute drought from 2004 to 2007 in the region. Soils of the watershed are shallow in depth (10-50 cm) and reddish to brownish red in color (Alfisols and Entisols), characterized by coarse gravelly and light textured with poor water holding capacity. Large portion of the watershed was in degraded stage, poor in organic matter and poor in nutrient status (Table 1).

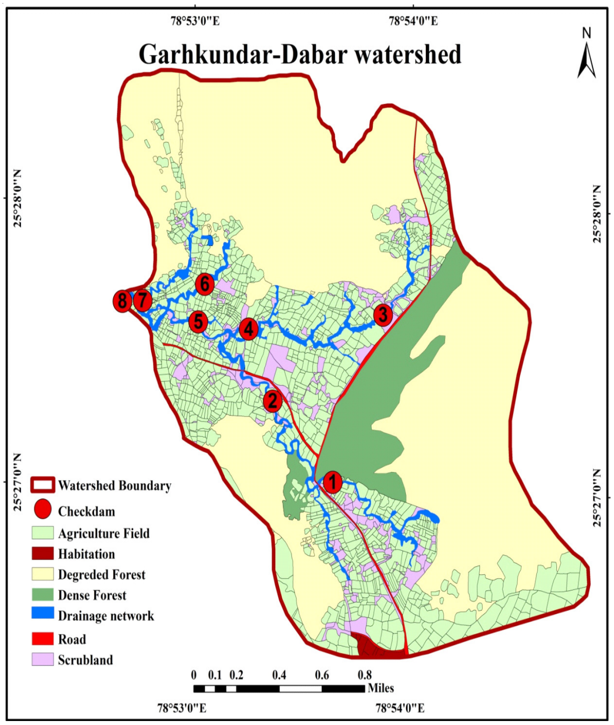

Fig. 1. Land use, drainage network and checkdams in Garhkundar-Dabar watershed

National Research Centre for Agroforestry, Jhansi selected Garhkundar-Dabar watershed to strengthen the rural livelihood through agroforestry in conjunction with *in-situ* and *ex-situ* rain water harvesting and surface/ subsurface water storage as the region depends upon perched water for drinking and irrigation purposes.

***Integrated watershed development interventions*:** To improve the condition of water resources, total eight drop structures/ check dams were constructed mainly on 2nd and 3rd order streams. Out of eight, two were low cost check dams, built using gabions inside, which were on an average 32 per cent cheaper than the normal ones. Further, to check erosion and conserve moisture, 150 gabions of various sizes were laid mainly on 1st and 2nd order streams. Three *khadins* (water spreader) were constructed in series to reduce erosive velocity of running water, apprehend soil loss and created water storage to augment the ground water recharge. Besides these structures, field/ contour bunding was done in an area of about 52 ha with the provisions of drainage structures. To develop resilient production system, agroforestry models were developed on 13 farmer's fields besides teak plantation on field boundary of 60 farmers. About 88 participatory crop trials related to all aspects of crop production like introduction of high yielding varieties, balance fertilization, crop diversification, etc. were also conducted.

Data monitoring: Data on water table in open shallow dug wells, runoff and sediment losses, agricultural water use, crop yields, adoption of agroforestry intervention, deposition of silt in drainage network, reduction of slope in agricultural fields and change in land use pattern were recorded.

Bio-Physical Indicators: Numerous bio-physical outputs could be derived from a watershed project. The primary endeavour of the project is to mitigate soil erosion occurring in any form on any kind of land within watershed along with water conservation. This leads to protection of watershed and improvement in quantity and quality of surface and groundwater which can be used for various purposes by stakeholders to improve their livelihoods. Following bio-physical indicators are worked out using methodologies suggested by Sharda *et al.* (2012) for pre (2003-04) and post project period (2011-12). Data for pre-project period (2003-04) were collected through participatory rural appraisal (PRA).

