Rebuilding Traditional Water Harnessing Systems for Livelihood Enhancement in Western Rajasthan

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ABSTRACT

Western Rajasthan in India is characterized by very low mean annual rainfall (100-400 mm), high inter-annual variability in rainfall & stream flows, and poor quality soils & groundwater. Under such conditions, water resources are managed on sustainable basis to ensure water for crop production and domestic water security to tide over drought impacts. The Ambuja Cement Foundation (ACF) is engaged in water management activities in this region. This paper focus on the interventions carried out by ACF for rehabilitation of *khadin* (traditional run-off farming system) and *nadi* (village pond) in the districts of Pali and Nagaur. Analysis indicates that these interventions have led to enhanced water storage in the traditional water systems during normal and high rainfall years, and increased availability of good quality water for domestic needs throughout. The pronounced impacts are on rural livelihoods as evident from increased area under cultivation, and enhanced crop yield & outputs.

Key Words: Western Rajasthan, Khadin, Village Ponds

1. INTRODUCTION

Western Rajasthan is characterized by low rainfalls and high aridity (Goyal 2010). This is compounded by extremely high inter-annual variability in annual rainfalls and rainy days. The years of deficit rainfall, characterized by fewer rainy days with long dry spells, and higher aridity see hydrological droughts leading to severe shortage of water not only for irrigation, but also for basic survival needs of human and animal population. But, wet years produce excessively high runoffs often causing flash floods. Traditional runoff farming systems such as khadins play a major role in storing this excess runoff water during wet years not only on the surface but also in the soil profile to enable good production of crops in kharif and winter. Similarly the village ponds have played a crucial role in domestic water supply provisions in villages of arid western Rajasthan. But with population growth and exponential increase in water demands for irrigation and domestic uses, communities shifted their dependence on groundwater, which used to serve as a buffer in years of drought, to grow irrigated crops and supply water for livestock and human consumption. While groundwater resources started depleting due to over-draft, the management of traditional systems was largely ignored. Thus, in spite of the social and environmental benefits these traditional water bodies used to provide, many had fallen under disuse over the years in the changing social milieu, due to lack of proper maintenance, and the simultaneous advent of modern superior water supply systems which ensured high reliability and better quality. Thus, revival of these traditional village water bodies becomes utmost important.

During the last two decades, traditional water harvesting systems such as khadins and village ponds in Rajasthan had captured the imagination of ethnographers, water resource scholars, water professionals and development organizations alike, with the result that initiatives to revive them had come from many quarters, including government and development organizations. Central Arid Zone Research Institute (CAZRI), Jodhpur has played an important role in revival of many such traditional water harvesting systems across western Rajasthan. Similarly Ambuja Cement Foundation (ACF) is actively involved in such attempts through its presence in the districts of Pali and Nagaur, Western Rajasthan. While large volume of anecdotes and popular literature exists about the benefits of these traditional water bodies, there has been no systematic effort or research on the impact of these interventions based on actual field data, though several anecdotes about the positive outcomes and impacts are available. This study assesses the hydrological and socio-economic impacts of such interventions carried out by ACF in the district of Pali and Nagaur in Western Rajasthan.

2. THE PHYSICAL ENVIRONMENT OF WESTERN RAJASTHAN

Western Rajasthan is arid to semiarid. The climate is characterized with low and erratic distribution of rainfall, extremes of diurnal and annual temperatures, low humidity and high wind velocity. With average annual rainfall of only 317 mm, this region is the most arid part of the country (Goyal 2010). Owing to these extreme climatic conditions, the region experiences an average potential evapo-transpiration of more than 2000 mm per year (Rao 2009), a negative water balance and acute water deficit (Narain *et al.* 2005).

The mean annual rainfall in western Rajasthan ranges from less than 100 mm in north-west part of Jaisalmer; to 200 to 300 mm in Ganganagar, Bikaner & Barmer regions; 300 to 400 mm in Nagaur, Jodhpur, Churu & Jalore regions; and more than 400 mm in Sikar, Jhunjhunu & Pali regions. More than 85% of the total annual rainfall is received during the southwest monsoon season (July to September). There is a high inter-annual variability in rainfall as reflected in its high degree of coefficient of variation (around 45% for Pali and 54% for Nagaur). Recorded annual rainfall data (Source: Rajasthan water resources department) from Jaitaran block, district Pali (from where khadin and village pond were selected) show similar trends (Figure 1). During last 52 years, the mean annual rainfall in Jaitaran was 407.9 mm with highest annual rainfall of 872.5 mm recorded in the year 1979 and lowest of 122.7 mm recorded in the year 1972. The rainfall variability, expressed in terms of coefficient of variation, is high (44.77%). The last five years (2005-09) have been even more parched with mean annual rainfall of only 383.4 mm. There is a definite trend in annual rainfall, with 20-year cycle consisting of wet and dry years, as shown by moving averages, but the peak values are reducing over the years.

