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Decentralized Water Harvesting and Groundwater Recharge

Can these Save Saurastra and Kutch from Desiccation?

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DECENTRALIZED WATER HARVESTING AND GROUNDWATER RECHARGE: CAN THESE SAVE SAURASTRA AND KUTCH FROM DESICCATION

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Abstract

There are few places in the world where water has become 'everybody's business' quite like it has in Gujarat, particularly, Saurashtra and Kutch. The decentralized movement for water harvesting and groundwater recharge that has emerged as a groundswell in this region represents an effort whose scale matches the magnitude of the water scarcity and droughtproneness that increasingly haunt Western India. Many questions arise about the impact of this movement of which four seem particularly relevant: First, in principle at least, can decentralized water harvesting and groundwater recharge result in net improvement in basin or region level welfare? If not, is there emerging evidence of the movement waning, and people getting disillusioned, now that it has operated in a hyper-active mode for over a dozen years? Has the decentralized water harvesting and recharge movement stayed just that—water harvesting and recharge movement—or has it marked the first step to decentralized water resource management by communities? And, for populous, water-scarce countries like India, does Saurashtra represent a quirky exception or the harbinger of a broader, mainstream trend? If so, what might be its wider implications?

In this paper, we adduce some relevant evidence recently gathered in course of several field studies that IWMI supported to understand the groundwater economy of Gujarat. Besides, we also report on a farmers meeting in Saurashtra, organized by local NGOs. Tentative conclusions indicated are: [a] one valuable impact the recharge movement does seem to have produced on agriculture in Saurashtra and Kutch is ensuring the security of the kharif crop through supplemental irrigation in later stages; [b] there is also ample evidence of significantly higher availability of groundwater after the withdrawal of the monsoon, roughly of the order of 1-1.2 km^3 in Saurashtra; [c] with the security of the kharif crop, there is some qualitative evidence of gradual change in the mindset of the farmer; this may result in enhanced investment in land care, in farm productivity and improved on-farm water management; [d] where water scarcity manifests itself in the form of reduced fresh-water availability in wells, there seems some indication of interest in water saving irrigation methods and technologies. This suggests that the next popular groundswell Saurashtra and Kutch need should aim at mainstreaming groundwater demand management practices.

I. Introduction

Gujarat has been undergoing uncommon turbulence in its water sector. Name a water resource or serviced management problem; and you see some part of Gujarat struggling with it—secondary salinity, water logging, groundwater depletion, floods, droughts, salinity intrusion, unviable urban water supply systems and non-functioning rural water supply systems, fluoride, nitrates, and other contaminants in drinking water. However, there are few regions in the world where water has become everybody's business quite like it has in Gujarat, especially in Saurashtra and Kutch (Shah 2000). Here, for over a decade now, individual farmers, communities, NGOs and CBOs, religious and spiritual organizations, Gram Panchayats and Municipalities have gone berserk, catching rain water, storing it in wells, ponds, tanks, check dams, drains, or wherever they can and finding ways to put it into the ground in the hope that it can be retrieved and used at a later date. Many outsiders find it difficult to believe how mass-based this activity has become, and how broad-based is the support for it. Now, there are at least three attempts to assess the scale and variety of the water harvesting activity in Saurashtra and Kutch (Shah 1999; Nagar 2002; Joshi 2002)

Local philanthropies, NGOs and grass-roots intuitive hydrologists have driven the water harvesting and recharge movement in Saurashtra and Kutch. But notable by their absence have been international donors, government, and the high science. Until the government of Gujarat threw its lot recently (December 2000) with these 'rain catchers' with a big Sardar Patel Water Conservation Scheme[1], these were all skeptical by-standers. For a long time, these were constructing big water projects and yearning for people's participation; and now people have begun acting, and the three-some are an ambivalent lot. Those espousing the movement in the government of Gujarat are a minority of politicians and administrators who are particularly close to the grassroots. Indeed, the Sardar Patel Scheme is the handiwork of the Water Resources Minister and the Secretary in the government of Keshubhai Patel; and in the state's water establishment, the only group that is whole-heartedly enthusiastic about the movement is the groundwater department.