$$\text{Land Levelling Index (LLI)} = \frac{\text{Recommended slope (\%)}}{\text{Existing or treated slope (\%)}} \quad \ldots 1$$

$$\text{Critical Area Index (CAI)} = \frac{\text{Benefitted critical area from structures}}{\text{Total critical area}} \quad \ldots 2$$

$$\text{Stream Slope Reduction (SR)} = \frac{\text{Equivalent slope of the gullies (\%)}}{\text{Expected equivalent slope (\%)}} \quad \ldots 3$$

$$\text{Stream Side Stabilization Ratio (SSR)} = \frac{\text{Avg. width of streams post project}}{\text{Avg. width of streams pre project}} \quad \ldots 4$$

$$\text{Gully Stabilization Index (GSI)} = \frac{0.5\,\text{SR} + 0.5\,\text{SSR}}{\text{SR} + \text{SSR}} X\ 100 \quad \ldots 5$$

$$\text{Cultivated Land Utilization Index (CLUI)} = \frac{\sum_{i=1}^{n} a_i d_i}{\sum_{i=1}^{n} \text{A} x\ 365} \quad \ldots 6$$

where, n are the total number of crops; a_i is the area occupied by i^{th} crop; d_i are the days that the i^{th} crop occupied in the a_i area; and A is total cultivable land area.

$$\text{Storage Efficiency (SE)} = \frac{\sum_{i=1}^{n} \text{Water actually stored in live storage cap.}}{\sum_{i=1}^{n} \text{Designed live storage cap.}} \quad ...7$$

$$\text{Utilization Efficiency (UE)} = \frac{\sum_{i=1}^{n} \text{Total water utilized out of live storage}}{\sum_{i=1}^{n} \text{Water actually stored in live storage cap.}} \quad ...8$$

$$\text{Water Storage Cap. Utilization Index (WSCUI)} = (0.4SE + 0.6\,UE) \times 100 \quad ...9$$

$$\text{Irrigability Index (II)} = \frac{\text{Additional gross irrigated area}}{\text{Net incremental irrigated area}} \quad ...10$$

$$\text{Crop Productivity Index (CPI)} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{yi}{Yi}\right) \quad ...11$$

where, n is the total number of crops cultivated in the watershed, y_i is the average yield of i^{th} crop cultivated in the watershed, and Y_i is the yield of i^{th}crop with standard package of practices or highest yield within the watershed.

Where, P_i is proportion of i^{th} crop in comparison with total cropped area and n is the total number of crops in the watershed.

$$\text{Crop Diversification Index (CDI)} = \sum_{i=1}^{n} Pi \log\left(\frac{1}{Pi}\right) \quad ...12$$

$$\text{Conserved Water Prod. Index (CWPI)} = \frac{\text{Avg. prod. achieved (equiv. yield)}}{\text{Prod. targeted (equiv. yield)}} \quad ...13$$

$$\text{Crop Fertilization Index (CFI)} = \frac{\text{Average NPK consumption}}{\text{Recommended/required NPK dose}} \quad ...14$$

$$\text{Induced Watershed Eco-Index (IWEI)} = \frac{\text{Add. area vegetated during the project}}{\text{Total area of the watershed}} \quad ...15$$

