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Impact assessment of watershed interventions under low rainfall situations in semi-arid Karnataka

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ABSTRACT

Impact assessment of an integrated watershed development project located in a low rainfall zone (417 mm) in semi-arid Karnataka was carried out. Rainfall distribution during the project period (2008-15) was erratic with four years out of seven receiving less than normal rainfall which led to changes in cropping patterns. Share of area allocated to maize and sorghum increased by 2.8% and 3%, respectively since these crops provide much needed fodder. Due to *in-situ* soil moisture conservation practices like bunding, yield of groundnut, sorghum, maize and onions in rainfed areas increased by 19.4, 9, 16 and 2.8%, respectively. Recharge of groundwater due to land based interventions in initial years led to an increase of 320% in number of bore wells and irrigated area increased by 22%, but extraction of water continuously along with low rainfall years led to failure of 75% of bore wells by end of the project period. Water quality also deteriorated over time and concentration of salts (Na^+, Mg^{2+} and HCO_3^-) increased. Direct employment of 5998 man days was generated over three years in different activities. Economic analysis indicated that the project was viable even under low rainfall condition and had a B:C ratio of 1.17 with an internal rate of return (IRR) of 11.92% and payback period of 10 years.

1. INTRODUCTION

Rainfed agriculture is practiced under a variety of soil types, agro-climatic and rainfall conditions ranging from 400 mm to 1600 mm annum^{-1} and occupies 58% of cultivated area in India. This area contributes 40% of food grain production, supports 40% of human and 65% of livestock population of India (Venkateswarlu and Prasad, 2012). Agricultural production from rainfed area contributes 33, 91, 91, 80 and 65% of nation's cereal, coarse cereals, pulses, oilseeds and cotton production, respectively.

Rainfed agriculture, particularly in semi-arid regions, has become highly vulnerable to rapidly changing rainfall patterns because very limited options are available for coping with variability in rainfall and temperature. Rockstrom and Falkenmark (2000) noted that even a decrease of one standard deviation from mean annual rainfall often leads to a complete loss of crops. Dry spells, which generally involve 2-4 weeks of no rainfall during critical crop growth stages, causing partial or complete crop failures, often occur every cropping season (Sharma *et al.*, 2010). High rainfall variability leads to significant impact on rainfed farming with farmers responding to these changes positively by changes in crop combination or crop diversification, and sometimes negatively by shifting to other professions or migrating out permanently.

Land degradation in India is widespread and all pervading. The harmonized database (Maji *et al.*, 2010) indicates that an area of 73.27 M ha and 12.40 M ha are affected by water and wind erosion, respectively and a total of 120.72 M ha is reported to be degraded due to various reasons. Rainfed areas are most affected by water erosion. Management of natural resources at watershed level to provide multiple benefits by enhancing food production, creating on farm employment and other sources of livelihood has been recommended (Ahluwalia, 2005). The Government of India (GoI) has accorded high priority to rainfed areas since they have lagged behind in crop productivity, poor infrastructural development and widespread natural resource degradation. Over the past four decades, India's watershed programmes have evolved from being externally driven, target driven top down approach to being people centric, demand driven participatory development based on recommendations of the Hanumantha Rao Committee (GoI, 1994a).

Impact assessment studies of watershed programmes carried out by many institutions and workers have indicated that properly planned and executed projects can significantly improve agricultural productivity, lead to crop diversification and increase income levels of farmers (Dhyani *et al.*, 2009). Evaluation of such programmes in 10 agro-ecological zones revealed that soil loss decreased by 10-18%, run off by 2-42% and productivity of arable lands increased from 4.2 to 15 q ha^{-1} (Ram Babu *et al.*, 1997). In a meta analysis of 311 case studies, Joshi *et al.* (2005) reported that these projects led to large scale employment generation, increased irrigated area and cropping intensity, and also conserved natural resources.

The state of Karnataka has a large area (5 M ha) under rainfed agriculture, which is second only to Rajasthan. Three-fourth of cultivable area in Karnataka is dry land and much of it can never be fully irrigated due to various constraints of terrain, rainfall, soil conditions and distance from rivers. Further, ground water extraction is high, and over the last decade, many districts in the state have become water stressed. Kumar *et al.* (2014) estimated the sustainable livelihood security index (SLSI) of Karnataka, which indicated that the state has a very low SLSI with only 21.7% of its population being in the sustainable category. More recently, Kumar *et al.* (2016) reported that 70% of the state's cultivated area, which represents 60% and 67% of livestock and rural population, face 'extreme to high' level of vulnerability and that there is an urgent need for a holistic approach at district level to minimize sensitivity to climatic variables (rainfall and temperature).

Among different districts in semi-arid Karnataka, Chitradurga district has a dubious distinction of being affected by frequent droughts of varying duration and intensity. In a recent report, this district has been ranked at serial number 22 (out of 499 districts), indicating a high prioritization for development of rainfed areas (NRAA, 2012). The district has a typical agrarian setting where land holdings are small and topography is undulating, which cause serious problem of erosion and result in poor crop productivity. Soil fertility is poor, crop failure or very low crop yields are common due to frequent droughts and lack of irrigation facilities. Stakeholders mostly belong to marginalized sections of society and have poor risk bearing capacity, and are not in a position to invest on land development measures from their own resources. Most farmers keep unproductive milch animals, including sheep and goats that provide neither sufficient milk nor FYM (due to free grazing), but are disposed off during times of need.