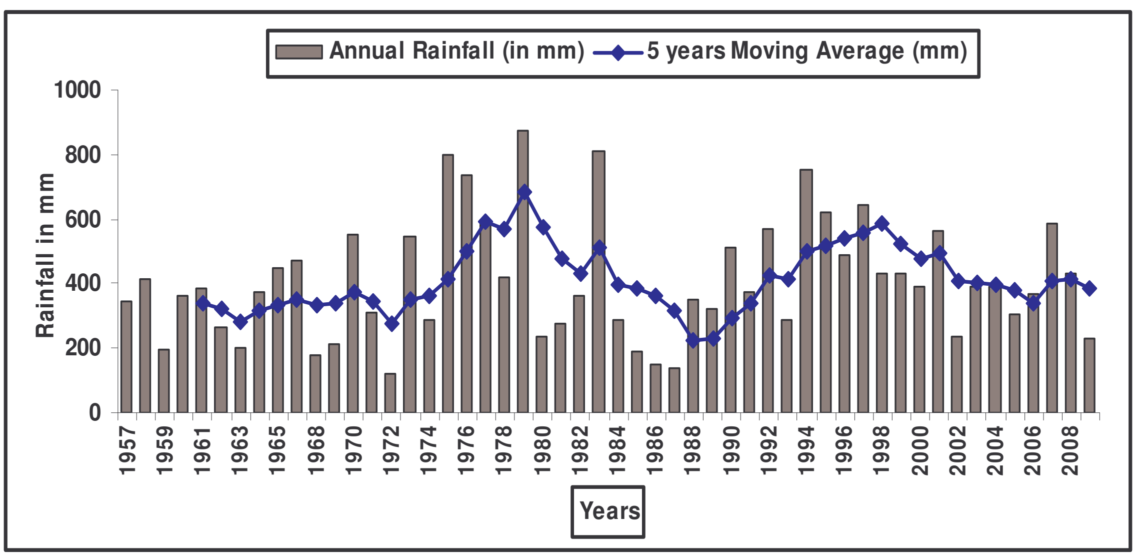

Figure 1: Annual rainfall and moving average (1957-2009), Jaitaran, Pali

Further, the years of high rainfall are also characterized by large number of rainy days. There is a strong correlation between the quantum of annual rainfall and number of rainy days in the year (Figure 2). The R square value for Jaitaran was 0.54. For Nagaur (district from where other village pond was selected), the mean annual rainfall was even low (385.67 mm based on data record of past 52 years) with highest annual rainfall of 1259 mm in the year 1975 and lowest of 110 mm in the year 2009. With coefficient of variation of 54.38%, the region too shows very high rainfall variability.

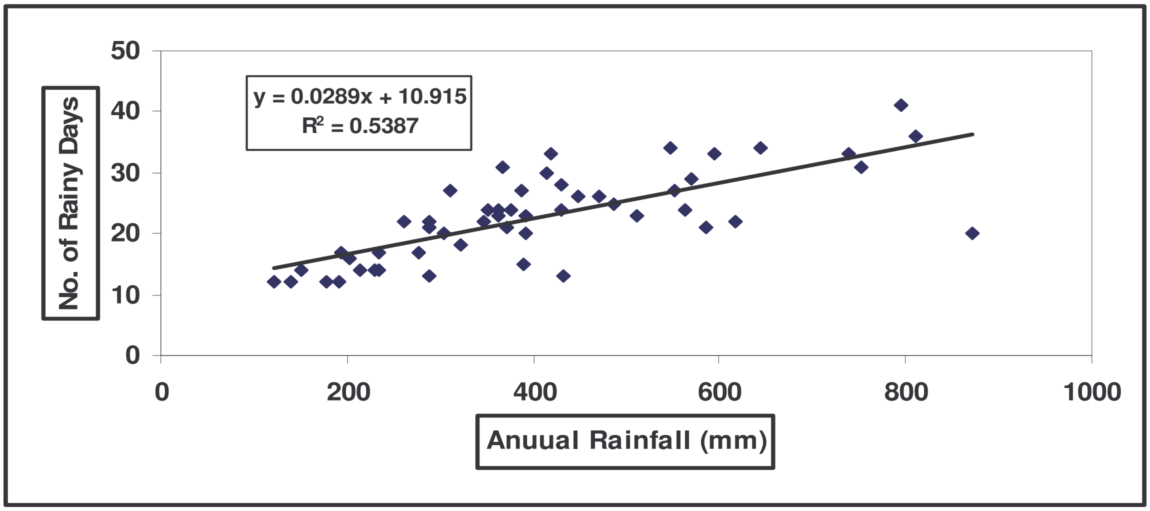

Figure 2: Relation between annual rainfall and rainy days

In western Rajasthan, solar radiation is high throughout the year. During winter, it varies between 15.12 and 17.71 MJ/m^2/day and in summer months the values range from 22.79 to 26.50 MJ/m^2/day. The region experiences extreme air and soil temperatures, which considerably increase the demand for water requirements by vegetations. Relative humidity in the region is low during summer and winter months but gradually increases to around 80% by monsoon. This low humidity combined with strong wind regime leads to evaporation loss more than the energy actually available through the solar radiation. The annual potential evapo-transpiration ranges from 1400 mm/year in the eastern part to more than 2000 mm/year in the western part of western Rajasthan (Rao 2009). Soil strata in these regions are alluvial with limestone and allied sedimentary rocks.

All three hydro-geological formations i.e. unconsolidated sediments, semi-consolidated sediments and consolidated rocks exist in western Rajasthan. Out of these, un-consolidated formations are dominant. The alluvial deposits are confined to Barmer, Jalore & Jodhpur district, and consist of sand, clay, gravel and cobbles. Semi-consolidated formations which include sandstones and limestone cover Jaisalmer and Barmer districts. In Pali region, groundwater occurs in a single and thin zone of saturation which extends through contiguous bodies of thin alluvium, and of igneous, metamorphic and consolidated sedimentary rocks. All the ground water that occurs in the rocks of this region originates from rainfall. Permeable rocks are present in the space between the land surface and the water table, making the ground water exists in a sort of a reservoir and water table to rise and fall freely as water is added to or discharged from the rocks. Thus, the water table rises during or after the heavy rainfall and fall during the dry season (Taylor *et al.* 1955).

Luni river basin covers few of the districts including Pali, Jalore, part of Jodhpur and Barmer in this western region. Remaining part of the western Rajasthan region is covered by endorheic or internal drainage basins. These are closed drainage basins that retain water and allow no outflow to other bodies of water such as rivers. Precipitation that falls on such basins leaves the drainage system either by evaporation or get lost to the salt sinks (for more details on the concept of closed basins please refer to Seckler 1996, Kumar 2010). As per the water scarcity index (Falkenmark *et al.* 1989), both Luni and internal drainage basin suffer from water scarcity (per capita water availability less than 1000 m^3/annum).