Four issues are of interest:

1. First, in principle at least, can decentralized water harvesting and groundwater recharge result in net improvement in *basin* or *region* level welfare?

2. If not, is there emerging evidence of the movement waning, and people getting disillusioned, now that it has operated in a hyper-active mode for over a dozen years?

3. Has the decentralized water harvesting and recharge movement stayed just that—water harvesting and recharge movement—or has it marked the first step to decentralized water resource management by communities? And

4. For populous, water-scarce countries like India, does Saurashtra represent a quirky exception or the harbinger of a broader, mainstream trend? If so, what might be its wider implications?

II Rejuvenating a Desiccating Groundwater Socio- Ecology: Can Decentralized Water Harvesting and Groundwater Recharge Do it?

Yes, say the protagonists of the water harvesting movement, mostly farmers, NGOs and local activists in Saurashtra, who have a simple arithmetic to explain why. Saurashtra's total geographic area is 60,000 km; and its topography is like an inverted saucer. The region receives an average rainfall of 500 mm which takes the total precipitation in a normal year to 30 km^3. But the 120 odd major and medium irrigation systems in Saurashtra have a total storage capacity of only 2.3 km^3. Over 27 km^3 of rainfall precipitation received in Saurashtra remains uncaptured and runs off

[1] Until December 2001, 11242 check dams had been completed or sanctioned in Saurashtra; but the distribution across districts varied greatly: 987 in Amreli, 2961 in Jamnagar, 1699 in Rajkot, 3781 in Bhavnagar, 1233 in Junagadh, 384 in Surendranagar and 197 in Porbandar. Gohil (2002) quotes a total of 13000 check dams built under Sardar Patel Water Harvesting Scheme. However, even before the government scheme came into existence, large numbers of well-recharge modifications, farm ponds, check dams, percolation tanks, etc were carried out. According to Joshi (2002), a single NGO, Saurashtra Jaldhara Trust supported 20,000 check dams, and organized free supply of 200,000 bags of cement for this purpose. Smaller, local agencies—such as the Savarkundala Taluka Gram Sewa Mandal, Vivekanand Research and Training Institute, Aga Khan Rural Support Program, UTTHAN, ORPAT Trust,—carried out their own programs. Joshi (2002) also cites a study by Gujarat Institute of Development Research, Ahmedabad which estimated that 10476 farm ponds were made in Saurashtra during the last 6 years of the millennium past.

into the ocean or evapo-transpires without much socio- ecological use. Local water harvesting of the type that has become popular in this region can augment the total quantum of water available to support the growing agricultural requirements, and instantly resolve the worsening drinking water problem of the region.

Similar is the case with Kutch, the second largest district of India where agriculture and pastoralism are the mainstay of rural society. 30% of the rural households here depend exclusively on livestock for their livelihoods. However, in recent decades, groundwater depletion has hit Kutch like a cancer; and out migration has been the predominant response of farmers as well as pastoralists. According to R K Sama of Vivekanand Research and Training Institute, Kutch's water strategy needs to be founded on its unique conditions. Its 400,000 ha of farmlands have 20, 00000 ha—or 20,000 km^2 of-- of (more-or-less) free catchments. At its normal rainfall of 320 mm, Kutch has a total precipitation of some 7000 million m^3. However, Kutch harvests only 128 m m^3 of this precipitation in minor and medium reservoirs; some 590 m m3 more goes underground as natural recharge. The remainder remains unmanaged. Sama accuses the state's irrigation department of managing only 5% of the state's water, which is stored in the reservoirs and suggests that in Kutch as well as much of water scarce Gujarat, the real challenge is rain-water management through decentralized harvesting and recharge.

Many hydrologists, water resource engineers and interested generalists--like Jayanarayan Vyas, the former Gujarat minister in charge of water resources—are, however, skeptical or even hostile. They have many worries; cannibalistic competition for run-off, limited aquifer capacity, high non-beneficial evaporation, up-stream/down-stream externalities.

