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Groundwater Management an Important Driver for Sustainable Development and Management of Watersheds in Dryland Areas

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Abstract

Globally, rain-fed agriculture is playing and will continue to play an important role for food security and sustainable development (Wani et al 2008, Rockström et al 2007) The Comprehensive Assessment of Water Management in Agriculture for Food and Health has discarded the artificial divide between the irrigated and rain-fed agriculture as none of these systems exist in isolation but are in a continuum from rainfed – rainfed with supplemental irrigation to fully irrigated systems (Molden et al. 2007). Depleting groundwater is a serious problem throughout Asia and more so in India as more than 22 million wells are operational in India supporting the economy

Integrated watershed management is the strategy adopted in the country for sustainable development of dryland areas. In most of the developed watersheds, with concerted efforts to conserve and harvest rainwater, groundwater availability is improved not only in the watershed but downstream areas also benefited with increased groundwater recharge (Wani et al. 2003, Sreedevi etal. 2006, Pathak et al. 2007). Along with the increased groundwater availability concomitantly private investments also substantially increased in the developed watersheds resulting in increased incomes as well as improved livelihoods (Sreedevi et al 2006, 2008 and Pathak et al 2007). Increased water availability also impacted positively for improving welfare for the women, reduced drudgery, and protected the environment. In few well-managed watersheds productivity per unit of land and water increased substantially (Wani et al. 2003). However, in many watersheds although production increased, productivity per unit of land and water was not much increased (Sreedevi et al. 2006). There is an urgent need to increase adoption of enhanced water use efficiency measures along with integrated management of water resources in the several watersheds for sustaining the development measures There are number of examples where with watershed development due to overexploitation of groundwater by the community groundwater level depleted further than before the watershed development. Increased numbers of wells (open and bore wells) along with increased number of pumping hours pose a serous threat for sustaining the development in the watersheds. The results from the watershed case studies from Andhra Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and Gujarat are used to derive the conclusions.

In the various watersheds of India like Lalatora, in Madhya Pradesh treated area registered a groundwater level rise by 7.3 m. At Bundi, in Rajasthan the average rise was at 5.7 m and the irrigated area increased from 207 ha to 343 ha. In Kothapally watershed, the groundwater level rise was at 4.2 m in open wells. In Rajasamadhiyala watershed number of open wells increased from 255 in 1995, with very poor yield with an average water column of 5.9 m to 308 wells with mean water column of 10.4 m. Overall there has been an increase of 4.4 m of water column in 2004, as compared to that of 1995. The average pumping duration of 5.25 hours per day in 1995 has increased to 10.4 hours per day in 2004 resulting in increased irrigated area by 58 per cent. Similarly, number of bore wells also increased from 102 to 200 during the period. Doubling of the number of the bore wells in the watershed is a cause of concern as in spite of farmers' experience of defunct bore wells in 1995 and earlier they have again drilled more bore wells than open wells. The marginal positive groundwater balance in lean and average rainfall years could tilt to negative side very soon if the farmers continued drilling bore wells and pumping at the rate they have done from 1995 to 1999. Although, villagers acted collectively for water harvesting there is no concern or awareness amongst the villagers for sustainable use of groundwater. There is a need of community monitoring of groundwater and its allocation to individuals. There is an urgent need to bring in the change in the attitude of all the stakeholders where most solutions for water management are thought from increasing water availability and not from demand management. Increased rainwater and groundwater use efficiency could maintain the incomes as well as sustain the development, however, groundwater management will need community participation, social and institutional mechanisms along with the enabling policy mechanisms through suitable incentive as well as punitive measures with legal support and execution. Results from on-farm community watersheds through groundwater management as important drivers for sustainable management of watersheds dryland areas are discussed in this paper.

Introduction

Groundwater, which is 38.5 % of the available water sources of the country, plays a major role in irrigation, rural and urban drinking water supply and industrial development. Groundwater meets nearly 55% irrigation, 85% of rural and 50% of urban and industrial needs (Government of India, 2007). The use of groundwater in agriculture sector has expanded rapidly because of the short gestation lags with which can be developed, control over irrigation that it provides, free or subsidized availability of power in some states, water requirements for the crop production during critical growth stages caused due to erratic rainfall in dryland agriculture and paucity of surface irrigation.

The average annual rainfall in the country is 1170 mm, which correspond to annual precipitation of 4000 billion cubic meters (BCM). Out of this volume of precipitation, 1869 BCM appears as average annual flow in rivers. Due to various constraints only 1123 BCM is assessed as the average annual utilizable water (690 BCM from surface water and 433 BCM from groundwater). The present total water use is 643 BCM of which 83% is for irrigation. This is projected to grow to 813 BCM by 2010, 1093 BCM by 2025 and 1447 BCM 2050, against utilizable quantum of 1123 BCM. As regards use, the extent of extraction has increased significantly over the years due to steep increase in the number of wells (tube and open wells). The average rate of increase in number of wells per year in India was 2.3%. The number of Tube and open wells increased at the rate of 6.3% and 2.4% per year respectively. It is estimated that there are currently 19 million wells in the country, out of which 16 million wells are in use and drawing about 213 BCM of water (Government of India, 2007).

