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Integrated watershed management for natural resource conservation and livelihood security in semi-arid tropics of India

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ABSTRACT

Present study was undertaken during 2005–06 to 2009–10 to assess the impact of integrated watershed management interventions, viz soil and water conservation measures, agroforestry development, crop demonstrations with improved package of practices, plantation and human resource development on natural resource conservation and livelihood security in Garhkundar–Dabar watershed. Soil and water conservation measures generated 25 thousand cubic m water storage capacity, reduced number of dry wells to 2 % from 86 %, increased average available water column depth in wells from 0.88 m to 4.36 m and enhanced water availability to round-the-year from four to five months during the study period. Runoff per unit area and soil loss from treated watershed was 46 and 42.2 % lower than the untreated watershed respectively in 2009. The average productivity of major crops and cropping intensity increased by 26 and 119.5% respectively in 2009–10 as compared to 2005–06. The fodder availability increased by 208 % and within four years, watershed became a fodder secure area with fodder surplus of 1.992 tonne/year/animal as compared to (-) 0.569 tonne/year/animal in 2005–06. The increased direct and indirect employment opportunities in watershed reduced migration to 9% in 2009–10 from 29% in 2007–08.

Key words: Integrated watershed management, Livelihood security, Natural resource conservation, Semi-arid tropics

Livelihood security with a strong commitment for natural resource conservation would be the foremost challenge of the 21st century, particularly in arid and semi-arid tropics. Semi-arid tropics, the home of over 560 million poor suffers from one or other kind of natural resource degradation. Absolute poverty, high livestock and human population pressure and degradation of production base are some of the problems defying solution in most developing countries including India in these regions (Grewel *et al.* 2001). In India, 65% of the 142 million hectares of arable area is rainfed with very low productivity (1–1.5 Mg/ha), largely due to low rain water-use efficiency (35–45%) for crop production. Integrated watershed management has been a prominent approach for resource conservation and livelihood security in these areas (Samra 1997). Meta analysis of 627 watershed case studies was done under a comprehensive assessment of watershed programs in India by ICRISAT led consortium (Wani *et al.,* 2007). It was observed that watershed development programs are benefiting rainfed areas with a B:C ratio of 2.01, IRR 27.43%, enhancing rural incomes by 58% and increasing agricultural productivity by 35%, besides protecting environment. Further, the irrigated area increased by 51.5%, cropping intensity increased by 35.5%, ground water table improved by 3.2 m, runoff reduced by 13% and generated 154 days/ha/year employment. The study further revealed that vast scope still exists to enhance the benefits and doubling the productivity of rainfed areas by upgrading watershed programs in the country with increased investments. Results from 30 years long-term studies at ICRISAT and yield gap analysis for crops in India revealed that current rainfed farmer's yields in India are lower by 2-5 folds than the achievable potential of rainfed agriculture and this potential needs to be tapped by adopting integrated watershed management approach on a large scale. Meta analysis emphasized that different approaches and activities for different agro-ecoregions need to be undertaken in watershed programmes.

The agroecosystem of Bundelkhand is characterized by undulating and rugged topography, highly eroded and

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dissected land, poor soil fertility, scarce groundwater resource, erratic rainfall leading to frequent droughts, poor irrigation facilities, heavy biotic pressure on forests, inadequate vegetation cover and frequent crop failures resulting in scarcity of food, fodder and fuel (Palsaniya *et al.* 2008). The climate is tropical semi arid with temperature ranging between 2 °C during December and January and 45 °C during May and June. The average annual rainfall of the area is around 900 mm, bulk of which (>90%) is received during June–September. It has been observed that in a cycle of five years, two are normal, two are drought and one is excessive rainfall year (Tiwari *et al.,* 1998). However, since last eight years, five are severe drought years (2002, 2004–07) and likely to be more recurrent in view of rise in temperature due to global warming and resultant climate change. Indiscriminate extraction of the ground water, scarcity of fuel and fodder, over grazing by livestock and unscientific land uses are further threatening to the livelihood and agro-ecosystem of the region (Palsaniya *et al.* 2010). Mass migration and hunger deaths are being reported from the region. There are also reports of distress sale of animals. Therefore, under such a scenario, it is vital to conserve natural resources and provide livelihood security through adopting integrated watershed management interventions.