The biggest worry is that unchecked, chaotic growth of local water harvesting structures (WHSs) would cannibalize government-built dams and reservoirs. For one, the statistical probability of a drought in any year is close to 0.5 in Saurashtra. Even in years with normal rainfall, the temporal pattern of rainfall events is such that most precipitation results in little or no run off to harvest and use for 'induced recharge' of aquifers. The growing profusion of small structures capture the bulk of the run off, leaving nothing for the government structures and people who have come to depend upon them for irrigation and domestic water requirements. Most of the irrigation reservoirs in Saurashtra have increasingly got sequestered for meeting urban municipal water supply; but if communities up-stream of these captured the water before it could reach the reservoirs, not only would the government investments turn useless but the region's towns and cities would remain perennially parched.

Other researchers—especially water resource scientists such as Dinesh Kumar--further argue that although total precipitation is 30 km^3, the actual run off generated in a given year may be hardly 1.5 or 2 km^3. Since storages compete not for precipitation but for run off, it is this 1.5 or 2 km^3 that matter. The check dam programs must, in his view, encourage cannibalistic competition for run-off. Even in a normal year with 500 mm precipitation, rainfall events delivering 70-100 mm may occur once in several years; and it is these which cause the real substantial run off giving large reservoirs a chance to fill up. If water is obstructed by a profusion of small WHSs, government investments in larger reservoirs are doomed; downstream effects are certain.

Finally, there is a distinct discomfort with the chaotic, disorderly and unscientific management of an increasingly scarce resource that such a mass movement implies. The 'capture it or lose it' rule that drives it means that the government and the rule of law have no role. Commenting on the court dispute about a check dam built by Tarun Bharat Sangh in Alwar in neighboring Rajasthan, and supported by the Centre for Science and Environment which potentially reduced water going to Bharatpur sanctuary downstream, a senior analyst commented: "In sum, this is a classic case of water management under scarcity, facing competing demands from various sectors. Either it is resolved by a shouting match involving slogans about "local" and "harvesting" and "stakeholder" and "participatory", or it is resolved through the law, based on appropriate technical advice and evaluation of options." (Chris Perry, pers. Comm. Email 17/7/2001).

Some technical researchers have grave doubts about whether such decentralized recharge can produce any beneficial result, given the basaltic nature of Saurashtra's hydro-geology that limits groundwater recharge to 8-12% of the precipitation[2]. Even if rainfall pattern were better behaved, Saurashtra's aquifers themselves are limited in their capacity; the weathered zone—20-22 meters under the ground surface-- has limited porosity and a specific yield of around 3%, thus leaving little room for storage except where sizeable lineaments are found. According to Sakthivadivel of IWMI, a typical hectare of an aquifer in Saurashtra cannot absorb and store more than 400-500 m^3 of water, which is a small fraction of the amount of water needed by a single crop. In other words, if 5 inches of rainfall were to be used to recharge through methods currently in use, aquifers in much of Saurashtra would fill up to the brim; any more water dispatched would reappear on the ground as 'rejected recharge'.

Finally, there is the big question of what is the best technology for water storage with 'dams for development' connotations. Considering its high temperatures and wind speeds, evaporation losses from surface water storages in Saurashtra and Kutch are naturally very high; in such a situation, storing water in a large, deep reservoir makes a great deal more sense than in storing the same amount of water in a large number of small WHSs [3]. But learning from some experiments in Negev in Israel, the Centre for Science and Environment has been arguing that precisely for the same reasons—high wind-speeds and mean temperatures—it makes more sense in arid and semi arid areas to capture and store water in small structures where it falls rather than allowing it to travel long distance to a big, deep reservoir since much of it would disappear en route. In an email conversation Chris Perry had with a leading hydrologist Geoff Kite, the

[2] While it is widely agreed that the recharge rates in the Deccan traps in Saurashtra would be 10-12%, a recent email discussion suggests these can be much higher in basaltic outcrops in general. Michael Zilberbrand found it to be 50-60% of annual rainfall in Auckland in highly weathered basalt flow and up to 15 meters of residual soil. Another researcher found the recharge rate to be 30-90% in the same region. One participant suggested, as a general trend, that young, relatively fresh material (unweathered) tends to have 100% infiltration -- or whatever remains after evaporation. Old terrain, deeply weathered, etc. will have the lowest infiltration rates -- including, locally, zero.