According to the report on 3rd Census of Minor Irrigation schemes (2005), the ultimate irrigation potential from groundwater source is 64.05 million ha, as compared to 46 million ha of land currently under groundwater irrigation. The report has however, revealed further scope for developing groundwater in some area (such as the eastern and north-eastern part of the country), but in many states, the irrigation potential created has exceeded the ultimate potential, showing that mining of groundwater, that is exploitation beyond the present level of dynamic resource (Table 1). The over-exploitation of groundwater in ten years from 1995 and 2004 increased by more than 4.5 times making groundwater use a matter of serious concern. The over-exploitation of groundwater in six states (Gujarat, Haryana, Punjab, Rajasthan and Tamil Nadu) is 54% against national average of 28%.

The prime cause of over-exploitation of groundwater is the rising demand from agriculture and rapid growth in urbanization and industrialization. In many groundwater irrigated areas, decisions on cropping pattern and cropping intensity are being taken largely independent of the ease of groundwater availability. Thus water intensive crops have tended to be grown in the face of scarcity of water. Such distortions occur partly due to the legal/regulatory regime governing groundwater (Aithal, 2007). In many states, groundwater extraction has exceeded annual recharge and water tables have gone down (Batchelor et al. 2000). Since groundwater is an open access resource, tragedy of commons occurs where everyone tries to extract as much as possible leading to sharp degradation of resource. There is an obvious urgency about managing groundwater in a sustainable way, which is an important driver for the sustainable development and management of productivity in dryland areas (Wani et al. 2005).

Over-exploitation of groundwater leads to: reduction in water yield in well, increase in pumping depth and cost of pumping, contamination of groundwater due to geogenic factors resulting in increasing levels of fluoride, arsenic, iron and most importantly failure of wells causing heavy economic lossess for the farmers. The groundwater management rather

Table 1. Groundwater exploitation status in India (1995 and 2004)

Total number of assessment units (Blocks/Mandals/Taluks/ Watersheds)	Year	Over-exploited	
		(No.)	(%)
7063	1995	428	6
5723	2004	1615	28

(Source: Ministry of Water Resources, 2005) than development is the major challenge facing water resources, particularly in dryland areas. Therefore, focus on development activities must be balanced by integrated management mechanism to achieve a sustainable utilization of groundwater resources, which is an important driver for sustainable development and management of watersheds in dryland areas.

IWM approach for groundwater management

Rainwater is the main source of water for agriculture but its current use efficiency for crop production ranges only between 30-45 %. Integrated Watershed Management (IWM) is the strategy adopted to enhance the water use efficiency for sustainable development of dryland areas. IWM clearly demonstrated that dryland areas with good soils could support double cropping while surplus rainwater could recharge groundwater. In IWM the emphasis is on in-situ conservation of rainwater at farm level with excess water taken out from the fields safely through community drainage channels and stored in suitable low-cost water harvesting structures (WHS). The stored water is used as surface irrigation or for recharging groundwater. Main components of IWM in addition to rainwater conservation and harvesting are: adoption of appropriate crops, improved crop varieties, cropping systems, and nutrient and pest management for increased productivity and water use efficiency (Wani et al. 2005).

Long-term on-station research at ICRISAT demonstrated that Vertisols with a rainfall of 800 mm y^{-1} have the capacity to feed 21 persons per ha (producing food grains 5.1 t ha^{-1}) compared with current productivity of 1.1 t ha^{-1} supporting 4-6 persons per ha y^{-1}. This increased productivity is achieved with two folds increased rainwater use efficiency from 30% to 67%, reduced soil loss by 75%, and reduced runoff loss by 66% as compared to the traditional system of cultivation.

At landscape level on community watershed management is used as growth engine for sustainable development in dryland regions of Asia through management of rainwater efficiently for enhanced crop productivity on sustainable basis through an innovative participatory IWM approach involving consortium and convergence of several institutions were implemented (Wani et al. 2003, 2007 and 2008a). This approach has substantially improved productivity (up to 250 %) and groundwater levels, while controlling / minimizing the degradation of natural resources. The research and development interventions are conducted at benchmark sites in several states/provinces in India, Thailand, Vietnam and China, Representing different semi arid tropical agroecoregions. The consortium strategy brings togetherinstitutions from the scientific, non-government, government and farmers group for knowledge management. Convergence allows integration and negotiation of ideas among actors. Cooperation enjoins all stakeholders to harness the power of collective action. Capacity building engages in empowerment of the communities for sustainability (Wani et al. 2005 and 2006). This approach has vastly improved the livelihoods of 250,000 poor people in watersheds of 368 villages across Asia.

Improving the availability of water (surface and groundwater) attributed to efficient management of rainwater and in-situ conservation (watershed-based efficient land management system, viz. contour cultivation, conservation furrows, broadbed and furrow system etc.) and establishing water harvesting and recharging structures especially low-cost structures (viz. percolation tanks, sunken pits, check dams, gabions and gully plugs etc.) through out the toposequence improved groundwater levels benefiting more number of small farmers (Fig. 1 and 2). *In-situ* water conservation measures were greatly helpful in reducing the pressure on groundwater extraction for crops by improving moisture regime in soils.