There is lack of information on impact of low rainfall situations in areas treated by integrated watershed projects and coping strategies adopted by stakeholders. This paper is an attempt to analyze the effect of continued low rainfall situations in a watershed developed in semi-arid region of Karnataka with financial assistance from the Department of Land Resources, Ministry of Rural Development, (GoI). The results described in the paper will improve understanding of coping strategies adopted by farmers in the region and encourage more investments to provide food and environmental security.

2. MATERIALS AND METHODS

Study Area

The Netrenahalli watershed is located in Molakalmur taluk, Chitradurga district of Karnataka, covering villages of Netrenahalli and Konsagara, ($14^0 37'50''$ to $14^0 38'47''$N latitude and $76^0 42'46''$ to $76^0 44' 51''$E longitude; Fig. 1) with its elevation ranging from 550 to 570 above mean sea level (msl). Out of the watershed area of 479 ha, about 389 ha is under agriculture. The watershed is 'petal' shaped with a mild slope of 2.5% and with a long opportunity time (71 minutes) indicating the potential of land surface modification for *in-situ* water conservation (Table 1).

The area under irrigation is only 7.5% of the total watershed area, while wastelands occupy about 5.23%. Konasagara village, which is situated in the lower part of the topography, has a larger area under bore well irrigation (11.8%) out of total area of the village (244.18 ha). There are a total of 187 farm families in the two watershed villages (128 in Netranahalli and 59 in Konasagara), with 99.2% and 74.6% belonging to ST category in the two villages, respectively. Most of the farmers are illiterate (59% each in Netranahalli and Konasagara) and are of the small and marginal farming categories on the basis of their land holdings.

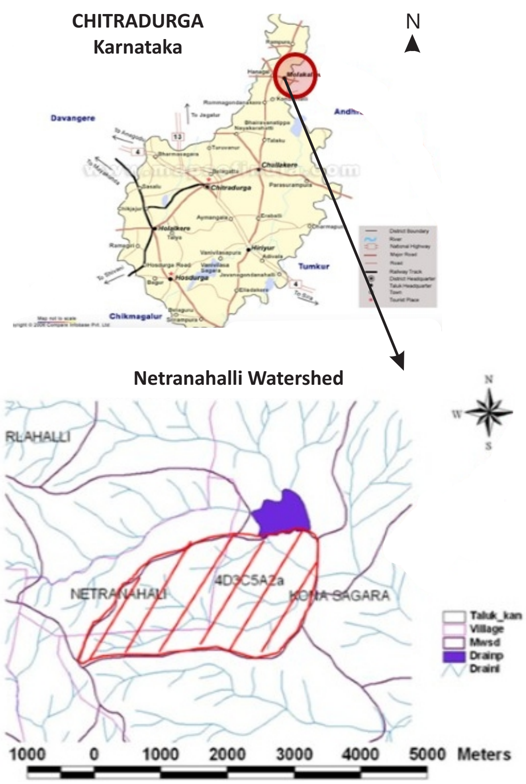

Fig. 1. Map showing location of watershed

Table: 1
Morphological characteristics of Netrenahalli watershed

S.No.	Feature	Formula	Value
1	Catchment area (A)	-	480 ha
2	Average slope	-	2.5%
3	Slope Length (L)	-	3800 m
4	Difference in elevation between highest point in remote and lowest point in the gully	-	30 m
5	Average width of the catchment "W"	A/L	1263 m
6	Form Factor (F)	W/L	0.33
7	Perimeter (P)	-	9800 m
8	Compactness Coefficient (C)	$\frac{0.28P}{\sqrt{A \times 10000}}$	1.25
9	Time of concentration (minutes) (Tc)	$\frac{L^{0.77}}{0.01948 \times S^{0.385}}$	71 min
10	Drainage density (DD)	(km/100 sq. km)	158
11	Slope of the major nala ranging from highest to lowest	-	2 to 5%

Agriculture is the main occupation, and major cultivated crops in rainfed areas include groundnut, sunflower, redgram, *bajra* and *ragi* as sole crops, and intercropping of groundnut with red gram, cowpea, green gram and horse gram. Castor is sometimes intercropped with groundnut or sown on field bunds. All the rainfed crops are cultivated during rainy/*kharif* season with onset of monsoon from June/July to December. In irrigated areas, sorghum, maize, paddy, sunflower and groundnut are raised in *kharif* and *rabi* or during early summer.

Climatic Conditions

The climate of the region is characterized as arid to semi-arid with an average annual rainfall of 417.3 mm in an average of 31 rainy days, out of which about 80% is received during north-east monsoon season (September to November). The mean maximum temperature is around 33^{0}C while the minimum is about 20^{0}C. The groundwater table is available at 100-300 feet and recharge is poor, since most of the runoff flows away in absence of conservation measures.