MATERIALS AND METHODS

Study site profile

Present study was undertaken during 2006–10 in Garhkundar –Dabar watershed located at Tikamgarh district of Madhya Pradesh in Bundelkhand region of Central India where National Research Centre for Agroforestry, Jhansi (Uttar Pradesh) is developing a model watershed based on agroforestry interventions since 2005 (Table 1). The watershed has predominance of people belonging to other backward classes (49.3%), followed by Scheduled castes (28.3%), Scheduled tribes (16.1%) and general category (6.4%). Marginal and small land holdings together comprise 86.3% of cropped area and rest 13.7% area falls under medium holding size with no large holdings in the watershed. Majority of people derive their livelihood from agriculture. Watershed area received 375, 454, 1271 and 769 mm rainfall in 2006, 2007, 2008 and 2009, respectively.

Table 1 General characteristics of the watershed (study site)

Location and area	
Latitude	25^0 26’ 24” - 25^0 28’ 31” N
Longitude	78^0 52’ 41” - 78^0 54’ 44” E
Altitude	280 to 230 m above MSL
Relief	50 m
Area	850 ha
Land use	
Cultivated area	296 ha
Forest area	463 ha
Habitat	13 ha
Drainage network	46 ha
Scrub land	32 ha
Resources	
Total population	895
No. of households	191
Animal resources	2648
Land holding	1.55 ha/household
Main *rabi* crops	Wheat, pea, gram and mustard
Main *kharif* crops	Groundnut, blackgram and sorghum
Vegetation resource	Highly degraded forests of *Anogeissus* and *Butea*
Soil resource	Low in N, P, SOC and medium in K
Water resource	107 open shallow dug wells existed in unconfined aquifer

Integrated watershed management interventions

Five major activities, viz soil and water conservation measures, agroforestry system development, crop demonstrations with improved package of practices, plantation and human resource development were taken up during the course of watershed development in participatory mode (Table 2). Soil and water conservation measures included construction of 150 gabions on first order streams, eight check dams in series on third and fourth order streams, Khadins (water spreaders) in depressions, and marginal bunding in 40 ha (3 km length) agricultural lands. Seventy-five on farm crop demonstrations for wheat, gram, sorghum, groundnut, blackgram, greengram, sesame, pigeonpea, vegetables, etc. were conducted during 2006–10 comprising improved agrotechniques including introduction of high-yielding varieties. Farmers were persuaded to adopt agroforestry for higher income and productivity, risk proofing against drought and increasing permanent vegetative cover for restoring ecological balance and as such, guava, Indian gooseberry (aonla) and citrus-based agroforestry systems were developed in 3 ha area on farmer’s field. Nearly 6000 multi purpose tree species were planted along water courses. Fish farming in check dams; natural gum and lac cultivation on *Butea monosperma*; incense making and ber budding were introduced as alternative income-generating activities. Self-help groups (SHG) were organized to take up joint venture for overall growth and development of rural economy.

Data collection

The area and productivity of cultivated crops were noted each year through survey and sampling. To get uniform samples (1 m × 1 m size) of crops from cultivated fields under eight check dams, each check dam was divided in to three reach (upper, middle and lower) and three samples for each crop were taken from each reach. Thus, there were 72 samples for each crop representing whole watershed area. To analyze the dry biomass productivity of forage grasses from

Table 2 Interventions taken up for resource conservation and livelihood security

Soil and water conservation measures	Number	Unit cost (₹* in lakh)
Check dam	7	2.35
Low cost check dam	2	1.6
Khadins/water spreaders	3	0.08
Gabion (3 cum.)	150	0.01
Spillways	15	0.01
Contour/field bunding	40 ha (3 km)	₹ 27/running meter
Gauging stations	6	
Crop demonstrations with improved package of practices		
2006 to 2010	75	
Agroforestry system demonstrations (2007–2010)		
Guava *(Psidium guajava)* based	5	
Citrus based	1	
Aonla *(Emblica officinalis)* based	4	
Plantation		
Plantation of MPTs	6000 (mainly along water courses)	
Ber improvement through budding	200 plants	
Area under agrihorticultural system	4.5 ha	
Area under agrisilvicultural system	1.5 ha	
Development of live fence	2.0 ha	
Human resource development and capacity building		
Training	Budding/Pruning, incense making, gabion mesh fabrication	
Exposure visit	05	
Self-help groups	4 (2 male and female each)	
Watershed committee	1	

Where * 1 US $ = ₹ 48.50

different land use categories, viz scrub land, forest, along the water course and field bunds, 15 representative samples each of 1 m × 1 m size quadrate were collected for each land use during second fortnight of September every year. Data on resources in general and livestock population and productivity in particular were collected through survey of 30% households of watershed during February and March 2006 and 2009–10. The data collected were subjected to simple statistical analysis. Cropping Intensity was calculated by dividing the gross cropped area with net cropped area and multiplied by 100.