[3] "Think about it -- evaporation from a free water surface in Saurashtra in the nine non-rainy months is about 1500mm. So any storage structure that is less than 1500mm (1.5m) deep will be empty before the next monsoon even if NO water is taken out for use! A storage that is twice this depth will, due to the "laws" of geometry, lose about 60-80% of its storage to evaporation. Additionally, water will seep through the bottom of any storage structure." (Personal. Comm. Chris Perry, email 12/10/2001)

latter opined: "I think that whether a series of small dams or one large dam will yield more water depends on the climate and topography. In the Negev I can quite believe that smaller dams yield more because of the high water losses through infiltration and evaporation along water courses. If you can catch the water early, near the source of the precipitation, then maybe more can be saved. It is probably not correct to extrapolate the experience of the Negev to the rest of the world. In more humid areas the efficiencies of a large deep reservoir with lower evaporation rates would dominate (Personal Comm. Chris Perry, email 12/10/2001). Perry marshals this advice in support of large over small structures but one might as well argue that, for most of the year, temperatures, humidity and wind-speeds (reference ET 1600) in Saurashtra and Kutch would be closer to Negev (reference ET 2100) than to many colder and more humid parts of the world.[4]

In this cacophony of conflicting scientific viewpoints and assertions, it is not easy to finally conclude whether, through the water harvesting and recharge movement, Saurashtra is better off in net terms or not. If all the recharge wells and check dams can put 1 km^3 of rain water into additional groundwater storage, as is claimed by local activists that should be a boob to the region especially since the evaporation loss from it is virtually zero compared to the 2.3 km^3 of government reservoirs. On the other hand, if the bulk of Saurashtra's aquifers have as little storage capacity as we are told, why worry about the recharge movement which can not use more than a small fraction of the precipitation? If all the government dams are grossly over-built so that they can fill up only in years of above normal rainfall anyways[5], why worry about cannibalistic competition since the big reservoirs with a total storage capacity of 2.3 km^3 will be unable to capture all the precipitation when they need to and are in any case not much use in other years. In below normal years, there is not enough run off to fill even a fifth of these. It is also plausible to argue that the central water management challenge facing Saurashtra—as of course much of Gujarat and Western India—is of managing the five-yearly monsoon cycle and existing government storage is just not equipped to do this. Over a five year period, probability is over 90% that at least one year will yield a precipitation of 700-750 mm in two or three rain fall evens that will generate large run off. Existing government storages are insufficient to capture these; and the large groundswell of tiny storages, and particularly the recharge structures, can play a vital role in capturing this precipitation to provide inter-year stability.

III. Impact of Decentralized Water Harvesting and Recharge: Voices from the Field

One way of settling the debate then is asking the 'experts'; but as we reviewed, experts need more data and to talk more amongst themselves before they can pass a final verdict on whether Saurashtra is progressing or regressing in its war against desiccation. Another way is to hear about it from the 'horse's mouth' by asking the farmer who is at the receiving end. And if we ask a large enough number dispersed

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[4] Take for instance Rapar district of Kutch: 14 out of last 25 were drought years here. Average rainfall is 232 mm; it has 9 rainy days; 44 mm/hr is the intensity of rainfall. It has 97 rivulets and *vokla*s (drainage channels). And over 90% of the rainfall it receives runs off unused.

[5] Just take the case of Aji I dam which was built to provide year-round water supply to Rajkot city. According to R K Nagar, its storage capacity is 29.5 mm^3 but its catchments of 142 km^2 has mean precipitation of 508 mm and thus a total precipitation of some 72 m m3. If the run off is assumed to be 15%, even in a normal year, only a third of the dam would get filled up

over a large enough area, chances are that we will get a balanced picture of the pros as well as the cons.