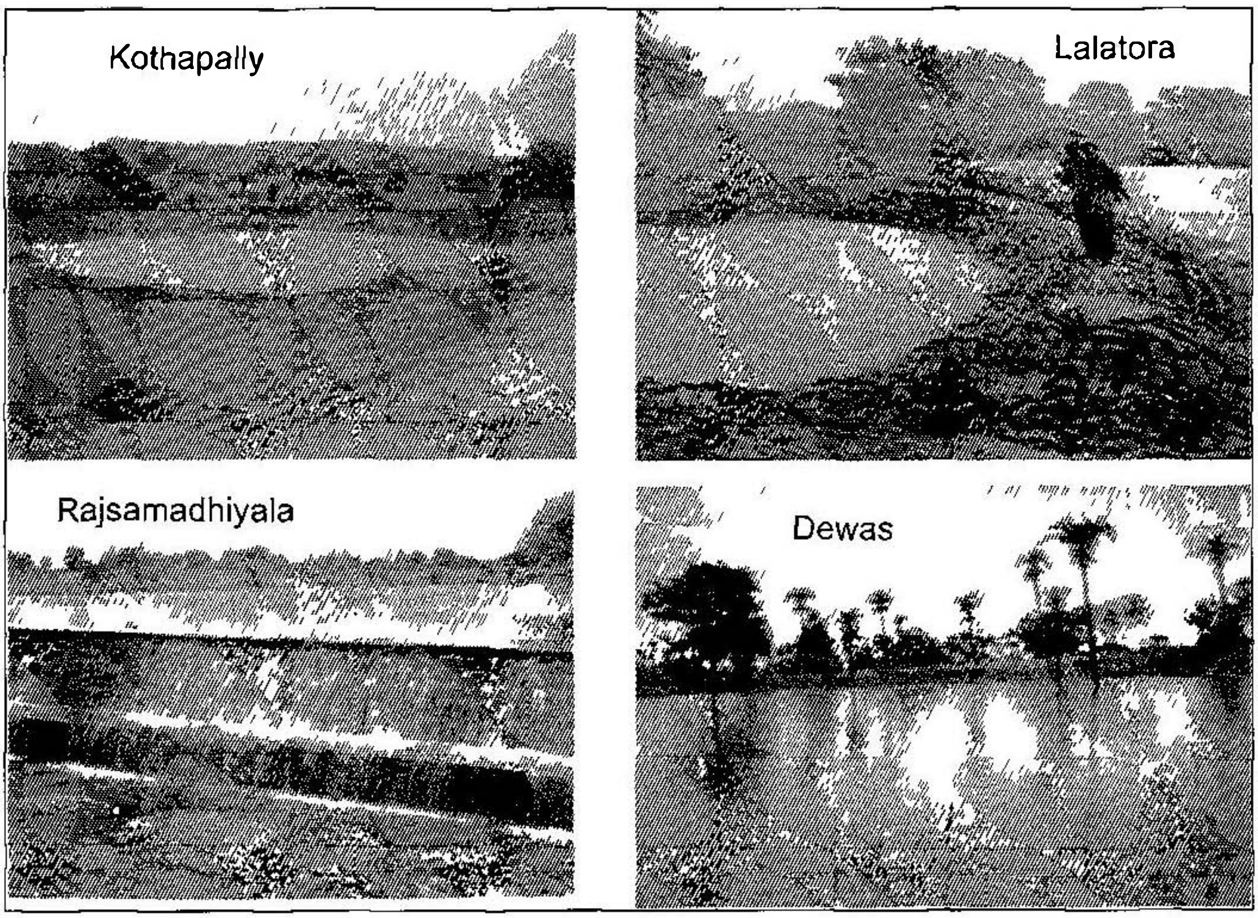

Fig. 1 Runoff harvesting structures constructed in community watersheds inIndia

In the various watersheds in India such as Adarsha watershed in Kothapally, Andhra Pradesh, Bundi watershed in Rajasthan, Laltora, Dewas and Madhusudhangadh watersheds in Madhya Pradesh, even after rainy season, the water levels in wells nearer to WHS sustained good groundwater yield (increase in quantity and duration) compared to those wells away from WHS (Fig. 3). Lalatora watershed in Madhya Pradesh groundwater

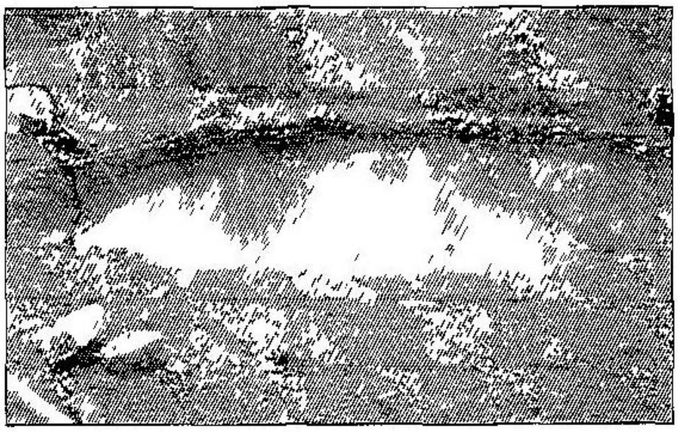

Fig. 2 A recharged open well with pump for irrigation at Shekta watershed, Maharashtra.

level in treated area registered an average rise by 7.3 m, at Bundi watershed in Rajasthan 5.7 m increase was observed and at Adarsha watershed, Kothapally in Andhra Pradesh 4.2 m rise was recorded (Wani et al., 2003). The total recharge taking place through natural and water harvesting interventions is greatly affected by amount of rainfall, its intensity, duration of monsoon, ground and sub-surface characteristic (i.e. percolation rate and runoff coefficient). The various WHS resulted in the average contribution of seasonal rainfall during normal rainfall year to groundwater was estimated ranged 27-34%. (e.g. Adarsha watershed, Kothapally, AP was 27%, Lalatora watershed was 29% and Rajsamadhiayala watershed, Gujarat was 34%) (Pathak et al. 2002 and Sreedevi et al. 2006).