The area just adjacent to treated watershed was monitored as untreated watershed to compare the impact of integrated watershed management interventions on runoff and soil and nutrient loss. No soil and water conservation interventions were carried out in untreated watershed except a check dam at the outlet. Gauging stations were constructed at check dams and data logger-based automatic stage level recorders were installed to measure runoff from treated and untreated watershed. Self-recording rain gauge was installed in the watershed to measure rainfall. Manual runoff water samples were collected at fixed intervals in bottles and analyzed in laboratory for soil, N and P loss using standard methodology. Total nitrogen in the runoff soil was determined by micro kjeldahl method (Bremner and Mulvaney 1982). Total runoff soil phosphorus was determined using $HClO_4$ digestion method (Jackson 1973). The water table depth in selected representative wells was measured at 15 days interval using measuring tap. To assess the general water availability scenario in the area, nearby villages (5–10 km away from treated watershed), namely Karguan, Tarichar Khurd and Khiria, having similar geomorphology were also surveyed.

RESULTS AND DISCUSSION

Water resource development and conservation

The water availability in watershed has increased in time and scale. Check dams generated about 25 000 m^3 water storage capacity in watershed. Adoption of integrated soil and water conservation measures in watershed reduced the number of dry wells to 2% in June 2009 from 86% in June, 2006. These dry wells were located at the farthest end from water course in the upper reaches and hillocks. The average available water column depth in wells increased steadily in 2006 (0.88 m) and 2007 (1.62 m) and thereafter, rapidly in 2008 (5.06 m) and 2009 (4.36 m). The water level in wells depends on rainfall and the watershed management interventions. The average annual rainfall of the watershed area is 951 mm. However, watershed received 375, 454, 1271 and 769 mm rainfall in 2006, 2007, 2008 and 2009 respectively. Therefore, higher water column in wells in

2008 may presumable be attributed to exceptionally high rainfall (1271 mm) in that year. So many peaks in water level in wells during 2008 at middle reach of the watershed may possibly be due to the fact that 2008 received exceptionally high rainfall (1271 mm). Most of the wells are located in the middle reach of the watershed. During *rabi* 2008 pumping of water for irrigation reduced the water level in wells and after stopping of irrigation, wells again recharged from abundant standing water in water courses and under ground flow from upper reaches.

Further, the depth of water column was more than 6 m in 40% wells and more than 4 m in 75% wells. These wells were continuously running for 10–12 hr with 5 HP pump. On the other hand, more than 50% of wells in untreated watershed were nearly dry and supporting only 5 HP pump for less than 1 hr. Similarly, the surface water availability in water courses and ground water availability in open dug wells in 2009–10 increased to round the year in middle and lower reaches and for more than five months in upper reach as compared to four to five months earlier in lower reach only (Fig 1).

The situation in areas around Garhkundar watershed was totally different. A survey of neighbouring villages (out side watershed) namely Karguan, Tarichar Khurd and Khiria was conducted on October 2009 to ascertain water availability in wells. Surprisingly, more than 95% wells in these villages were dry. Even wet wells had hardly 1.0 m water column which could be pumped within an hour or so using 5 HP motor.

Reduction in runoff

During 2009 total rainfall received was 768.9 mm, 21% lesser than the mean annual rainfall of the region. It was spread over 39 rainy days. The peak discharge was lower from treated watershed (0.018 m^3/s/ha) as compared to untreated watershed (0.028 m^3/s/ha). Similarly, the total runoff recorded from treated watershed was lower (41.5 mm or 5.4% of annual rainfall) than the untreated watershed (77.3 mm or 10.1% of annual rainfall). Further, runoff per unit area from treated watershed (415 thousand lit/ha) was 46% lower than the untreated watershed.