Groundwater development in western Rajasthan exhibits alarming trends. Out of the 11 districts in the region, groundwater resources are overexploited in seven, critical in two, and semi-critical in one districts. With negative groundwater balance of 1264.19 MCM and stage of groundwater development nearly 140%, the region has limited scope for further groundwater development except in few blocks. Stage of groundwater development is 200% in Jhunjhunu, 197% in Jodhpur, 181% in Jalore, 168% in Nagaur, 134% in Sikar, 114% in Pali and 104% in Barmer (CGWB 2006). In district Pali, out of 10 assessed blocks, 5 have been categorized as over-exploited and 5 as critical. Similarly in district Nagaur, out of 11 assessed blocks, 7 have been categorized as over-exploited, 2 as critical, 1 as semi-critical, and only 1 as safe. Average rate of depletion of groundwater table in the districts of Pali and Nagaur has been more than 0.4m per year. Further, increasing pollution of the water sources by the industrial units and over-abstraction of groundwater has led to water quality problems. Between 1996 and 2001, the number of villages and habitations suffering from quality problems in drinking water in arid western Rajasthan has gone up. The percentage was higher for habitations than the village settlements, as the main villages are often covered by multiple or alternate sources (Rathore 2007). In some districts including Barmer, Bikaner, Churu, Ganganagar, and Jaisalmer nearly all the habitations were affected by quality problem in drinking water.

3. SOCIO-ECONOMIC FEATURES OF THE REGION

Districts of wetsern Rajasthan cover a total area of 2.09 lac sq. km and a population of around 2.25 crore persons. Population density (no. of persons per sq. km) is highest in Jhunjhunu (323) and lowest in Jaisalmer (13) which is the western most district of region. Joshi (2007) explained that the population density in Rajasthan is directly proportional to the average annual rainfall. Thus as the rainfall decrease from east to west, the population density also depicts proportionate decease. The total area under cultivation in the region is 109.20 lac ha. highest being in Barmer (16.49 lac ha.) and lowest in Jhunjhunu (4.33 lac ha.). The per capita cultivated land is highest in Jaisalmer (0.95ha.) and lowest in Sikar (0.23 ha.). However, the highest percentage of land under cultivation with reference to total area is found in Ganganagar (71%) where there are fertile alluvial soils and availability of canal water for irrigation. The lowest percentage area under cultivation is in Jaisalmer (12%) as much of the land area here is unfit for cultivation. In absence of any perennial river system, more than 90% of the water supply schemes in the region are based on groundwater. The net annual groundwater availability in western Rajasthan is 3170.78 MCM, highest being in Nagaur (548.38) and lowest in Jaisalmer (60.09). The per capita groundwater availability is highest in Jalore (300 m3/annum) and lowest in Churu (70 m3/annum) (please refer to Table 1 for more details). The groundwater in the western region is already over-exploited and there is presence of high salinity and fluoride content, making it unfit for human consumption.

Pali district covers a total area of 12,331 sq. km with a population of around 18.2lac people, about 78.5% of which living in rural areas. There are around 936 inhabited main villages in the district; most of which are covered with drinking water facilities (Source: Census of India 2001). The district has a total cropped area of 5,829 sq. km, out of which only 1121 sq. km (19%) is irrigated (Goyal *et al.* 2009). Naguar (another district Nagaur where ACF is operating) covers a total area of 17,644 sq. km. with a population of around 27.75lac, about 83% of which resides in rural areas. There are around 1480 inhabited main villages in the district; out of which 1466 are covered with drinking water facilities (Source: Census of India 2001). The district has a total cropped area of 13,654 sq. km, out of which only 2948 sq. km (21.6%) is irrigated (Goyal *et al.* 2009). The water supply schemes in both Pali and Nagaur districts are based on groundwater. However, the ground water in these regions has excessive salinity and fluoride presence which pose a serious threat to public health. The fluoride content in the groundwater in Nagaur district ranges from 3 ppm to 16 ppm which causes skeletal and dental fluorosis on consumption. The quality problem in drinking water is more acute in the habitations of both the districts as compared to main village settlements. Further, the frequency of piped water supply is very erratic. Thus, there is a nominal dependence of village community for meeting drinking water needs from the water supply schemes. Most of the domestic water requirements are met through village ponds and others sources which include dug wells, tankers etc.

Table 1: Population, land use and groundwater availability, western Rajasthan

Districts	Total Area (sq.km)	Population (000')	Population Density (no./ sq.km)	Area under Cultivation (000' Ha.)	Per capita Cultivated Land (ha)	Net Annual Groundwater Availability (MCM)	Per capita Groundwater Availability (m3/annum)
Barmer	28387	1964.83	69	1649.22	0.84	256.45	130
Bikaner	27244	1674.27	61	1477.98	0.88	227.08	140
Churu	16830	1923.88	114	1151.22	0.60	128.98	70
Ganganagar	20634	3307.43	160	1476.32	0.45	312.52	90
Jaisalmer	38401	508.25	13	485.47	0.95	60.09	120
Jalore	10640	1448.94	136	648.62	0.48	432.33	300
Jhunjhunu	5928	1913.69	323	433.25	0.23	235.13	120
Jodhpur	22850	2886.50	126	1265.94	0.44	375.64	130
Nagaur	17718	2775.06	157	1237.48	0.44	548.38	200
Pali	12387	1820.25	147	576.22	0.32	282.16	150
Sikar	7732	2287.79	296	518.40	0.23	312.02	140
Total	**208751**	**22510.89**	**108**	**10920.14**	**0.48**	**3170.78**	**140**

(Source: Data compiled from Census of India 2001, CGWB 2006 and Joshi 2007)

The foregoing discussion regarding the physical environment and socio-economic features clearly signifies the water scarcity problem existing in western Rajasthan. While the surface water resources are extremely limited, groundwater resources are also heavily over-exploited. Even this limited availability of water resources gets further reduced during the period of drought. The negative groundwater water balance indicates the problems this water parched region will be up to in future. Under these extreme conditions, water conservation even at field or micro-level can increase water availability at the local level. This paper attempts to assess the hydrological and socio-economic impacts of such interventions carried out by Ambuja Cement Foundation (ACF) near to its location at Jaitaran (District Pali) and Marwar Mundwa (District Nagaur) Blocks.

4. OBJECTIVES AND METHODOLOGY

The main objective of this study is to evaluate the hydrological and socio-economic impacts of reviving Khadins and traditional village ponds. For the purpose, 1 khadin constructed by ACF near village *Balada* (block Jaitaran, district Pali) and two ACF rehabilitated ponds near to village *Balada* and another near to village *Marwar Mundwa* (block Mundwa, district Nagaur) were selected. To understand the impacts of these interventions, random sampling of respondents which includes farmers, well owners and household occupants was performed.