Standardized precipitation index (SPI) calculated from annual rainfall data for 36 years period (1971-2009) showed that the value was negative for 56% of cases, and 3 years *viz.*, 2004, 2005 and 2006 experienced moderate to severe drought, with the

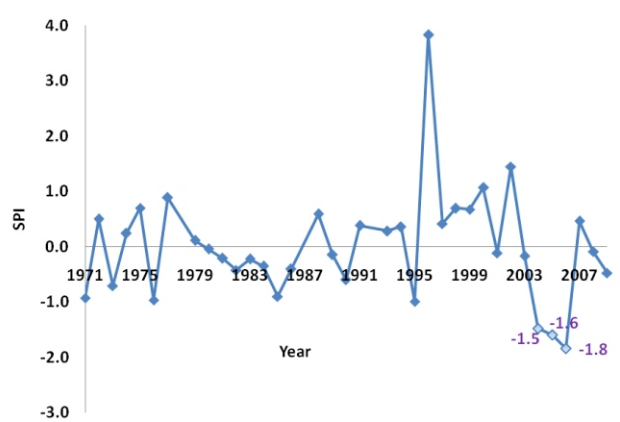

Fig. 2. Annual standardized precipitation index (SPI) values for 36 years rainfall at Chitradurga district

values being less than-1 (Fig. 2). Rainfall analysis of the taluk for the period 1994 to 2011 revealed that out of 18 years, the area received deficit rainfall for 9 years and there was a severe drought during 1994, 1995, 2003, 2008 and 2011. The year 2011 was observed to be the driest year with a negative SPI value for all the months except April and August, the effect of which continued in 2012 when rainfall in the pre-sowing season was 10% below average.

During the project period (2008-15), rainfall distribution was quite erratic, with four years out of seven receiving less than normal rainfall. The year 2008 was a low rainfall year (277.2 mm) which is 66.5% of the mean average and only 92.2 mm was received in 6 rainy days during the *kharif* season. The next two years (2009 and 2010) were years with good rainfall and well distributed rainy days (Table 2). During 2011, while 80% of rainfall was received, it was unequally distributed and *kharif* and *rabi* seasons received only 215 mm of rain in 23 rainy days, which affected crop productivity and yields. The year 2012 received 466.1 mm of rain but rainfall distribution during the cropping seasons was poor and 284.5 mm (68.1% of annual average) was received in only 16 days, indicating high intensity storms, which caused increased soil erosion and runoff. Similarly in 2013, out of total rainfall of 447.1 mm received, only 161.6 mm (36%) was received during *kharif* season and no rain was received during *rabi*. The year 2014 received sufficient rainfall (619.2 mm) in 31 rainy days, which were well distributed. These trends clearly indicate that rainfed farming in the region is highly vulnerable to rainfall variability and continues to be risk prone.

Soil Quality

The soils have a low available water capacity (AWC) of <50 mm m^{-1} due to shallow depth, high gravel content, low clay content and moderate to severe erosion. These soils are classified as Lithic Ustrothents, Lithic Ustropepts and Typic Ustorthents. Texture of soil varied from loamy sand to sandy clay loam with bulk density ranging between 1.36 g cc^{-1} and 1.65 g cc^{-1} with an average of 1.48 g cc^{-1}. Extensive soil sampling was done in initial phases of project implementation (2007-08). Soil samples were collected at 2 depths (0-15 cm and 15-30 cm) from 46 locations in the watershed and were analyzed for various

Table: 2
Distribution of rainfall and number of rainy days during two cropping seasons

Year	Total rainfall (mm)	Total rainy days	*Kharif* season (July - September)		*Rabi* season (October - November)	
			Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)
2008	277.2	17	6	92.2	0	0
2009	773.8	32	16	431.4	5	153.8
2010	861.2	40	17	370	11	173.9
2011	338.5	37	15	134.8	8	80.1
2012	466.1	26	13	149.8	3	134.7
2013	447.1	19	10	161.6	0	0
2014	619.2	31	17	307.6	6	74
2015*	26.2	3	-		-	

**Data upto 31st March 2015*

Table: 3
Chemical characteristics of soil samples (0-15 and 15-30 cm depths) collected from farmers' fields of Netranahalli watershed during 2009

S.No.	Parameters	0-15 cm depth		15-30 cm depth	
		Range	Average	Range	Average
1.	pH	6.71-8.83	7.85	6.34-8.82	7.65
2.	EC	0.01-0.40	0.13	0.01-0.29	0.12
3.	Organic carbon (%)	0.08-0.84	0.40	0.12-0.82	0.44
4.	Available N (kg ha^{-1})	90.9-573	273	103-572	284
5.	Available P_2O_5 (kg ha^{-1})	10.7-339	70.9	11.8-276	51.6
6.	Available K_2O (kg ha^{-1})	137-1102	452	137-794	376
7.	Zinc (ppm)	0.19-0.70	0.49	0.19-0.78	0.45
8.	Copper (ppm)	0.31-2.47	1.27	0.24-3.11	2.01
9.	Iron (ppm)	2.06-33.50	19.25	1.83-35.0	20
10.	Manganese (ppm)	2.77-25.45	18.65	4.40-25.5	17.3

fertility characteristics *i.e.* texture, bulk density, pH, EC, organic carbon, N, P_2O_5, K_2O, Zn, Cu, Fe and Mn.

The results (Table 3) indicate that almost all fields were low in organic carbon and available N, while available P_2O_5 and K_2O status are adequate. The status of micro-nutrient availability is high to very high except for zinc. Hence, application of FYM or vermi-compost @ 5-7.5 t ha^{-1} alongwith additional dose of nitrogen fertilizer is recommended. Application of zinc sulphate @ 20 kg ha^{-1} is also recommended to enhance crop yields since the status of zinc is low in general (Prabhavathi *et al*., 2013). Detailed soil mapping was carried out over the arable lands, as per survey numbers, and soil fertility maps were prepared. Along with this, maps for organic carbon and zinc status were also prepared. Each farmer was subsequently provided with a soil health card with an advisory.