The detailed study of groundwater scenario in Rajsamadhiayala watershed, Gujarat during pre- and post-watershed interventions revealed that the mean total groundwater recharge has increased by three folds in different rainfall situations and the water requirement has doubled after the watershed interventions due to increased cropped area, cropping intensity and change in cropping pattern (Sreedevi et al. 2006). The water requirement in Rajasamadhiyala has doubled after the watershed interventions due to increased cropping intensity and change in cropping pattern (Table 2). There were as many as 255 open wells existed in 1995 with very less yield with an average water column of 5.9 m in 1995, but after 10 years (2004) there are 308 wells with mean water column of 10.4 m (Fig.4). The average depth of wells in the watershed is 18 m. The increase in water column during kharif was 6.6 m, rabi was 5.3 m, and in summer was 1.3 m. Over all there was an increase of 4.4 m of water column in 2004 compared to that of 1995. This had a direct impact on production and income, which have increased considerably. But productivity data suggests that there is still good scope to increase productivity per unit of water used by implementing appropriate water use efficiency measures.

Not only increase in water column is observed, significant improvement in water yield in wells were also reported as evident by the duration of pumping hours per day for irrigation. The average pumping duration of 5.25 hours per day in 1995 has increased to 10.4 hours per day in 2004, which means that there is a net increase of 5.2 hours per day of pumping (Sreedevi et al, 2006).

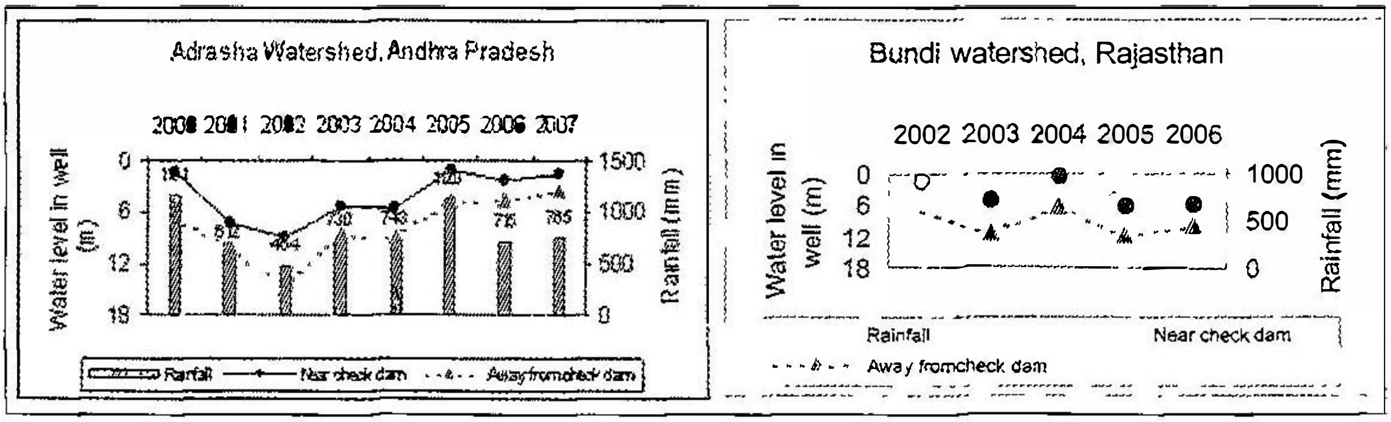

Fig. 3 Mean annual groundwater levels in wells as influenced by the WHS at Kothapally and Bundi watersheds, India.

Table 2. Pre- and Post-interventions scenario of total water requirement for crop irrigation and total groundwater recharge for good, average and lean rainfall years in Rajasamadhiyala watershed, Gujarat

Rainfall year	Pre-intervention groundwater (GW) scenario (in MCM)			Post-intervention groundwater (GW) scenario (in MCM)		
	Total GW recharge	Total water requirement for irrigation	Net ground water balance	Total GW recharge	Total water requirement for irrigation	Net ground water balance
Good	1.40	1 08	0.32	4.03	2.31	1.69
Average	1.00	0.86	0.14	3.13	1.8	1.33
Lean	0.41	0.42	-0.01	1.07	0.95	0 12