Soil and nutrient conservation

The soil loss from untreated watershed was 76 and 73% higher as compared to treated watershed in 2008 and 2009 respectively. The soil loss in 2008 was 6.57 kg/ha and 11.56 kg/ha from treated and untreated watershed respectively while the corresponding loss in 2009 was 1.67 kg/ha and 2.89 kg/ha. The N and P losses in 2008 from treated watershed were 7.35 and 4.97 kg/ha, respectively while the corresponding losses from untreated watershed were 12.6 and 8.54 kg/ha. Similarly, the corresponding losses in 2009 were 3.29 and 1.17 kg/ha in treated and 5.70 and 2.03 kg/ha in untreated watershed. Construction of marginal field bundings, gabions on primary streams, water spreaders in depressions and series of check dams on secondary and tertiary streams in treated watershed reduced the soil and nutrient losses in comparison to untreated watershed.

Crop productivity and intensity

The productivity of major crops like wheat, gram, pea, mustard, sorghum and groundnut was increased by 1.46,

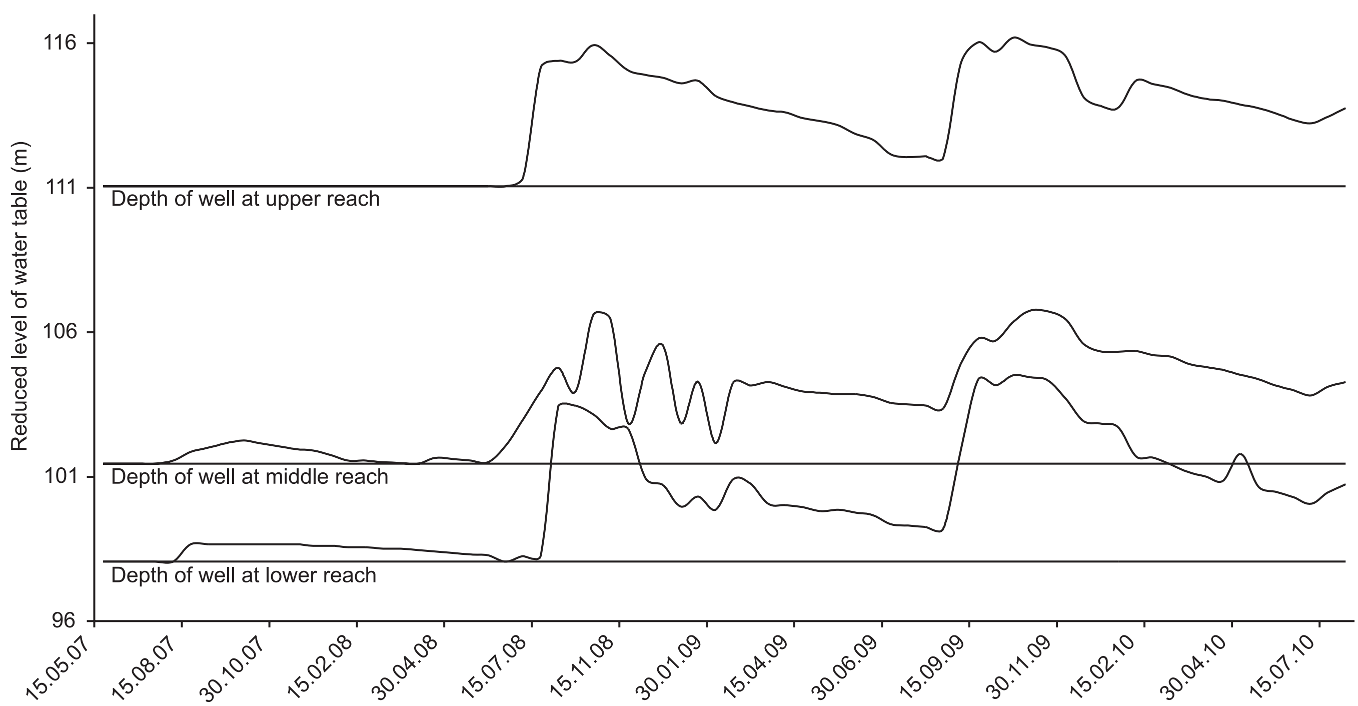

Fig 1 Groundwater availability in watershed

Table 3 Change in productivity and acreage of major crops in watershed

Crop	Productivity (tonne/ha)			Acreage (ha)		
	2005–06	2009–10	% change	2005–06	2009–10	% change
Rabi						
Wheat	1.80	3.26	81	54.0	200.7	272
Gram	1.00	1.13	13	13.5	36.0	17
Pea	1.20	1.74	45	27.0	11.0	–59
Mustard	0.90	1.54	71	20.3	10.0	–51
Barley	2.40	2.90	21	3.0	8.0	167
Kharif						
Sorghum	0.80	1.40	75	24.5	6.2	–75
Groundnut	1.00	1.42	42	14.0	12.5	–11
Sesame	0.35	0.50	43	12.6	107.9	756
Black gram	0.60	0.70	17	10.5	8.8	–16
Mean	1.12	1.62	26			

0.13, 0.54, 0.64, 0.6 and 0.42 tonne/ha, respectively in 2009–10 as compared to 2005–06 (Table 3) with an overall increase of 26% for all the crops. Crops like wheat, sorghum and mustard recorded increase in productivity as high as over 70% while it was nearly 20% in case of gram, blackgram and barley. Further, the cropping intensity increased to 153.4% in 2009-10 from 69.9% in 2005-06 (Table 4) due to substantial increase in cultivated area during *rabi, kharif* and *zaid* seasons. The area under pea, mustard, sorghum, blackgram and groundnut decreased and replaced with wheat during *rabi* and sesame during *kharif.* Hardly 20% of the watershed area was under irrigation during 2005–06 which increased to nearly 90% in 2009-10 due to abundant water availability as a result of water harvesting and conservation measures. This encouraged farmers to grow more wheat during winter and as a result, its acreage increased from 54 ha to 200 ha in 2009–10. Farmers preferred wheat over other crops because they considered wheat more profitable and less risky as it is rarely affected by insect, pests and diseases. The cropped area during *rabi* 2005–06 was only 135 ha which increased to 292 ha in *rabi* 2009–10. Thus nearly 157 ha additional cropped area was added mostly to wheat acreage during *rabi* 2009–10 due to watershed programme. Similarly, additional 83 ha cropped area was added to *kharif* acreage during the study period.