For intervention on khadin, five farmers cultivating their land inside the water spread area of khadin were surveyed. For village ponds, 30 households (HHs) dependent on rehabilitated pond near village *Balada* (called as *Balada* pond) and 20 HHs dependent on rehabilitated village pond near village *Mundwa* (called as *Lakholav* pond) were selected. Random sampling technique was followed for the selection of respondents. Structured questionnaires addressing to various interventions were prepared and administered on the selected respondents for collecting primary data. For secondary data, records from ACF officials and information from various reports were obtained & analyzed. Literature survey was performed to refer to the journal papers, scientific reports, and data reports pertaining to the interventions. Group discussions were carried out to understand the existing situation of the region and resultant impact from the various interventions. Various tools in statistics were used for the analysis of primary and secondary data.

The hydrological impacts (physical) of khadin and village ponds were analyzed by comparing the pre & post monsoon fluctuation in water levels in wells which were influenced by these interventions. The socio-economic impacts of khadin were assessed by analyzing: a) difference in input use, yield and net income from crops which are benefited by khadin and b) difference in area under crops post intervention. For village ponds, the socio-economic impacts were assessed by estimating: a) the amount of time saved in fetching potable water from other common sources; b) the amount of money saved in purchase of potable water from vendors; and c) the reduction in expenditure on medicines for mitigating the health impacts of exposure to poor quality water.

5. KHADIN INTERVENTION OF ACF

Khadin is a traditional runoff farming system which is popular in western Rajasthan (Agarwal and Narain 1997). This system has a great similarity with the irrigation methods that were practiced in the Middle East, the Negev desert and the southwestern Colarado (Baindur 2007, Prinz and Singh *n.d.*). In *khadins*, runoff from the upland surface is collected in the farmland against an earthen embankment having a masonry waste weir for outflow of runoff excess. The water-saturated *khadin* beds were then used for crop production. A rainfall of 75-100 mm is adequate to charge the *Khadin* soils with sufficient soil moisture to raise a successful local crop (Prinz and Singh *n. d.*). The soils in *Khadins* are generally fertile due to deposit of fine sediments by the runoff.

A *khadin* farm is developed on the basis of rainfall probability, available catchment area and its runoff generation potential. For efficient agriculture, a minimum of 15:1 ratio of catchment area to crop area is required (Prinz and Singh *n.d.*). Ponding of water in khadin also induces groundwater recharge (Narain *et al.* 2005). The subsurface water is extracted through bore wells developed inside the khadin or in the immediate vicinity downstream. *Khadin* of 20 ha area developed by CAZRI in Baorali-Bambore watershed has resulted in water conservation and provided an opportunity for farmers to take *Kharif* and *Rabi* crops (Goyal 2010). During the severe drought of 2002 in western Rajasthan, *khadin* farmers were able to meet domestic water needs and also grown sorghum for fodder. The average rise in the water level in shallow wells was 0.8 m in sand stone and 2.2 m in deep alluvium (Khan 1996). Till the month of November 2010, ACF has constructed nearly 8 *khadins* near to its *Rabriyawas* location and 1 khadin near to its *Marwar Mundwa* location with a total storage capacity of 2.13 million cubic metres. Recorded data from the observation wells (10 downstream and 1 upstream) under the influence zone of *Khadin* (constructed by ACF near the village *Balada*), show the average rise of 2.21 m in the water level between pre- and post-monsoon months (Figure 3).

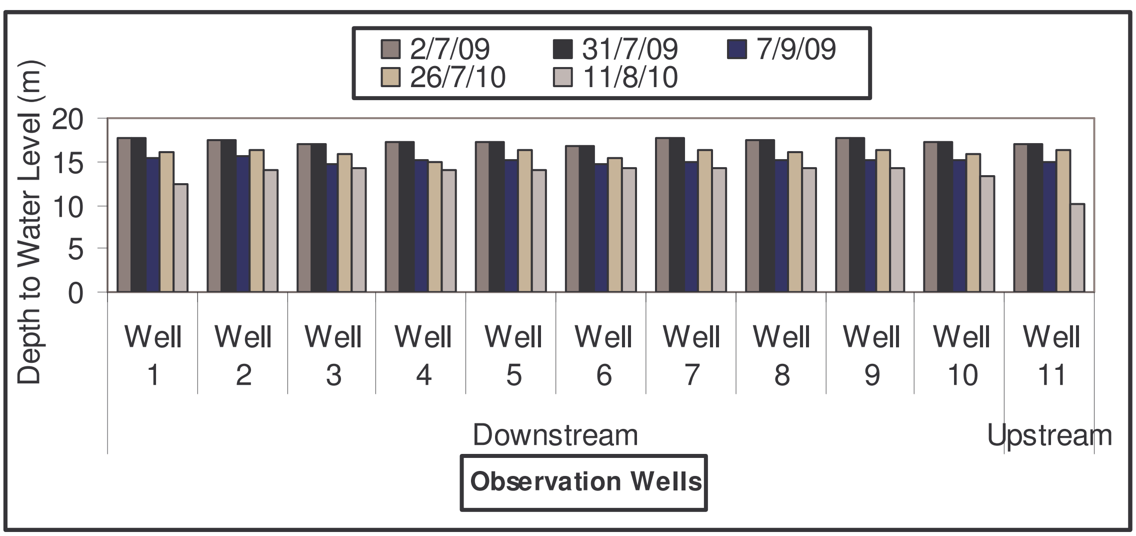

Figure 3: Rise in water level for observation wells under the influence of *Khadin*, near village *Balada*

6. ECONOMIC IMPACT OF *KHADIN*

The *Khadin* structure near village *Balada* was constructed in the year 2008 at a total cost of Rs. 3.5 lac. It basically consists of constructing an embankment with a waste weir. The structure has a total catchments area of 1700 hectares and an earthen embankment of about 1.3 km length. The intervention has led to increase in cropped area and well recharge benefits in the immediate vicinity. After the construction of *Khadin,* nearly 41 hectares of land belonging to 5 households has been brought under crop cultivation. The major crops which were taken inside the water spread area of structure include bajra, jowar and green gram. Presently no irrigated crops are taken inside the *khadin* but farmers were confident of growing crops like mustard and wheat in the coming years.