An opportunity to do this has arisen from a research project on 'Gujarat's Groundwater Economy' that the IWMI-Tata Program has been carrying out in collaboration with the Sardar Patel Institute of Economic and Social Research, Ahmedabad. The objective of the project was to encourage social science teachers in rural colleges of Gujarat to engage in researching and understanding groundwater management issues in their locality. The teachers were free to decide their research problem and execute it as each saw appropriate; one assumption in doing this was that on their own, teachers would pick up issues and events that dominate local thinking. As it turned out, many teachers from rural Saurashtra chose to work on the social impact of a water harvesting activity in their locality. The studies had many features in common: [a] each involved interviews with at least 100 respondents; [b] the researcher based his analysis solely on the perceptions of the respondents without triangulating the conclusions formed based on these; and [c] the studies focused primarily on socio-economic variables. Most treated the water-structure and its hydrological interactions as a 'black box', and concentrated on the ultimate impacts on the variables in which the researcher was interested. This limited the usefulness of the research somewhat; even so, I find the information compiled useful because of the sheer scale of the research effort—some 2400 respondents interviewed from some 16 districts of Gujarat during October-November 2001. It is also useful because it tells us something about how ordinary people perceive the social value of the water movement.

When this enterprise began, we had expected that at least in some locations, there would be interesting information on adverse side effects; at least some researchers would pick up respondents who are disillusioned with the water harvesting movement now in progress for over 12 years. Such mass phenomena tend to occur in waves. Since the water-harvesting wave began in Saurashtra, several small waves came and died down.[6] But it is difficult to find farmers who show frustration and disenchantment with water harvesting and recharge 'wave'. The studies we review echo this strong, upbeat sentiment. In the remainder of this section, we provide an overview of the opinions, perceptions and information provided by over a thousand

[6] As part of this study, we came across several instances when farmers took to an innovation in the hope of benefiting substantially; but if they failed in their hopes, they candidly said so. For example, one response to water scarcity in Saurashtra is farmers taking to water-saving commercial crops in large numbers. This has involved experimentation that has begun and ended in the manner of a wave. The first major wave was of Jojoba which many farmers tried especially in coastal areas since it is known for its high salinity-tolerance; but as one farmer pointed out at a recent workshop, " during those 10 years, the farmer got crushed into oil but no Jojoba oil is known to have been produced in Saurashtra". The came the '*bor* wave' followed by an 'Amla wave". In each case, herd-like, farmers took to the new crop with high hopes of reaping fortunes, the *niche* market got glutted, prices crashed, and, farmers cut down plantations they had taken years to raise. A second '*bor* wave' is in the offing in some parts of Saurashtra and North Gujarat and seems destined to meet the same fate as the earlier ones. Now, of we talk to farmers about these, it is unlikely that most would say they have benefited from these if they have actually not. Therefore, with respect to recharge movement, if large number of farmers interviewed say they have benefited in various ways, there is no *prima facie* reason not to use such evidence for making an assessment of the recharge activity.

farmers from various parts of Saurashtra who were interviewed during November-December 2001 by a dozen researchers. [7]

Impact of water conservation on improved water levels in wells in Rajkot district(Joshi, Mahes,2002)