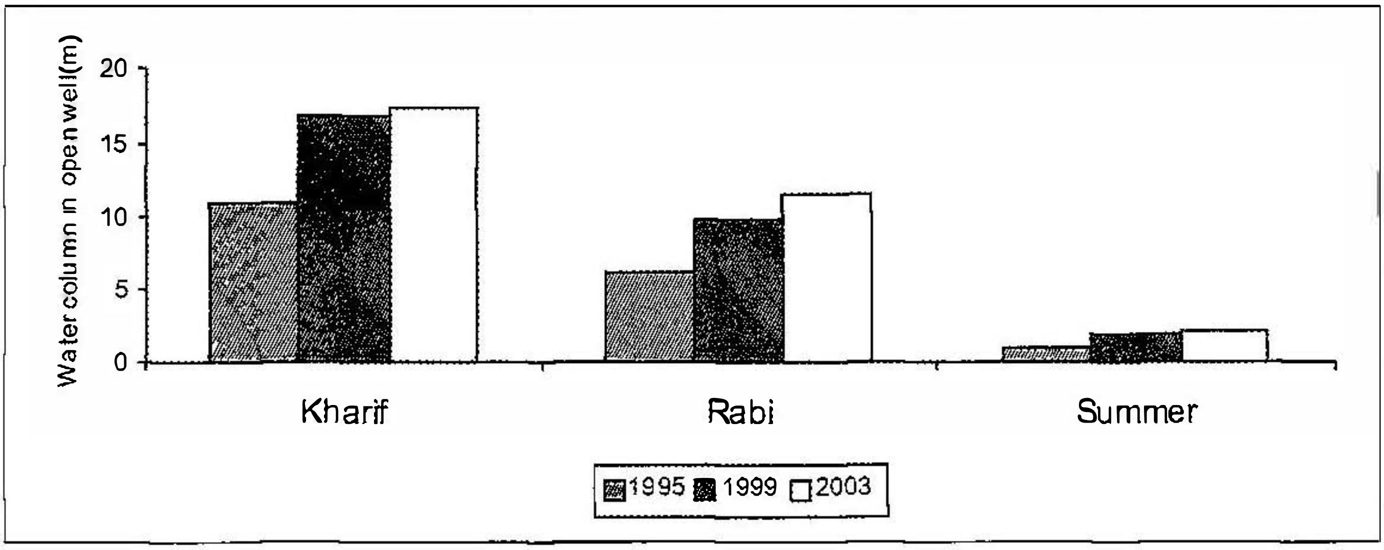

Fig. 4 Average water column in open wells in Rajasamadhiyala Watershed, Gujarat, India

Similarly in Bundi watershed, Rajasthan, watershed interventions have resulted in significant improvement in groundwater both in terms of duration of water available and the water yield from the wells. Before watershed interventions, only 88 wells use to have water for 8 to 12 months in a year where as after the watershed interventions it increased to 187 (Fig. 5). Before watershed interventions, 52 wells out of 227 were functional only for 1-4 months mainly during rainy season, where as after the watershed interventions particularly due to the construction of WHS, majority of the seasonally functional wells have become functional through out the year. Similarly, the mean depth of water column in the wells before the watershed interventions was 4.5 m, compared to 9.5 m after the interventions (Fig. 6).

There is a big increase (more than 100%) in the mean depth of water column in the wells after the watershed interventions. Particularly during the post-rainy season the depth of water column in wells has increased substantially.