Comparison of mean yields (kg/bigha) for the crops shows that farmers were able to get 36% higher yield for jowar and 25% higher yield for green gram inside the *Khadin* in comparison to the cropped land outside the khadin. Further the mean net returns (Rs/bigha) were higher for all the three crops taken inside the *Khadin*. For bajra it was nearly 9%, for jowar it was 42% and for green gram it was 54% higher in comparison to the crops taken outside the khadin area (Table 2). The higher yields were attributed to better soil moisture regime, and better availability of micro and macro nutrients in khadin land, which is endowed with nutrient-rich silt from its catchment. The higher yield increased the gross return, while the better nutrient content in the soil reduced the expenditure on fertilizers and thus the input costs. The net result is substantial improvement in net return. Please note that the mean net incremental income figure provided in Table 3 is the difference between the mean net returns of the crops taken inside khadin over that outside the Khadin area.

Table 2: Crop economics, inside and outside water spread area of Khadin

Crops	**Bajra**		**Jowar**		**Green Gram**	
	Inside	*Outside*	*Inside*	*Outside*	*Inside*	*Outside*
Cropped Area (bigha)	145	85	90	37	20	110
Irrigated Area (bigha)	0	85	0	37	0	60
Mean Input Cost (Rs/bigha)	2260	2890	2400	2808	1950	2850
Mean Crop Yield (kg/bigha)	440	500	410	300	250	200
Mean Net Return (Rs/bigha)	7300	6710	7100	4991	8550	5550
Mean Incremental Income (Rs/bigha)	**590**		**2109**		**3000**	

(Source: authors' own analysis using primary data)

From benefit-cost point of view *Khadin* structure near village *Balada* was found to be performing fairly well. The economic evaluation of the system was carried out assuming that the farmers will continue with the same cropping pattern and it will be normal monsoon for at least five out of the 15 years of life of the system. However, the normal years are assumed to occur at after every three years. With these propositions, the B/C ratio (direct benefit cost ratio) for the Khadin (for normal wet years) was estimated by taking the incremental net benefit from crop production using khadin and the incremental cost of the system, including the capital and operating costs. The discount rate assumed for estimating the present worth of the costs and benefits was 7 per cent. The B-C ratio comes out to be 2.35 (Table 3). Important to note that although the expected active life of Khadin can be up to 15 years, the incremental income from the crops will vary significantly between the wet and dry years (when the crops yields get substantially reduced) in this water scarce region. Here, we have assumed the benefits during the dry years to be zero.

Table 3: Benefit-Cost Ratio for *Khadin*, near village Balada

Year	**Cost (Rs)**			Net Incremental Income (Rs)	Present worth of the Costs (Rs)	Present worth of Total Benefit in (Rs)
	Capital	Repair & Maintenance Cost (Rs)#	Total			
0	3,50,000	-	3,50,000	-	3,50,000	

						-
1	-	35,000	35,000	3,35,360	32710.28	313420.56
4	-	35,000	35,000	3,35,360	26701.33	255844.54
7	-	35,000	35,000	3,35,360	21796.24	208845.35
10	-	35,000	35,000	3,35,360	17792.23	170480.02
13	-	35,000	35,000	3,35,360	14523.76	139162.48
Total			**5,25,000**	**16,76,800**	**463523.00**	**1087752.95**
B/C Ratio					**2.35**	

10 per cent of the capital cost

7. POND REHABILITATION WORK OF ACF

ACF started the pond rehabilitation work near to its location at *Rabriywas* (district Pali) and *Marwar Mundwa* (district Nagaur) in the year 2006-07. The main activities under the rehabilitation work included pond deepening's and de-siltation. By the year 2010, ACF had rehabilitated 72 village ponds in district Pali and 106 village ponds (including 2 mined out areas) in district Nagaur. The maximum number of ponds was rehabilitated in the year 2008-09. These works had led to average annual increase in the storage capacity of ponds by 0.40 million cubic metres. The capacity increase per village pond (in volume) was highest in the year 2010 (Figure 4). With respect to availability of drinking water, around 79,230 people in Pali and 52,050 people in Nagaur districts were benefited. Further, a total of 1.65 lakh livestock population met their water needs in both the locations. Pond rehabilitation in district Pali had led to recharge of 551 wells, benefiting 2356 farmers. Through the recharged water, farmers were able to bring 2,820 acres of more land under cultivation. In Nagaur district where silt from the ponds was used by the farmers in their farm, soil fertility improvement was achieved for total of 290.45 acres of farm land.

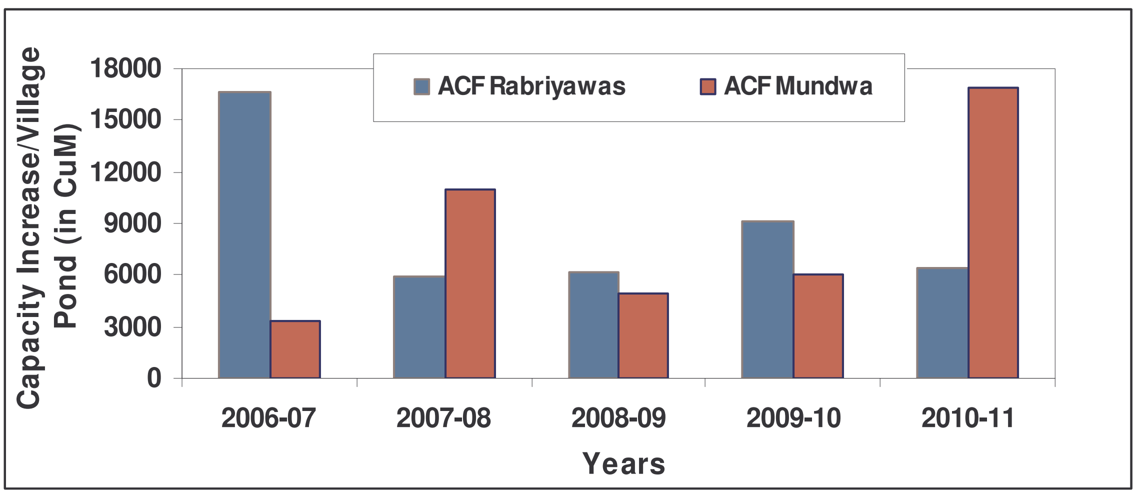

Figure 4: Capacity increase of village ponds (in volume), ACF *Rabariyawas* and *Mundwa* location

8. RESULTS OF POND REHABILITATIONS

The selected village ponds i.e. *Balada* and *Lakholav* have a total storage capacity of 0.83 million cubic metre and 0.44 million cubic metre respectively. In the years of good rainfall, both the ponds get fully filled with water. Traditionally the village ponds were used for meeting year round domestic and livestock water needs (given a normal wet year). Over the years, capacity of these village ponds decreased mainly because of poor or no maintenance and excessive siltation. The neglect of the ponds resulted in village community receiving insufficient quantities of water from the ponds and no water during the peak summer months.