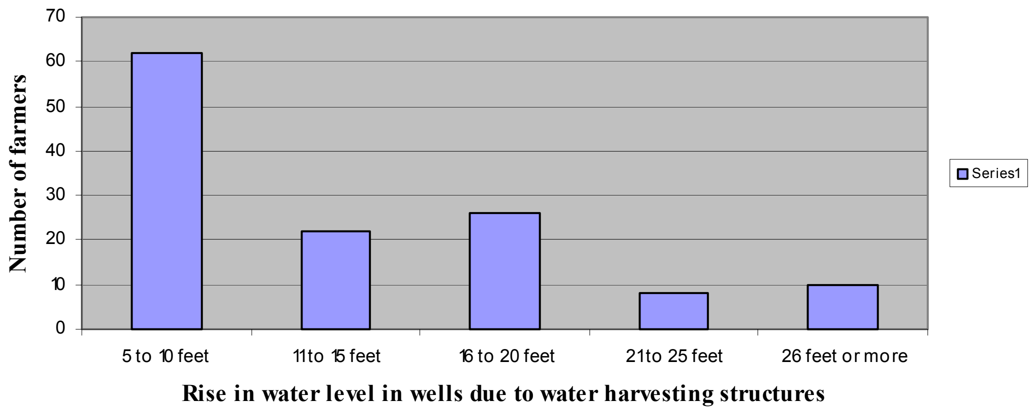

Figure 1

Weathered rock aquifer areas

A good example is the study by Mahesh Joshi who interviewed 160 farmers in three talukas of Rajkot district[8]. Joshi found that the most notable impact has been on the improved productivity of irrigation wells which has imparted a powerful stimulus to the local agrarian economy (Figure 1); over 60 farmers reported 5-10 feet increase

Increased use of hired labour due to water harvesting movement by a sample of 160 farmers in Rajkot district (Joshi 2002)

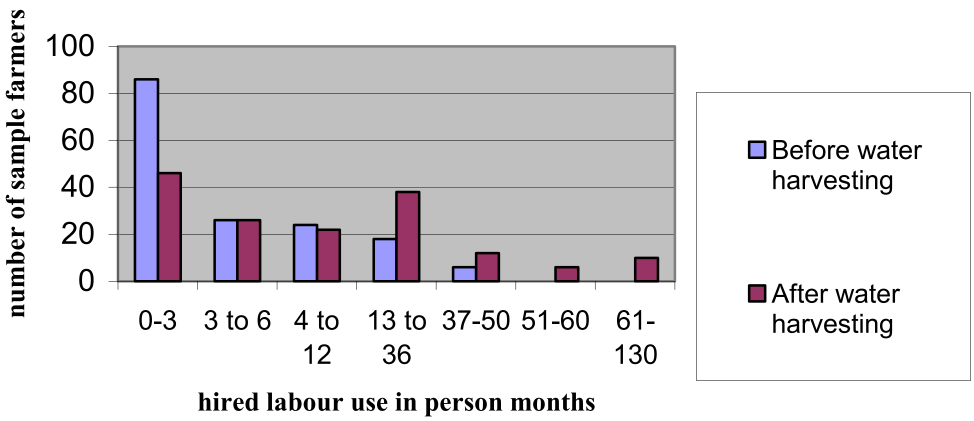

Figure 2

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[7] Each of these researchers designed his/her own research instrument to find an answer to the same question: how has water harvesting movement affected local communities.

[8] 20 each from Rajsamadhiala and Aniara villages in Rajkot taluka, Jasapar in Jasdan taluka, Kathivadar and Ningala in Rajula taluka and Dhar and Borala villages in Kundala taluka.

in post-monsoon water level in their wells before and after the structures; on the other extreme, some 20 farmers reported over 20 feet increase in post-monsoon water level. This had a direct impact on farming. There was not much change reported in the cropping pattern; however, crop yields in a year of normal rainfall have shot up very substantially, according to Joshi's survey results. Equally, there is substantial increase in the use of wage labour by beneficiary farmers (see Figure 2). 74 of the 160 farmers surveyed by Joshi used hired labour even before the water harvesting movement took off; however, these seem to use much more hired labour now than they did before. Joshi estimates that 74 farmers who used 942 person

months of hired labour earlier now use 2546 person months, up by 270 %. The estimates farmers gave of the increase in farm output due to water harvesting work in a normal rain year too are equally upbeat (Figure 3). All these production and income impacts are a result of improved productivity of wells, which now benefit from more abundant recharge. 128 of the 160 farmer respondents suggested significant increase in average water levels in their wells; the remainder said they benefited because of longer hours of continuous pumping made possible although there was no significant rise in the water tables in their wells.