Quality of Groundwater

Irrigated agriculture in the semi-arid tracts is carried out mainly by ground water extracted from open wells or bore wells. While this was once an assured form of irrigation, it has in recent years become unpredictable due to poor recharge and rapidly declining water table because of uncontrolled extraction. Due to inherent nature of hard rock layer overlying aquifers, there is a possibility that irrigation is being carried out using water that is not suitable for irrigation. In the beginning of the project, bore well water samples (15) were collected from fields situated at three topographic situations (upper, middle and lower reaches) of watershed, and analysis was carried out immediately. Analysis was carried out for parameters necessary for irrigation water (APHA, 1995); the parameters studied were - pH; electrical conductivity (EC); cations like calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+); and, anions like carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}). The pH and EC were measured by Systronics pH meter, Sulphate (SO_4^{2-}) by Spectrophotometer, Na and K using Flame Photometer. Calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2}), bicarbonate (HCO_3^-), chloride (Cl^-) were determined by titrimetric analysis. Sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC) were estimated by procedure adopted by Saxena (1990) and Mg/Ca ratio was calculated. Subsequently, water quality parameters were assessed at end of the project period to determine the impact of deficit rainfall and poor recharge.

Watershed Interventions

A number of interventions were implemented in Netrenahalli watershed covering arable and non-arable lands; development of water resources; soil conservation activities; field bunding in 250 ha; crop production activities covering groundnut, cowpea, redgram, *bajra* and maize; dryland horticulture by creation of compact blocks of mango, pomegranate, sapota, lime, coconut (on field boundaries) and tamarind; development of fodder resources (fodder blocks of guinea grass, para grass and hybrid napier); vegetable cultivation (cabbage, carrot, hybrid tomatoes, cauliflower) etc., which were aimed to provide conservation of natural resources, increased retention of runoff water in arable lands, and thereby improve crop productivity in rainfed areas. For brevity, these interventions have been summarized in Table 4.

Impact Estimation of Conservation Measures on Soil Loss

Estimation of soil loss reduced by construction of field bunds was carried out by silt survey in which volume of silt held up against waste weirs located in upper, middle and lower reaches of treated arable land was estimated. This was carried out in 165 ha and quantity of soil retained within the bunded area was estimated.

Socio-economic Data

In order to compare the effect of watershed interventions, primary data on crop yields, cropping pattern, land use patterns and change in irrigated area were collected from different farm categories following proportionate stratified random sampling with help of a pre-tested and semi-structured schedule and compared with pre-project information. A total of 126 farmers were investigated for impact assessment of interventions.

Analytical Tools

To quantify additional benefit of watershed interventions, incremental profit was estimated for major four crops *viz*., groundnut, sorghum, maize and onion. These crops accounted for 99% and 97.5% of gross irrigated and rainfed cropped areas, respectively.

$$\Delta P_i = \left(I_{AW} - I_{BW}\right)_i - \left(C_{AW} - C_{BW}\right)_i$$

Table: 4
List of major soil and water conservation measures implemented in Netrenahalli watershed

S.No.	Conservation measures	Description
1.	Soil conservation measures in non -arable areas	Impounding area of one *nala bund* and one check dam was de-silted and storage capacity restored. Two water courses were deepened to facilitate safe disposal of runoff water. Nine farm ponds were de-silted and restored to their original capacity.
2.	Soil conservation measures in arable land	249.93 ha area was covered under field *bunding* (and with waste weirs and stone revetments) of size 0.81 sq.m cross section (top width - 0.45 m, bottom width - 2.25 m and height 0.6 m).
3.	Crop production activities	Improved varieties of groundnut (TMV2 and K6), cowpea (C 152) Red gram (ICPL 87 and BRG 2), *bajra* (cultivar ICTP 8203) and maize cultivar (Super 900 M Gold) were introduced in the watershed in 27 demonstrations.
4.	Drainage line treatment in non-arable lands	Channels from non-arable areas were treated by construction of rock-fill dam and gabion structures (1 m wide, 1 m height, 0.7 m above GL, 0.3 m bgl) in critical areas.
5.	Introduction of forage legumes on bunds and creation of fodder banks	Sowing of *Stylosanthes hamata* (Stylo) seeds was carried out on newly formed field bunds in 16 locations, the bund length varying from 102 m to 550 m and a total length of 4907 m was covered. Additionally, Guinea grass (*Panicum maximum*), Para grass (*Bracharia decumbens*) and hybrid Napier (*P. purpureum* x *P. typhoides*) were also introduced.
6.	Development of dryland horticulture	A total of 50 ha area was developed under dry land horticulture by planting mango (var. Mallika, Baneshan and Alphanso), sapota (Cricket Ball and Kalipatti), guava (Allahabad safeda), lime (Balaji), *mosambi*, coconut (var. Tiptur tall) and tamarind (PKM-1) in the field of 18 farmers during 2010-11 and in fields of 50 farmers during 2011-12.
7.	Demonstrations on vegetable cultivation	Efforts were made to promote high value-low volume crops such as hybrid tomato (H. No.618), cabbage (F1- Balaji), carrot (var. Tokito) and cauliflower (F1 - Utapati).
8.	Afforestation, planting of tree borne oilseeds (TBO's) and silvi-pastoral development	Rehabilitation of *nala* banks in upper reaches of the watershed was done by planting (during 2011) of 550 seedlings of different species like - *Pongammia pinnata* (Karanj), *A. indica* (Neem) *Tectona grandis* (teak), *Grewellia robusta* (Silver oak) all along the *nala* bank, in pits of size 60 cm^3.