Garhkundar-Dabar watershed is surrounded by forests from three sides and all the villages are located out side the watershed boundary. None of the farmers reside within the watershed boundary, particularly during *kharif* season. There is heavy grazing pressure due to Annapratha (leaving animals free for grazing) and also blue bull problem during *kharif*. Weeds are also a major problem during *kharif*. Most of the fields remain fallow during *kharif*. Therefore, the area under *kharif* is less than the *rabi* crops in this particular watershed. Despite of the above facts, area under *kharif* increased to 153 ha in 2009–10 from only 70 ha in 2005–06. Sesame emerged as a dominant *kharif* crop because it requires less care as it is least preferred by grazing animals and blue bulls, no weed problem due to smothering effect and comparatively better economic return without much investment. The increased productivity and cropping intensity in watershed is attributed to enhanced water availability for irrigation, spread of high yielding variety seeds (> 70% farmers use high-yielding seeds), optimum and balanced use of fertilizers, etc.

Table 4 Change in crop acreage and cropping intensity in watershed

Particular	2005–06	2009–10	% change
Net cultivated area (ha)	296	296	-
Cultivated area – *kharif* (ha)	70	153.2	(+)118.9
Cultivated area – *rabi* (ha)	135	292	(+)116.3
Cultivated area – *zaid* (ha)	2	9	(+)350.0
Gross cultivated area (ha)	207	454.2	(+)119.4
Cropping intensity (%)	69.9	153.4	(+)119.5

Fodder security and livestock production

To know the overall impact of integrated watershed development interventions on fodder requirement, availability and productivity, the fodder balance was calculated and it was observed that despite of increase in stall fed animal population, the watershed area has become fodder surplus (Table 5). The fodder requirement was higher as compared to availability during 2005–06 and as such, the watershed was fodder deficit by 0.569 tonne/year/animal. This fodder deficit was met through import from outside watershed area. However, adopting integrated watershed development approach, fodder availability from all land uses increased to 2041.42 tonne in 2009–10 from 663.17 tonne in 2005–06 (higher by 208%) and within four years the watershed became a fodder secured area with fodder surplus of 1.992 tonne/year/animal. The contribution of cultivated land in total fodder production (mostly in the form of crop byproducts)