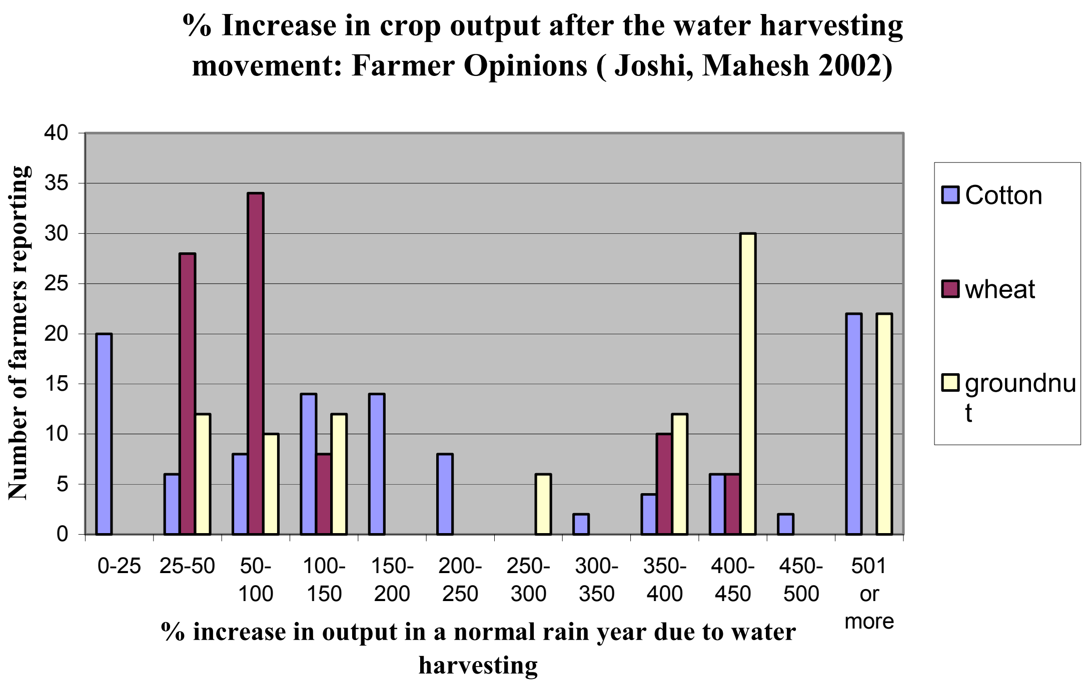

Figure 3

Another study by Aswin Rawal makes an assessment of the government sponsored SardarPatel Water Conservation Scheme in 12 villages of Jamkhambhalia taluka of Jamnagar district. Under this scheme, a total of 185 check dams were constructed in the 12 villages during 1998-99 (figure 4); of these, Rawal selected 36 and interviewed 3 farmers from the command of each, taking his sample size to 108 farmers.

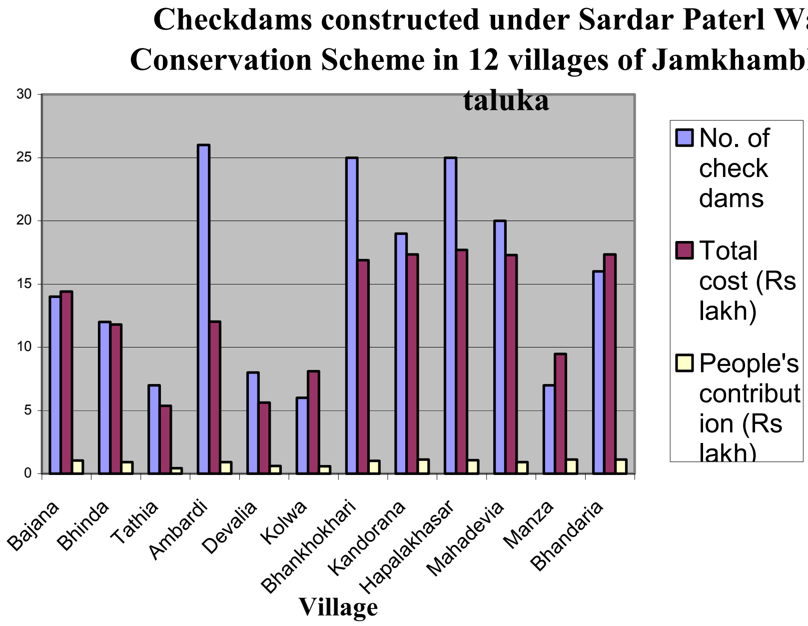

Figure 4

Once again, we have glowing tributes paid to the positive and beneficial results of the WHS activity in terms of local water balance and impact of local agrarian economy and livelihoods. But it provides room for an alternative view of why respondents are so impressed with the check dams. One argument often made is that the recharge activity—at least when government sponsored and financed-- is energized more by demand for wage work than people's belief and faith in the capacity of these structures to improve their water situation. Rawal's study provides some figures on volumes of paid labour generated. There may be something in this argument; wage labour generated in the 12 Jamkhambhalia villages averaged nearly 4 months (112 days) of paid work, which in a drought year, can offer much needed succor to poorer households.