Where, ΔP_i = incremental profit per ha from i^{th} crop; I_{BW} = gross income per ha from i^{th} crop during before watershed interventions; I_{AW} = gross income per ha from i^{th} crop after watershed interventions; C_{BW} = cost of cultivation per ha for i^{th} crop before watershed interventions; C_{AW} = cost of cultivation per ha for i^{th} crop after watershed interventions. Then, the total incremental benefit from the watershed can be computed as:

$$\Delta V = \sum_{i=1}^{n} \Delta P_i \, \Delta A_i$$

Where, ΔV is the value of total benefits from major crops at watershed level and ΔA_i is the incremental area (difference between the cropped area before and after watershed project) for the i^{th} crop.

Economic feasibility indicators were estimated under the following assumptions: (a) life of project was assumed to be 25 years, (b) discount rate was taken as 10%, (c) it is assumed that the watershed will yield same incremental benefits during its life, (d) the cost of interventions was taken by summing up expenditures accrued for soil and water conservation and other interventions which was ₹ 25,47,745/- (field bunding, recharge filters, quality seed distribution, de-siltation of existing pond, renovation of water harvesting structures, drainage line treatments and construction of vermi-compost units), and which apparently have impact on crop production.

3. RESULTS AND DISCUSSION

Impact on Soil and Water Conservation

Survey of silt deposition behind *bunds* indicated that about 685 cu m of soil from 165 ha was conserved within arable lands due to adoption of soil conservation measures. Besides the retention of soils within the inter-bunded area, the measures also led to higher *in-situ* moisture availability in soil profile that was reflected in marginally increased crop yields in rainfed areas, in-spite of low rainfall in four consecutive years. Creation of ponds, de-siltation of village tank and deepening of *nalas* also led to creation of additional water storage of 4657 cum (Table 5).

Impact on Ground Water Extraction Patterns

Number of borewells (existing and functional) were enumerated and compared with pre-project status (Table 6). After implementation of the project, a

Table: 5
Water storage created at Netranahalli watershed during project period

S.No.	Structure	No. of structures created	Additional storage created (cum)	Expenditure Incurred (₹)
1.	Village tanks and *nala bund* / *nala* deepening in a length of 452 m	5	1958	44055
2.	Ponds	9	2612	58770
3.	Check dam	1	87	19578
	Total			104783

Cost of storage is ₹ 22.50 per cum

Table: 6
Changes in number of borewells in Netranahalli watershed over six years period

Parameter	2008 (Pre proj.)	2014 (Post proj.)	% increase
No. of borewells existing	250	1050	320
No. of borewells functonal	122	235	93
% of failed borewells	51.2	77.6	

sudden increase in number of bore wells was observed which can be attributed to a well known fact that implementation of watershed projects leads to increase in groundwater availability. There was an increase of 320% in number of borewells but continuous poor rainfall forced many farmers to go in for drilling of new wells, with a large number of failures. While the actual increase in ground water availability could not be measured, well distributed rainfall in 2009 and 2010 (Table 2) may have led to some recharge of groundwater resources that led to increase in number of bore wells and consequent increase in irrigated area. Due to continuous low rainfall situation subsequent to project implementation, most of the existing and new bore wells are not functional, although at the time of evaluation the number of functional bore wells was twice the number before project implementation. The annual rainfall recorded during 2011, 2012 and 2013 was 338.5 mm, 466.1 mm and 458.9 mm, respectively against long-term average of 534 mm. This, coupled with higher groundwater extraction, reduced water availability for irrigation and groundwater table declined by 16 m between 2010 and 2014. The decline in groundwater level also resulted in decline in its quality during the same period. The depth of water availability has now increased to 200-240 feet.

Increase in area under irrigation has been an explicit objective of watershed projects, since water conservation and harvesting structures lead to ground water recharge. In a recent paper by Grewal (2016), it was reported that construction of 15 earthen dams and levelling of 85 ha of wastelands led to increase in water harvesting but also led to significant increase in number of tubewells (2 to 128) which led to a decline in water table by 3.6 m and change in cropping patterns. Shivamurthy *et al.* (2006) reported from a watershed in Karnataka, that net irrigated area increased by 26% and yield of water from wells increased by 70%. As a consequence, the area devoted to water intensive crops like paddy and sugarcane increased from 33 acres to 114 acres while it declined in areas outside the watershed. They also reported inequity in access to ground water, with 15% farmers having access to 25% of the ground water. There is thus a need to develop participatory ground water use practices which will be acceptable to all stakeholders and also ensure sustainable use of the precious resource.