Results and Discussion

Bio-physical indicators were computed and presented in Table 2. Land Levelling Index (LLI) improved from 0.22 to 0.57 as the farmers of the watershed improved their fields through field bunding after assured availability of water for irrigation and on account of awareness created by the implementing agency. Critical Area Index (0.80) shows that 80 per cent critical area is benefitted through IWD interventions. Gully Stabilization Index of 50 point-out that the gully is under stabilization as the 100 indicates fully stabilized gully. Due to assured availability of irrigation water, Cultivated Land Utilization Index (CLUI) increased by 257 per cent, however, Water Storage Capacity Utilization Index (WSCUI) was 368 per cent as the ratio of harvested water vs. surface storage created is more than 8 times which indicating base flow for longer duration. Irrigability Index of more than 1.0 indicated judicious utilization of harvested water. Crop Productivity and Diversification Index increased by 29.3 and 18.53 per cent due to IWD interventions (Table 2; Fig. 2). Values of various indicators are in agreement with the results reported in different regions of India by Sharda *et al.* (2012). Conserved Water Productivity Index (CWPI) of 0.65 shows value close to targeted production. Crop Fertilization Index (CFI) increased by 157.77 per cent. The value of 0.57 specifies that farmers of the watershed using 57 per cent doses of recommended fertilizers during post project period which was only 22 per cent before implementation. Induced Watershed Eco-Index (IWEI) indicates that 41 per cent additional area brought under vegetation through crops and agroforestry interventions.

Table 1. General characteristics of Garhkundar-Dabar watershed

Morphometric characteristics	
Location	25^0 27' N latitude, 78^0 53'E longitude
Area	842 ha
Altitude	280 to 200 m above MSL
Relief (m)	80
Length (m)	3747
Width (m)	3544
Perimeter (km)	13.03
Drainage density (km/km^2)	2.69
Landuse	
Agricultural land (ha)	264.33 (31.39%)
Waste (scrub) land (ha)	78.49 (9.32%)
Dense forest (ha)	62.84 (7.46%)
Degraded forest (ha)	403.00(47.86%)
Others (ha)	33.34 (3.96%)
Resources	
Land holding	1.55 ha/household
Rabi crops	Wheat, gram, pea
Kharif crops	Sesame, black gram and groundnut
Soil resource	Low in N, P, SOC and medium in K.
Means of irrigation	115 open shallow dug wells existing in unconfined aquifer
Vegetation resource	Highly degraded forests of *Anogeissus* and *Butea*

Table 2. Bio-physical indicators in Garhkundar-Dabar watershed

Indicators	Pre Project (2003-04)	Post Project (2011-12)	Percent increase
Land Levelling Index	0.22	0.57	157.77
Critical Area Index	-	0.80	-
Gully Stabilization Index (GSI)*		50	-
Cultivated Land Utilization Index	0.21	0.74	256.67
Water Storage Capacity Utilization Index WSCUI)**	-	368.36	-
Irrigability Index	-	1.25	
Crop Productivity Index	0.71	0.92	29.30
Crop Diversification Index	0.71	0.85	18.53
Conserved Water Productivity Index	-	0.65	-
Crop Fertilization Index	0.22	0.57	157.77
Induced Watershed Eco-Index	-	0.41	

*Values for Stream Slope Reduction (SR) 1.25 and Stream Side Stabilization Ratio (SSR) 0.80

** Values for Storage Efficiency (SE) 818.15 and Utilization Efficiency (UE) 68.51

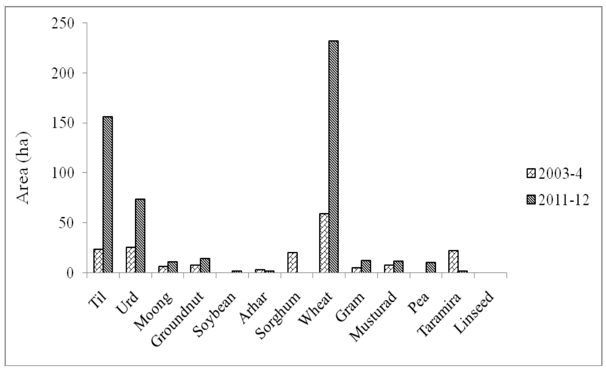

Fig. 2. Area under different crops during pre and post project in Garhkundar watershed

The values of different bio-physical indicators indicate that farmers of the watershed showed keen interest in utilizing harvested water and brought significant area under vegetation through agroforestry interventions.The information generated could be used by different watershed development implementing agencies in SAT region for targeting outcomes before implementing such projects. This would result in more quantitative detailed project reports of watershed projects.

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