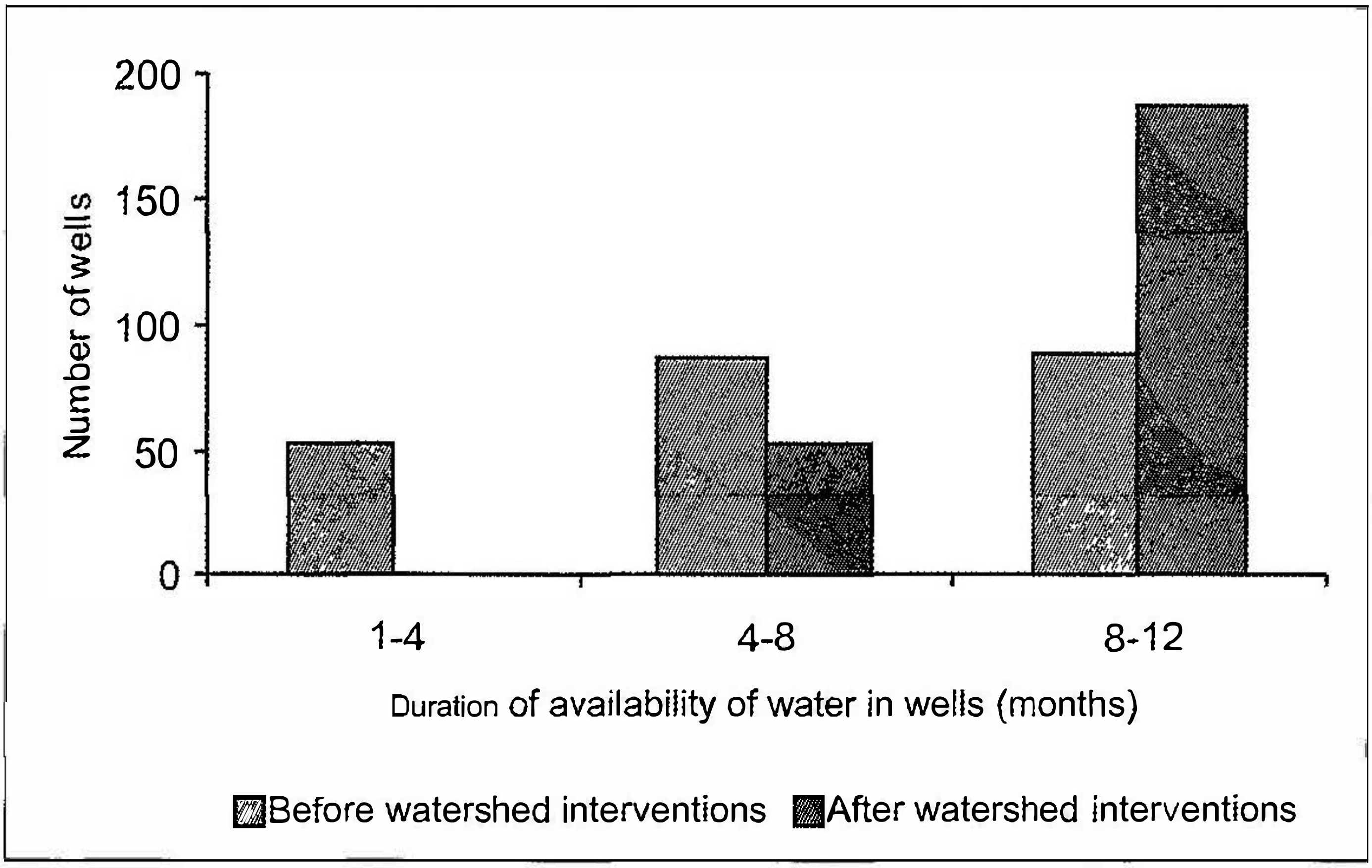

Fig. 5 Effect of watershed intervention on duration of groundwater in Bundi watershed, Rajasthan, India

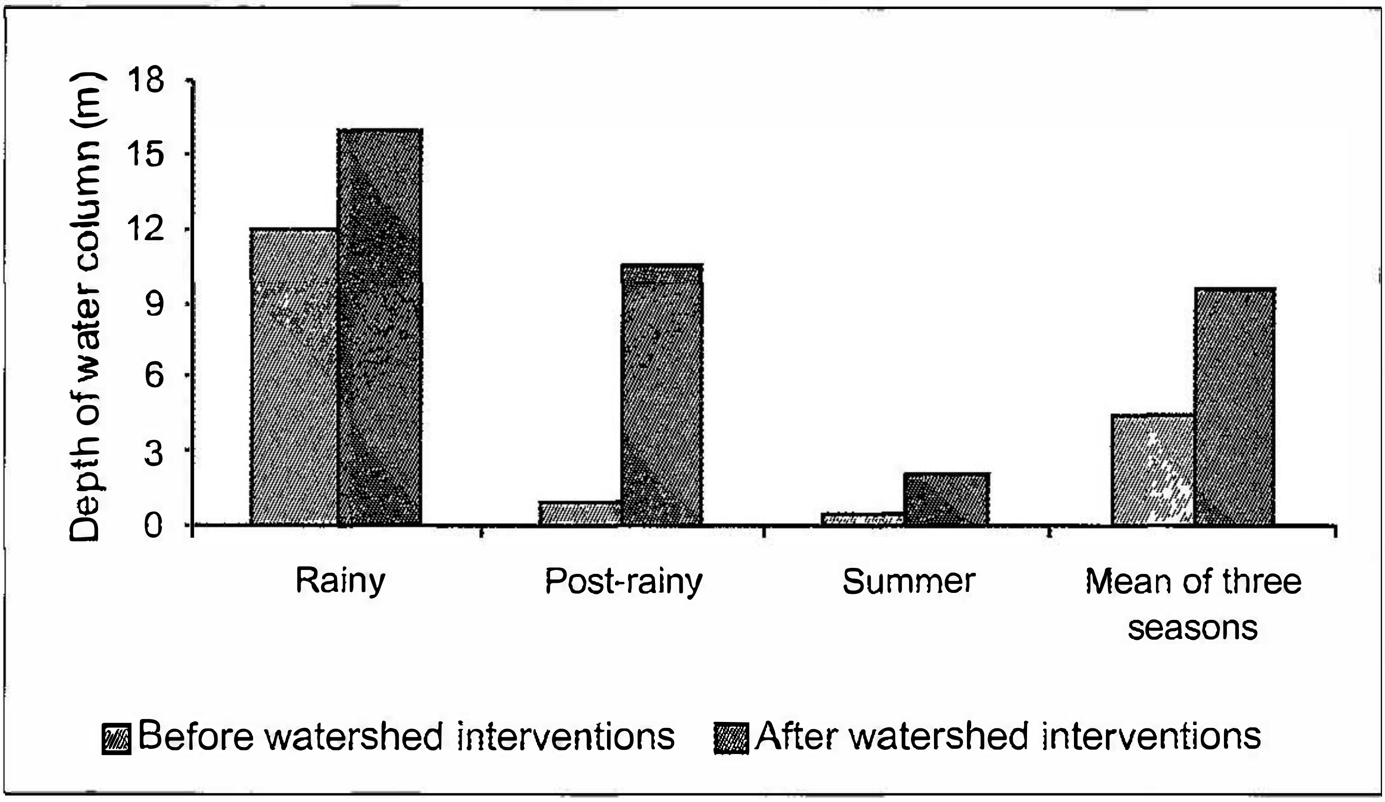

Fig. 6 Effect of watershed intervention on water column in wells, Bundi watershed, Rajasthan, India

There is a three-fold increase in the mean pumping duration, substantial improvement in water recovery or recharge period and area irrigated by wells during post watershed interventions periods (Table 3).