ACF started the rehabilitation work on the ponds in the year 2006-07. Till 2010, *Balada* village pond was deepened and desilted 5 times and *Lakholav* village pond was deepened and desilted 4 times. Cost of rehabilitation was shared between the ACF and the village community. This was necessarily done in order to get greater participation and make village community responsible for the tank rehabilitation program. Total cost of rehabilitation on *Balada* was estimated to be Rs. 22,84,800/- (59.5% contributed by villagers) and on *Lakholav* was Rs. 5,80,000/- (62.5% contributed by villagers). Unit cost of pond rehabilitations comes out to be Rs 42/cu.m of additional storage created. This cost was shared by ACF and village community in 17:25 ratio. Contribution from village community was mainly for performing labor work and removal of silt from the ponds.

8.1. Ponds Status after Rehabilitation

As a result of the rehabilitation effort, the average annual increase in storage capacity of *Balada* pond was 10,880 cubic metre and that of *Lakholav* pond was 3,626 cubic metre. After rehabilitation, the ponds are able to meet water needs of 11,500 people and 4,900 livestock population. Benefit was more in the case of *Lakholav* pond as this is the only source available to the village habitations of *Marwar Mundwa* for meeting their drinking water demand. Other sources in the village which are mostly groundwater based, have high fluoride content, thus making them unfit for human consumption.

Pre-rehabilitation, water from *Balada* pond was available only between the months of June and March. But after the rehabilitation works, there was a year round availability of good quality drinking water. During the field visits, it was observed that the villagers were able to get water from the pond and from the wells recharged from the pond even during the month of May. Similarly year round availability of good quality water was noticed in *Lakholav* pond. These results were further confirmed by the 96% of the respondents from *Balada* and 90% of the respondents from *Marwar Mundwa* (for the *Lakholav* pond)

8.2. Hydrological and other Physical Impacts of Village Ponds Rehabilitation

Rehabilitated *Balada* pond led to recharge of 27 wells in the surrounding area, benefiting 108 farmers. Through the recharged water, farmers were able to bring 120 acres of more land under cultivation. Recorded data from the 14 observation wells which were recharged by *Balada* pond, show an average rise of 1.52 m and 1.06 m in the water level between pre- and post-monsoon months of the year 2009 and 2010 respectively (Figure 5).

In the year 2009, the maximum rise in water level was observed in well no. 1 (2.74 m) and minimum in well no.14 (0.3 m). Whereas in the year 2010, the maximum rise in water level was observed in well no. 4 (1.9 m) and minimum in well no.12 (0.2 m). In case of rehabilitation of *Lakholav* pond where silt from the pond was used by the farmers in their farm, soil fertility improvement was achieved for total of 2.3 acres of farm land.

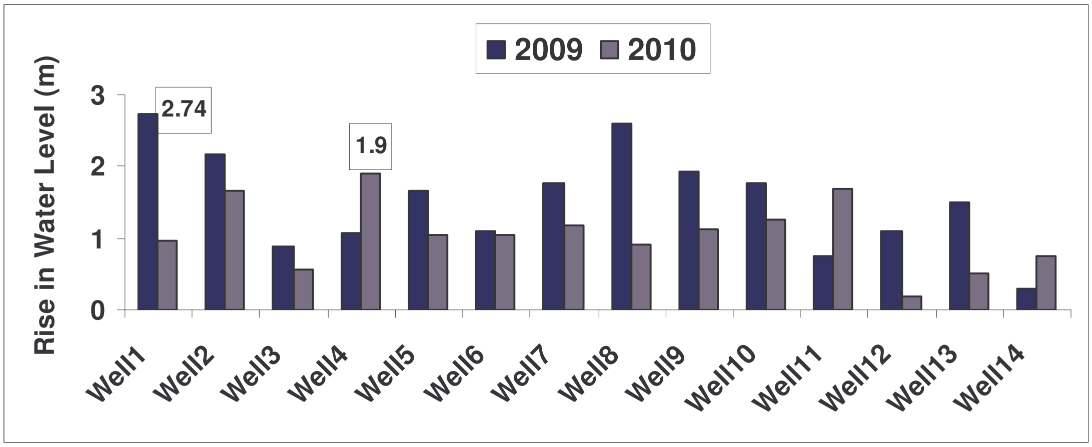

Figure 5: Rise in water level for observation wells recharged through *Balada* pond

8.3. Changes in Water Source and Water Use

Comparison of water usage from different sources pre and post rehabilitation shows that there was a shift in the preference of source vis-à-vis water for various uses. In pond location near to village *Balada*, it was observed that the number of households' dependent on village pond to meet their drinking water needs increased from 17 to 22 (29% increase) post rehabilitation. Whereas number of households' depended on piped water supply had gone down from 3 to 1 (66% decrease) and those dependent on tanker water had decreased from 7 to 3 (57% decrease). Also, the number of households' collecting pond water for livestock purpose had increased from 10 to 12 (20% increase) post pond rehabilitation. However, no major change in source was observed vis-à-vis the source of water for washing, sanitation, floor cleaning and other uses. There was a shift in the water source especially for drinking purpose towards rehabilitated pond as other source of water supplies were highly contaminated. Moreover only 40% of the household had access to piped water supply, receiving water only once in every five days. No major change in water use for different activities was noticed but certainly the number of months for which the water is available from the ponds and from the wells recharged through ponds had increased (Figure 6).