Impact of Low Rainfall on Groundwater Quality

The quality of bore well water during 2011 (Table 7) indicates that the water is alkaline in nature with a pH of 8.52 and Mg/Ca ratio of 2.47, which is more than the ideal ratio of <1. A higher ratio will hamper

Table: 7
Quality of water samples collected from borewells in Netranahalli watershed during 2011

S.No.	Particulars	Range	Average	Permissible limits
1.	pH	7.31-8.71	8.43	6.5-8.5
2.	EC (dS m^{-1})	1.07-2.40	1.78	1.5
3.	Ca (meq l^{-1})	1.40-4.60	2.56	3.75
4.	Mg (meq l^{-1})	3.40-10.20	6.81	2.5
5.	K (meq l^{-1})	0.03-0.28	0.19	0.25
6.	Na (meq l^{-1})	6.70-29.26	11.39	4.35
7.	CO_3 (meq l^{-1})	0.0-1.60	0.80	-
8.	HCO_3 (meq l^{-1})	5.60-9.60	7.31	-
9.	Cl (meq l^{-1})	1.00-3.40	2.13	7.04
10.	SO_4 (meq l^{-1})	1.28-26.09	5.66	6.25
11.	Mg/Ca	1.96-5.71	2.84	<1
12.	SAR	4.00-11.22	5.25	-
13.	RSC	-6.80-3.40	-1.26	-
14.	SSP	43.82-68.27	54.53	-

Table: 8
Changes in chemical composition of groundwater in upper and lower portions of Netranahalli watershed over time interval 2011 to 2014

Parameter	Upper reaches				Lower reaches			
	2011		2014		2011		2014	
	Mean	SD±	Mean	SD±	Mean	SD±	Mean	SD±
pH	8.51	0.21	8.69	0.19	8.53	0.14	8.71	0.12
EC (dS m^{-1})	1.30	0.41	1.58	0.37	1.35	0.54	1.43	0.39
TDS (mg l^{-1})	833	259	1010	237	809	275	917	251
Ca^{2+} (mg l^{-1})	76.0	19.1	124	29.9	58.7	24.8	95.5	20.3
Mg^{2+} (mg l^{-1})	94.7	18.5	152	17.6	88.8	14.8	124	10.9
Na^{+} (mg l^{-1})	155	25.5	275	57.4	143	24.6	228	52.0
K^{+} (mg l^{-1})	11.5	3.0	15.1	3.29	10.0	1.51	11.0	1.72
Co_3^{-} (mg l^{-1})	ND	-	ND	-	ND	-	ND	-
HCO_3^{-} (mg l^{-1})	571	70	1144	119	556	76	866	93.8
So_4^{2-} (mg l^{-1})	76	21.0	80.4	18.5	108	25.6	111	31.9
Cl^{-} (mg l^{-1})	320	138	341	123	256	129	289	114

ND - Not Detected

calcium availability to crops, weaken soil structure, and reduce infiltration and permeability. These waters must be used after treatment with gypsum to replace Na by Ca and to bring Mg/Ca ratio upto the desirable level.

In order to assess the impact of continuous low rainfall situations, samples from 19 bore wells (upper-10 and lower-9 portions of the watershed) were analyzed which had also been sampled in the pre-monsoon season of 2011, and were repeated again in 2014. Results indicate (Table 8) that the pH has now increased to 8.7, and average electrical conductivity to 1.28 dS m^{-1}. The general order of abundance in respect of cations is Mg^{2+}> Na^{+}> Ca^{2+}> K^{+}, and in respect of anions is HCO_3^{-}> Cl^{-}> SO_4^{-2}. Cations were observed to be higher in upper portion of the watershed as compared to lower portion. An increase in concentration of individual ions such as Na^{+} (77%), Mg^{2+} (61%) and HCO_3^{-} (100%) was recorded, which can be attributed to three consecutive years of low rainfall coupled with higher groundwater extraction. During 2014, 21% of the samples were in the 'high salt hazard' zone, while groundwater in 50% of the watershed indicates a potential alkalinity hazard expressed as RSC, indicating that water should be used with caution for irrigation during years of low rainfall in order to prevent soils from becoming salt-affected. A detailed analysis of the impact of low rainfall and simultaneous ground water extraction has been reported recently by Biswas *et al.* (2017) from the same location.

In semi-arid hard rock regions of the Deccan, the beneficial effects of water harvesting structures have been reported earlier by Adhikari *et al.* (2013). They reported that groundwater quality improved in close vicinity (<100 m) of water harvesting structures. Badiger *et al.* (2016) reported that investments in water harvesting structures were financially feasible and economically viable in the Deccan, while Jat *et al.* (2016) reported similar results from Rajasthan. Therefore in the dry regions, it is necessary that due importance to water harvesting structures in watershed projects must be given since they are effective in improving recharge and water quality.

Cropping Patterns and Area Allocation to Different Crops

Before implementation of the project (2008), gross cropped area was 337.45 ha, which increased to 412.55 ha (2014), indicating an increase of 22.26% over the pre-project year. With increase of 69 ha in gross irrigated area, a change in cropping pattern was observed in the watershed (Table 9). The increase in gross irrigated area can be attributed to increase in number of functional bore wells and partly to an increase in water yield of some of older bore wells situated in lower part of the watershed. After watershed project implementation, the share of area allocated to irrigated crops such as sorghum and maize increased by 2.83% and 3.06%, respectively, but share of onion, groundnut and *ragi* showed no change or even decreased.

Prior to the project, around 96.2% of gross cropped area was under rainfed groundnut cultivation with a small share under sorghum (1.87%), maize (0.75%)

and onion (1.17%). However, after a period of five years of watershed project implementation, an increase in share of sorghum, maize and onion was recorded, and some diversification in rainfed areas was also observed with introduction of *bajra* and horse-gram. This can be attributed to three consecutive years of low rainfall or poorly distributed rainfall, which increased the risk of crop failure and financial loss in case of groundnut and forced farmers to change over to crops like sorghum in irrigated areas, and to *bajra* and horse gram under rainfed situations, since these crops could meet some of the food requirements. The above changes also indicate trends of coping strategies being adopted by farmers, by shifting from water requiring crops (like cotton, rice, etc.) to low water requiring crops like maize, which can satisfactorily yield even with one irrigation and also provide much needed fodder for livestock.