Similar results have been observed from Shekta watershed in Maharashtra. Due to the water harvesting and various soil and water conservation structures there is a significant improvement in the groundwater status. Prior to watershed interventions there were about 189 wells, out of which 73 were functioning for 1-4 months, 35 wells were functioning 4-8 months, 25 were functioning 8-12 months, and 56 wells were not in use. At present 280 wells exists, out of which 110 have water 1-4 months, 113 are functioning 4-8 months and 48 are functioning 8-12 months, where as only 9 wells are not in use. Overall there is an increase of 48 % in the total number of wells and 51 % increase in the seasonally functional wells (1-4 months), while there is a drastic increase of 223 % wells functioning during 4-8 months in a year and 128 % increase was observed in perennially functioning wells (8-12 months in year). There is a sharp decrease was observed in the number of non-functioning wells (about 83 % decrease) as a result of water conservation measures. The status of groundwater in terms of water column during pre-interventions of watershed programs was 1.5 m in rainy season, 0.90 m in post-rainy season and 0.65 m in summer, while after watershed interventions, water column in wells during rainy season was 4.5 m, during post-rainy season was 3.5 m and in summer was 1.5 m existed. An average water column of wells through out the year was 1.02 m before watershed intervention where as after watershed interventions were implemented the water column in wells was 3.17 m, which is about 211 % increase in the water column was found.

Impact of groundwater management on socio economic and livelihoods

In Rajsamadhiayala watershed, Gujarat the increased availability of water in wells has increased the area under irrigation significantly, particularly in summer (Table 4). In case of Bundi watershed in Rajasthan, the area under irrigation has increased by 66% after

Table 3. Effect of watershed interventions on the performance of open wells in Bundi watershed, Rajasthan, India

Season	Pumping duration in hours		Recharge / recovery period in well (h)		Area irrigated by each well (ha)	
	BWI*	AWI*	BWI	AWI	BWI	AWI
Rainy	4	11	13.5	10	1	2.5
Post-rainy	1.5	6.5	21	16	0.5	1.5
Summer	0	1	30	21	0	0.2
Mean	1.83	6.2	21.5	15.7	0.5	1.4

*BWI is before watershed interventions and AWI is after watershed interventions

Table 4. Area under irrigation (ha), 1995-2003, Rajsamadhiayala watershed, Gujarat				
Cropping season	1995	1999	2003	% Increase in 2003 over 1995
Kharif	402	518	643	60
Rabi	356	469	551	55
Summer	11	18	24	118
Total	769	1005	1218	58

the implementation of watershed program. Area under rainfed agriculture came down due to increased availability of water in the watershed. This resulted in marked reduction in crop failures in the watershed area and gave greater confidence to farmers to use improved agricultural inputs. In addition about 35 ha land was brought under horticulture with irrigation facility (Table 5).

The changing scenario of land use pattern in the Shekta watershed clearly reveals that the availability of groundwater had lead to a significant increase in the area under irrigation, increase in seasonally irrigated area was 96% while the increase in perennial area was 88% during post-intervention period compared to pre-intervention period. There is also considerable increase in the area of pasture/ grazing land. The area left as cultivable fallow was totally brought under cultivation (Table 6).

Table 5. The changes in land use pattern at Gokulpura-Goverdhanpura watershed, Bundi during 1997-2004.		
Land use system	Area (ha)	
	Before watershed interventions (1997)	After watershed
interventions (2004)		
Irrigated	207 (15)*	343 (25)
Rainfed	327 (24)	209 (15)
Pasture	167 (12)	114 (8)
Horticulture	Nil	35 (3)
Forest	360 (27)	360 (27)
Dwelling and river	294 (22)	294 (22)
Total	1355	1355

*Values in parentheses are the percent of total area

Table 6. Land Use Pattern in the Shekta watershed, Maharashtra.		
Area under different land use (ha)	Before watershed interventions (1998-99)	After watershed interventions (2004-05)
Rainfed	675.60	581.34
Seasonally Irrigated	94.51	185.24
Perennially Irrigated	64.28	120.52
Pasture/ grazing	00.00	32.68
Cultivable wasteland	85.39	00.00
Govt. forest	132.60	132.60
Total	1052.38	1052.38

Source: Sreedevi et al.2008

The number of diesel engine pumps declined by 22 % over the period (1995 to 2003), while there was considerable increase by about 80% in the electric motor pump. Farmers increased investments in irrigation equipments is evident from 156% growth in number of farmers with the equipments, which helps in preventing the water loss through seepage and increases the irrigation efficiency (Table 7). There was considerable increase in procurement of drip and sprinkler irrigation sets also.

Due to increased availability of groundwater, total number of farmers having access to irrigation has increased by 188% from 1995 to 2003. There is a sharp increase in the number of small and marginal farmers who have access to irrigation compared to large farmers (172%) increased by 292 and 317 percent respectively (Table 8).