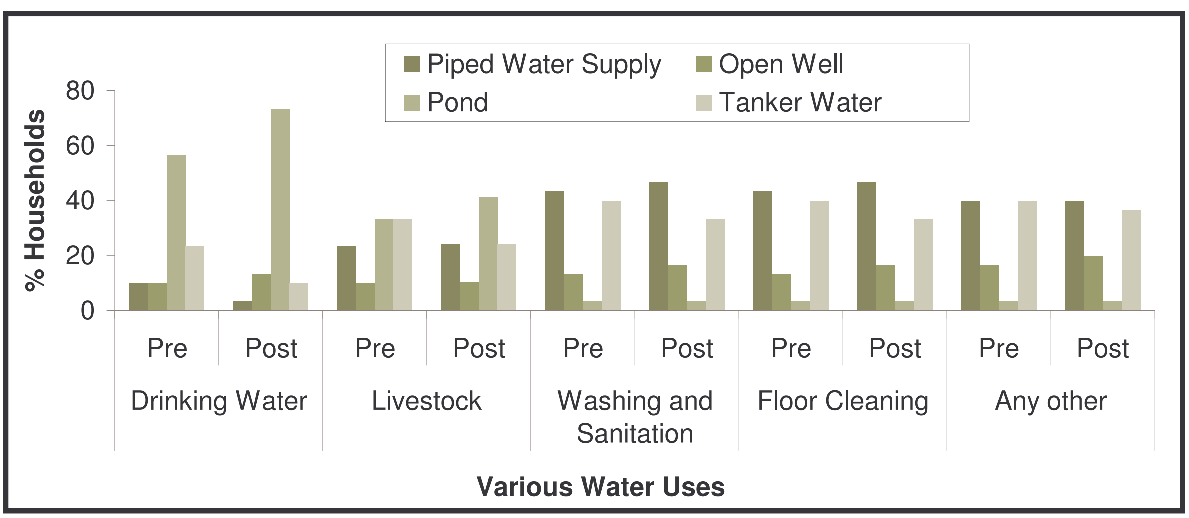

Figure 6: Change in water source for households located near *Balada* pond

In pond location near to village *Marwar Mundwa*, no major changes in sources of water were observed. In the village, around 90% of the households in village habitation were totally dependent on pond for all their water requirements as there is a presence of high fluoride in other sources of water supply. Piped water supply is highly unreliable, supplying water for about half an hour every alternate day. Villagers did perceive that rehabilitation work has increased the storage capacity of the pond and has also led to improvement in the quality of available water, as indicated by the response of all the sample households.

Overall, significant change in water use was noticed post rehabilitation (Table 4), in volumetric terms. The total water use per household had increased by 18%, maximum increase in water use was found in the case of drinking and cooking purpose (33%) followed by livestock (21%) and other uses (11%) which include washing, bathing and cleaning uses. These results clearly show the positive impact of pond rehabilitation on quality and quantity of available water for domestic purpose, which had improved domestic water security and quality of life of people.

Table 4: Water use pattern for household located near *Lakholav* pond

Uses	Water Use (Litres/Household/Day)	
	Pre Rehabilitation	*Post Rehabilitation*
For Drinking and Cooking	66.25	88.25
For Livestock	130.26	157.89
For other Uses: Cloth washing, Bathing, Toilet Use, Floor and Utensil Cleaning	205.42	227.63
Total Water Use	**401.93**	**473.78**

8.4. Impact on Expenditure on Water Purchase and Water Related Diseases

Pond rehabilitation had a strong impact on the household expenditure on water purchase and treatment of water-related diseases. For the village families located near the pond *Balada*, the annual expenditure per household on purchasing good quality water had reduced by around 14% post rehabilitation. This reduction was 67% for the households located near the pond *Lakholav*. Further, the annual expenditure on health had reduced by 22% post *Balada* pond rehabilitation and 47% post *Lakholav* pond rehabilitation (Table 5). Prior to ponds rehabilitation, major portion of health expenditure was on treatment of skeletal and dental fluorosis which were caused by the consumption of water having high fluoride content. However post rehabilitation, lower incidence of water related diseases was reported by around 86% of the households dependent on pond *Balada* and 100% of the households dependent on pond *Lakholav*. These outcomes were attributed by the villagers to the availability of good quality water in larger quantities from the ponds after their rehabilitations.

Table 5: Expenditure pattern pre and post pond rehabilitation

	Balada Pond, Balada		**Lakholav Pond, Marwar Mundwa**	
	Pre Rehabilitation	*Post Rehabilitation*	*Pre Rehabilitation*	*Post Rehabilitation*
Annual expenditure on water purchase/ HH (Rs)	2338.18	2014.29	1500	500
Annual expenditure on Health/ HH (Rs)	9158	7158	7500	4000
Total Saving/HH (Rs)	**2323.90**		**4500**	

8.5. Impact on Time Spent in Water Collection

Pond rehabilitation work had actually helped the village community to drastically reduce the time spent on water collection. The households were able to save, on an average, 3.4 hours per day post

Balada pond rehabilitation and 3.10 hours per day post Lakholav pond rehabilitation. The maximum reported time saving was 5 hours and minimum was 2 hours per day. Similar trend was seen in the case of RHWS in coastal Saurashtra, where the time saving for water collection was in the range of 1-7 hours. It should be inferred that the time saving has essentially come from reducing the distance traveled for fetching water from the piped water supply schemes, and saving in the waiting time for water to be collected. Mostly it is the women member of the households who go to fetch water from the village delivery point of the pipeline scheme. The time saving has actually increased the ability of parents to send the children school on time. This change was perceived by all the respondent households located near rehabilitated *Balada* and *Lakholav* ponds.

8.6. Impact on Wage Employment

The pond rehabilitation had brought about significant changes in the household wage employment pattern. Post *Balada* pond rehabilitation, the benefited households were able to find more time for doing various socio-economic production functions. Out of the 30 surveyed households, 24 (80%) indicated increased time availability to work in their own farms, 27 (90%) were able to give more time for household work and 10 (33.33%) were able to find new wage labour opportunities. Similarly post *Lakholav* pond rehabilitation, out of the 20 surveyed households, 13 (65%) indicated increased time availability to work in their own farms, 20 (100%) were able to give more time for household work and 15 (75%) were able to find new wage labour opportunities. Table 6 presents the season-wise data vis-à-vis increased time available with the benefited households for undertaking various works. Increased availability of time to spend in the farm is expected to result in increased agricultural productivity. Whereas, increased time ability to work as wage labourers would lead to more income gains for the family.