Table 5 Forage production and security in watershed

Land use and particulars	Total area (ha)	Effective area *for forage production (ha)	Dry forage productivity (tonne/ha)		Total dry forage production (tonne)	
			2005–06	2009–10	2005–06	2009–10
Scrub land	32	12.8	0.87	1.73	11.14	22.14
Forest land	463	92.6	1.23	2.25	113.90	208.35
Along water course	46	15.2	2.51	5.40	38.15	82.08
Crop field	296				499.98	1728.85
Total fodder availability (tonne/year)	663.17	2041.42				
Fodder requirement (tonne/year)**	853.37	1147.20				
Fodder security (tonne/year)	(-) 190.20	(+) 894.22				
Fodder security(tonne/year/animal)	(-) 0.569	(+) 1.992				

*The effective acreage that is actually producing fodder was taken as 40,20,33 and 0.03% in total scrub lands, forest lands, area in water course and field bunds (of cultivated area), respectively.

**Calculated @ 7 kg dry matter/animal/day (2% of the body weight of an ACU of 0.350 tonne)

increased to 85% in 2009–10 from 75% in 2005–06. Contrary to above, the contribution of forests, scrub lands and area along water course in total fodder production reduced indicating that grazing pressure on forest and scrub lands reduced which is a positive aspect of watershed development projects.

The distress sale of animals particularly during 2004–07 drought was widely reported in the region. Farmers usually sale their animals during drought primarily to get some money to purchase food and secondly due to lack of fodder, drinking water and man power to take care of livestock as family members migrate to nearby cities in search of employment. Distress sale of animals is defence mechanism against the hydro meteorological disasters like drought. Contrary to this, in Garhkundar-Dabar watershed, the total livestock population remained almost constant while that of larger animals (bullock, buffalo and cow) increased by 56.9% during the study period. These large animals mainly stall fed and increase in their population showed ample availability of fodder in the area. Farmers purchased large ruminants, especially buffaloes which are more profitable. The population of small ruminants (sheep and goat) decreased by 15.3% during study period due to decrease in grazing lands as the fallow lands were used for cultivation of crops as a result of enhanced water availability. The average milk productivity from buffalo and cow increased to 6 and 3.5 litres/animal/day in 2009–10 from 4.5 and 2.5 litres/animal/day in 2005–06, respectively.

Employment generation and migration

The impact of integrated watershed management interventions is clearly reflected in terms of employment avenues and migration from watershed area. Now enough employment opportunities are available within watershed and as such, migration reduced to 9% in 2009–10 from 29% in 2007–08 (Table 6). The increase in gross cropped area from 207 ha in 2005–06 to 454.2 ha in 2009–10 generated 29 664 additional man days/year in watershed apart from indirect employment opportunities. Moreover, the proportion of women migrants reduced from 42% in 2007–08 to 26% in 2009–10 showing the gender-friendly aspect of watershed management. The seasonal migration scenario in watershed during 2007–08 was almost well distributed and out of total people migrated (576), *zaid*, *kharif* and *rabi* comprised 45, 30 and 25%, respectively. However, only 9% of the total migration (181) took place during *rabi* 2009–10 and majority was migrated during *zaid* season (57%) which is largely an off season as far as agricultural activities are concerned. This is due to the fact that now ample employment opportunities are available within the watershed, particularly during *rabi*. Generally, rural youth out migrates during off season (summer) to earn additional income and come back for cropping season. Therefore, forced migration has stopped and strategic migration during off season has started in the watershed which is a healthy sign of watershed development programme.

Table 6 Migration scenario in watershed (N= 380 households)

Particulars	2007-08	2008-09	2009-10
Total sample population	1985	2004	2010
Total migrated population	576	260	181
Male	334	155	134
Female	242	105	47

Under present study, the integrated watershed management interventions proved highly efficient in natural resource conservation in Bundelkhand area having fragile agro-ecosystems under semi arid tropics. The soil and water conservation measures along with improved agronomic practices like introduction of high-yielding varieties, balanced use of nutrients, micronutrients, biofertilizers, etc. not only enhanced crop production, productivity, cropping intensity, fodder availability and livestock productivity but also increased employment opportunities within the watershed and thus, ensured livelihood security of the watershed dwellers.

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