Before watershed interventions, mostly the traditional method of lifting irrigation water

Table 7. Change in irrigation facility and equipments available in watershed (1995-2003), Rajasamadhiyala Watershed, Gujarat, India				
Irrigation facility/equipments	1995	1999	2003	Increase or decrease (%)
Diesel engine pumps	208	188	162	-22
Electric pump	205	281	368	80
No. of farmers procured pipeline	48	84	123	156
Drip irrigation set	16	22	38	138
Sprinkler irrigation set	1	2	4	300

Table 8. Change in the number of farmers having access to irrigation, Rajsamadhiayala watershed, Gujarat				
Farmers category	1995	1999	2003	Increase in 2003 over 1995 (%)
Small	25	82	98	292
Marginal	16	28	35	317
Large	32	65	87	172
Total	73	175	210	188

of chadas (traditional leather bucket system of water lifting using a pair of bullocks) was used in Bundi watershed. The increased availability of water in wells encouraged farmers to invest more to acquire improved irrigation facilities. Post-project scenario reveals that about 76% increase in the number of diesel pump sets and 38% increase in the electric pump sets for lifting irrigation water along with increase in the pipeline to save water from seepage loss were recorded (Table 9).

Increase in crop productivity is common in all watersheds due to watershed interventions in a short span of time. In Adarsha watershed, Kothapally, Andhra Pradesh, integrated watershed management technologies increased maize yield by 2.5 times and sorghum by 3 times. Over-all, in 65 community watersheds, implementing best-bet practices resulted in significant yield advantages in sorghum (35-270%), maize (30-174%), pearl millet (72-242%), groundnut (28-179%), sole pigeon pea (97-204%), and as an inter crop (40-110%).

Table 9. Effect of watershed program on irrigation equipments at the Gokulpura -Goverdhanpura watershed				
Irrigation equipment*	Before watershed interventions		After watershed interventions	
	Number of equipments	Number of families	Number of equipments	Number of families
Chadas (traditional method)	164	221	110	151
Diesel pumps	79	145	139	202
Electric pumps	8	18	11	18
Pipeline length (m)	1685	50	5982	82

*Some of the equipments jointly owned by the families

Table 10. Growth rate of productivity, net return, increase in cropping intensity, B:C ratio and per capita income due to watershed interventions from community watersheds in India.

Watershed	Compound growth rate		Increase in Cropping intensity (%)	Increase in B:C ratio (%)	Increase in per capita income per year(%)
	Productivity	Net returns			
Kothapally, Andhra Pradesh *(1999-2006)	101%	34%	30	88	78
Bundi, Rajasthan (1997-2004)	6.5 – 14.3	7.9 – 36.3	55	45	28
Rajsamadhiayala, Gujarat (1995-2003)	4.6 – 9.1	8.7 – 21.6	44	55	39
Shekta, Maharashtra (1999-2005)	2.2 – 16.6	4.5 – 22.7	30	47	19

*productivity and net returns are the pecent increase after intervention over the base line data

Figure 7 shows the similar trend in Bundi watershed, Rajasthan. Adarsha watershed, Kothapally, Andhra Pradesh, due to additional groundwater recharge, a total of 200 ha were irrigated in post-kharif season and 100 ha in post-rabi season, mostly vegetables and some flowers.

Integrated watershed management through primarily water (surface and groundwater) conservation and management compounded with other improved practices have shown a significant increase in productivity, cropping intensity and income,. while controlling degradation of natural resources (Table 10). Compound growth rate (CGR) of productivity, net returns and benefit cost (B:C) ratio are mean of few major crops. In case of Kothapally watershed, the increase in cropping intensity, B:C ratio and per capita income ranged 30-55 %, 45-88% and 19-78 % respectively in community watershed after the implementation of watershed interventions over the baseline data.

The science-led participatory watershed development and management through consortium and convergence approach enhanced agricultural productivity and incomes, decreased poverty of rural poor, reduced labor migration and improved environmental quality.

Conclusion

Groundwater development in the country has expanded extensively. Over-exploitation of the resource in some parts of the country has led to rapid decline in water table. This has threatened not only food security and environment but also sustainable development. Further depletion of groundwater resource has been affecting the small and marginal farmers the most, threatening their livelihood in many cases. An important way of addressing the issue is by augmenting groundwater supplies in shallow aquifers on micro watershed basis through groundwater recharging and rainwater harvesting system. Our experience from landscape community watersheds showed recharging can be made much more effective by the use of scientific inputs and analysis than otherwise. It may however be noted that even if entire potential of recharge is utilized, shortage will still persist, underscoring the need for limiting extraction. In limiting the extraction probably the legal regime alone would not meet the goal but participatory management of water resources ensuring equity along with enabling policies to incentivise promotion of water efficient technologies and crops along with punitive measures are needed. While the measures suggested in the National Water Policy to promote sustainability of groundwater should be the cornerstone of the groundwater development and regulation strategy in the country (Government of India, 2007).

Access to groundwater can be a major engine for poverty alleviation and economic development in rural areas. The effective management and use of groundwater not only as a source of water for agriculture and other consumptive purposes but also as a supplementary source of surface water flows, of wetlands and of wildlife habitats calls for increasing attention to two major and interdependent source of concern: depletion and pollution. Therefore, the focus on development activities must be balanced by management mechanisms to achieve a sustainable utilization of groundwater resources. The groundwater management rather than development is the major challenge facing the organizations/institutions dealing with water resources.

Acknowledgement

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