Table 6: Season-wise increased time availability with the benefited households for undertaking various works

Type of Work	Village Balada- Mean Increased Time availability (hrs/ benefited HH/ Day)			Village Marwar Mundwa-Mean Increased Time availability (hrs/ benefited HH/Day)		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
For work on Own Farm	1.67	1.71	1.67	1.46	1.46	1.46
For general HH work	1.30	1.33	1.35	1.20	1.20	1.20
For Wage Labour	1.50	1.50	1.50	1.35	1.35	1.35

8.7. Emergence of Water Sellers

Post *Balada* pond rehabilitation, a few households in the neighborhood had even started selling water to other villages that are facing water shortage. These are the households which are located very near to the pond and have wells which get recharged from the pond. One such household was found to be selling 15-20 tankers of water per day during peak summer months. The household has around 6 wells in the vicinity of the pond and sell water for total of around 100 days in a year. Each tanker contains 5,000 litres of water and was sold at the rate of Rs. 100/tanker. There is a need to carefully monitor this progress as this may lead to inequity in water availability for the households within the village.

9. MAJOR FINDINGS OF THE RESERACH

Some of the important findings of this research study are:

i. Wells under the influence zone of khadins and ponds were able to get the recharge benefits, indicated by higher rise in water levels after monsoon.

ii. The irrigated area expansion was quite remarkable for khadin. Post intervention, greater proportion of the land was allocated to irrigated winter crops such as wheat, mustard and isabgol.

iii. There has been a substantial increase in the crop yield (kg/acre) and net income returns per unit of land (Rs/acre) post water interventions such as khadins. Also the income returns (net) were better for the farmers located inside than those located outside the influence zone of khadins.

iv. The benefit-cost ratio for one of the khadins built in the project area was estimated to be 2.35. This considered the incremental economic benefits from increased crop production in the khadin area during kharif alone, against the incremental capital and operating costs due to khadins. Further, it was assumed that the khadins would yield benefits only during wet years, which were assumed to be only five out of the total assumed life of 15 years for the khadin.

v. Pre rehabilitation, water from ponds was available only for 8 months from July-March. Also, the available water was not of good quality. But after rehabilitation, there was a year round availability of good quality water (provided a normal or wet year) for the household in the village habitations. The benefits were more significant for the habitations located near *Lakholav* pond as it is the only water source available to them to meet their domestic and livestock water demand. Currently, water needs of 11,500 people and 4,900 livestock population are met from these two ponds.

vi. Unit cost of pond rehabilitations is estimated to be Rs 42/cu.m of additional storage created. Greater contribution from village community made sure their participation and accountability in pond rehabilitation works.

vii. Groundwater recharge benefit of rehabilitation of Balada pond was remarkable. Around 27 wells got recharged, benefiting 108 farmers who were able to bring 120 acres of more land under cultivation. Recorded data from the 14 observation wells in the vicinity of *Balada* pond show an average rise of 1.52 m and 1.06 m in the water level between pre- and post-monsoon months of the year 2009 and 2010, respectively.

viii. Soil fertility improvement was achieved for total of 2.3 acres of farm land by using excess silt from the *Lakholav* pond.

ix. With the rehabilitation of ponds, the dependence of the households for piped water scheme and tanker water in the village for meeting their drinking and cooking needs had drastically come down. In village *Balada*, it was observed that the number of households dependent on village pond to meet their drinking water needs increased by 29% post pond rehabilitation. Whereas number of households dependent on piped water supply and tanker water had decreased by 66% and 57% respectively.

x. The water use at the household level for domestic and livestock purposes had increased in volumetric terms, after rehabilitation. In village Marwar Mundwa, the total water use per household had increased by 18%. Maximum increase was found for drinking and cooking use (33%) followed by livestock (21%) and other uses (11%) which include washing, bathing and cleaning.

xi. The quality of water collected in the rehabilitated ponds was perceived to be good physically, chemically and biologically. Water quality improvement resulted in major reduction in average annual expenditure on purchase of good quality water and on health, and lower incidence of water related health problems. For instance, in village Balada, the average annual expenditure on purchase of good quality water and health reduced by around 14% and 22%, respectively post rehabilitation. Similarly in *Marwar Mundwa*, the average annual expenditure on purchase of good quality water and health reduced by around 67% and 47%, respectively, post rehabilitation.

xii. After rehabilitation, the households could reduce the time spent on water collection significantly; up to a minimum of 2 hours and a maximum of 5 hours in a day. The immediate outcome was that the adult members of some of the families were able to take up additional wage employment, while members of majority of the families were able to find more time to do their farming operations. This would have a significant impact on family income. Besides these socio-economic benefits, the parents were able to send children to school on time.

10. CONCLUSION

Traditional water harvesting interventions undertaken by ACF in the arid western Rajasthan has resulted in beneficial impact on the regions groundwater balance, improvement of farmers' livelihood and domestic water security. The *Khadins* have great impacts on the agricultural production during wet years as experienced by the farmers. They were able to bring more land under crop cultivation and received higher net returns. Farmers were also planning to take winter crops using the residual moisture present in the Khadin bed. On the other hand, Pond rehabilitation had improved domestic water security for the community in both the study villages. The design of the rehabilitation programme was such that it made village community responsible right at the initiation phase of the work. Not only were the impacts visible at the level of household in terms of water security, but also on the local groundwater regime and farm economy. With recharge of wells by rehabilitated ponds, village community was able to get drinking water even during the summer months.

Improvements at the household water security level is manifested by a sharp fall in the number of households depending on the long distance pipeline schemes and tanker water after the pond rehabilitation, and increase in volumetric water use for domestic purpose. At the next level, with significant reduction in the amount of time spent in water collection by the households, the families were able to send their children to school on time. Also, with increased availability of time, the family members were also able to allocate more time for their farming operations. Additionally, with consumption of good quality water from the ponds, household expenditure on purchase of good quality water and medical expenditure reduced remarkably.

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