Crop Yields

In irrigated areas, the yields of groundnut, sorghum, maize, onion and *ragi* increased by 22.5, 14.6, 19.9, 8.5, and 5.7% over that observed in pre-project year (Table 10). Similarly, in case of rainfed areas, a positive impact on crop yield was observed, which may be attributed to watershed interventions. Construction of field bunds along with waste weirs led to increased moisture availability in soil profile and yields of groundnut, sorghum, maize and onion increased by 19.4, 9.0, 16.2 and 2.8% over the pre-project period. Properly placed waste weirs allowed for quick movement of runoff water and no impounding was observed which improved ground nut and maize yields in rainfed areas. Ashalatha *et al*. (2012) reported that yield reduction which ranged from 60% in cotton to 34% in groundnut, was attributed to low rainfall, warmer temperatures and also loss of soil vigour. In this watershed, conservation measures partly offset the effect of low rainfall, and yield increases (ranging from 2.8% to 19%) were recorded, indicating that *in-situ* moisture conservation were effective even in low rainfall situations.

Table: 9
Change in cropping pattern in Netranahalli watershed

Crop	Irrigated Area				Rainfed Area			
	Before Project		After Project		Before Project		After Project	
	Area (ha)	Share (%)	Area (ha)	Share (%)	Area (ha)	Share (%)	Area (ha)	Share (%)
Groundnut	1.94	6.26	3.84	2.49	272.16	96.21	262.22	90.42
Sorghum	16.15	28.93	38.78	31.76	5.80	1.87	10.09	3.48
Maize	17.77	31.85	42.62	34.91	2.33	0.75	5.57	1.92
Onion	16.76	30.02	36.70	30.05	3.63	1.17	5.05	1.74
Ragi	0.51	1.64	0.58	0.79	0.00	-	0.00	-
Rice	0.17	0.54	0.00	-	0.00	-	0.00	-
Vegetables	0.24	0.76	0.00	-	0.00	-	0.00	-
Bajra	0.00	-	0.00	-	0.00	-	1.48	0.51
Horse gram	0.00	-	0.00	-	0.00	-	5.63	1.94
Total	53.53	100.00	122.51	100.00	283.92	100.00	290.04	100.01

Before project - 2008; After project - 2014

Table: 10
Change in yields (kg ha^{-1}) of different crops grown in Netranahalli watershed

Crop	Irrigated Area			Rainfed Area		
	Before Project	After Project	Increase (%)	Before Project	After Project	Increase (%)
Groundnut	586	718	22.53	468	559	19.44
Sorghum	1360	1559	14.63	1150	1254	9.04
Maize	1667	1998	1.86	1250	1452	16.16
Onion	5690	6201	1.95	4463	4569	2.38
Ragi	1590	1680	22.53	-	-	
Rice	1224	-		-	-	
Bajra	-	-		-	516	
Horse gram	-	-		-	360	

Before project period - 2008; After project - 2014

Employment Generation

Different types of treatment activities carried out in the watershed, like soil and moisture conservation measures in agricultural lands, drainage line treatment, water resources development/management, crop demonstration, horticultural plantations and afforestation works as per needs and priorities of the watershed community and their technical feasibility led to increased casual employment. A total of 3623 and 2375 man days employment worth ₹ 5.29 and 3.49 lakh at the then prevailing wage rates have been generated under different engineering works and plantation/afforestation works, respectively during 2009 to 2011. The magnitude of employment is significant; further, these activities will help in generating regular employment in future when trees will yield fruits. It is a well established fact that participatory watershed development leads to generation of immediate casual employment and subsequent regular employment from activities like horticulture, dairying and diversified agriculture (Ram Babu *et al.*, 1997; Arya *et al.*, 1994)

Economic Viability of Netrenahalli Project

The economic viability of watershed investment was examined with help of indicators, namely payback period, net present value (NPV), B:C ratio, and IRR. Discounted cash and cost flow were generated at 10% discount rate, and the life of the project was taken to be 25 years. Positive values of NPV (₹ 3,82,532), and B:C ratio of >1.0 (1.17) indicate the investment made in watershed is economically viable. The IRR is 11.92%, which is higher than the discount rate, shows that investment made in watershed is worth taking up in comparison to other low-risk alternatives. The results are in contrast to a report by Joshi *et al.* (2005) who suggested that higher investments are required to be made in regions with rainfall between 700-1000 mm yr^{-1} where the impacts will be more 'visible'. Our results show that properly planned and implemented projects in low rainfall (<700 mm yr^{-1}) regions are more necessary, since they are beneficial in creating employment (reduce migration during low rainfall years), ensure food security and are financially viable, except for a longer payback period (10 years), which is expected due to high variability in rainfall distribution over the years.

4. CONCLUSIONS

Natural resource conservation and socio-economic development in a drought prone area was attempted using participatory approaches for integrated development. Results indicate that even under low rainfall situations, these projects can help in soil and water conservation leading to increased crop yields, and allow stakeholders to diversify to crops that are low water requiring and yield fodder as a by-product, although the payback period of the project may be extended. Direct/casual employment generated during implementation phase will help to reduce out-migration of residents while a wide range of interventions will yield beneficial results under normal rainfall situations. There is also a need to create awareness about the negative impact of excessive groundwater withdrawal and encourage participatory groundwater use in the semi-arid regions.

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REFERENCES

Adhikari, R.N., Singh, A.K., Math, S.K.N., Raizada, A., Mishra, P.K. and Reddy, K.K. 2013. Augmentation of groundwater recharge and water quality improvement by water harvesting structures in the semi-arid Deccan. *Curr. Sci.*, 104(11): 1534-1542.

Ahluwalia, M.S. 2005. Reducing poverty and hunger in India: The role of agriculture. *Annual Report Essay*. IFPRI 2004-2005. DOI: http://dx.doi.org/10.2499/0896297519.E02.

APHA. 1995. *Standard Methods for Examination of Water and Waste Water.* 15th Edition. American Pub, Health Association, Washington, DC.

Arya, S.L., Kaushal, R.C. and Grewal, S.S. 1994. Economic viability of watershed management project selected to rehabilitate degraded Arvalli foothills of Haryana. *Ind. J. Agric. Econ.*, 49(4): 591-600.

Ashalatha, K.V., Munisamy, G. and Bhatt, A.R.S. 2012. Impact of climate change on rainfed agriculture in India: A case study of Dharwad. *Intl. J. Environ. Sci. Dev.*, 3(4): 368-371.

Badiger, R., Lokesha, H., Hugar, L.B., Nemichandrappa, M. and Reddy, B.S. 2016. Impact of rainwater harvesting on farm income in northern Karnataka - An economic analysis. *Indian J. Soil Cons.*, 44(1): 8-12.

Biswas, H., Raizada, A., Kumar, S., Prabhavathi, M. and Mohan Kumar, P. 2017. Impact of deficit rainfall coupled with high groundwater exploitation on water quality in semi-arid region of Karnataka. *Indian J. Soil Cons.*, 45(1): 60-65.

Dhyani, B.L., Raizada, A., Ghosh, B.N. and Juyal, G.P. 2009. Impact of technology extension on land use changes, food security and economic prosperity in a Central Himalayan watershed. *Indian J. Soil Cons.*, 37(2): 133-143.

Government of India. 1994 *Report of the Technical Committee on Drought Prone Areas Programme and Desert Development Programme*, Ministry of Rural Development, New Delhi, 73 p.

Grewal, S.S. 2016. Impact of rainwater harvesting on ground water recharge in water stressed Arvalli hill ecosystem. *Indian J. Soil Cons.*, 44(2): 141-148.

Jat, M.L., Mahela, M.K., Dadhich, S.K., Sharma, R.K., Punam Mhetre and Dashora, R. 2016. Economic feasibility of refinement or renovation of a water harvesting structure (*Nadi*) - A success story. *Indian J. Soil Cons.*, 44(1): 87-92.

Joshi, P.K., Jha, A.K., Wani, S.P., Joshi, Laxman and Shiyani, R.L. 2005. *Meta-analysis to Assess Impact of Watershed Program and People's Participation*. Research Report 8, Comprehensive Assessment of Watershed Management in Agriculture. International Crops Research Institute for the Semi-arid Tropics and Asian Development Bank, 21p.

Kumar, S., Raizada, A. and Biswas, H. 2014. Prioritizing development planning in the Indian semi-arid Deccan using sustainable livelihood security index approach. *Intl. J. Sustain. Dev. World Ecol.*, 21(4): 332-345.

Kumar, S., Raizada, A., Biswas, H., Srinivas, S. and Mondal, B. 2016. Assessment of vulnerability to climate change: A case study of Karnataka. *Indian J. Soil Cons.*, 44(3): 314-320.

Maji, A.K., Obi Reddy, G.P. and Sarkar, Dipak. 2010. *Degraded and Wastelands of India Status and Spatial Distribution*. ICAR & NAAS, New Delhi, 167 p.

NRAA. 2012. Prioritization of Rainfed Areas in India. *Study Report 4*, NRAA, New Delhi.

Prabhavathi, M., Patil, S.L. and Raizada, A. 2013. Assessment of soil fertility status for sustainable crop production in a watershed of the semi-arid tropics in Southern India. *Indian J. Soil Cons.*, 41(2): 151-157.

Ram Babu, Dhyani, B.L., Agarwal, M.C. and Samra, J.S. 1997. *Economic Evaluation of Watershed Management Projects.* Bulletin No. T-33/D-23, CSWCRTI, Dehradun, 83 p.

Rockstrom, J. and Falkenmark, M. 2000. Semi-arid crop production from a hydrological perspective - gap between potential and actual yields. *Crit. Rev. Plant Sci.*, 19(4):319-346.

Saxena, M.M. 1990 *Environmental Analysis of Water, Soil and Air*. Agrobotanical Publication, India, pp 1-16.

Sharma, B.R., Rao, K.V., Vittal, K.P.R., Ramakrishna, Y.S. and Amarasinghe, U. 2010. Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements. *Agric. Water Manag*, 97: 23-30.

Shivamurthy, N., Eswarappa, G. and Swaroop, N.N. 2006. Impact of watershed treatment on groundwater recharge in Southern India-An analysis. In: *Proc. of the 14th International Soil Conservation Organization Conference (ISCO) - Water Management and Soil Conservation in Semi-Arid Environments*. Marrakech, Morocco.

Venkateswarlu, B. and Prasad, J.V.N.S. 2012. Carrying capacity of Indian agriculture: issues related to rainfed agriculture. *Curr. Sci.*, 1026: 882-888.

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