However, if Rawal and his informers are to be believed, this investment of Rs 14.9 million is probably the best the village's agricultural economy has received. Wells and bore wells throughout the area have been rejuvenated and become much more productive than they were in a long time. Prior to 1998, these had water only during the rainy season; but now, wells have water throughout the year. The indicator of well productivity used by Rawal, as others, is increase in water in the well or bore well after the withdrawal of the monsoon. And the average increases that Rawal got from his respondents from 12 villages for different seasons are shown in figures 5 and 6.

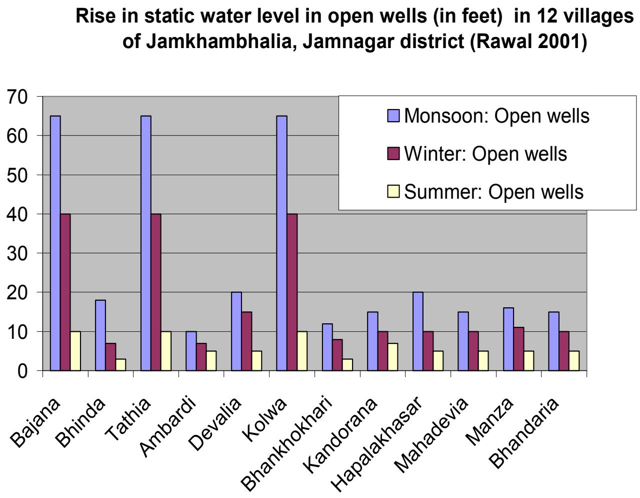

Figure 5

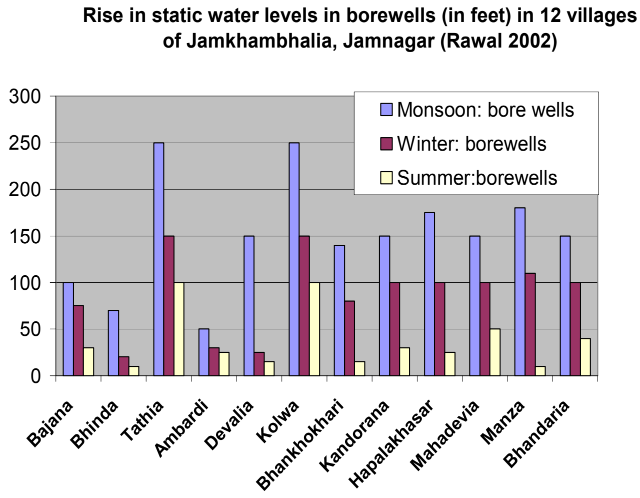

Figure 6

Ashok Trivedi's study of the impact of a VRTI[9]-implemented watershed program is based on the researcher's interviews with 100 farmers from all land-holding classes in 3 villages of Shihor taluka in Bhavnagar district. The watershed interventions involved are essentially groundwater recharge structures and the study alludes to powerful groundwater impacts of 5 check dams, 7 stop dams and 4 farm ponds constructed under the Rs 1.5 m project covering 500 ha. 180 wells experienced major increases in their water output which in turn produced significant income impacts on the farm households which were affected. The entire discussion on water harvesting and recharge movement generates little information on equity dimensions of the change process; this study, for one, does offer an interesting finding about the impact of watershed activity on the poorest: in Trivedi's sample, farm households in the lowest 2 income intervals have moved upwards into higher income brackets (figure 7). This is a direct result of increased productivity of irrigation wells as figure 8 suggests.

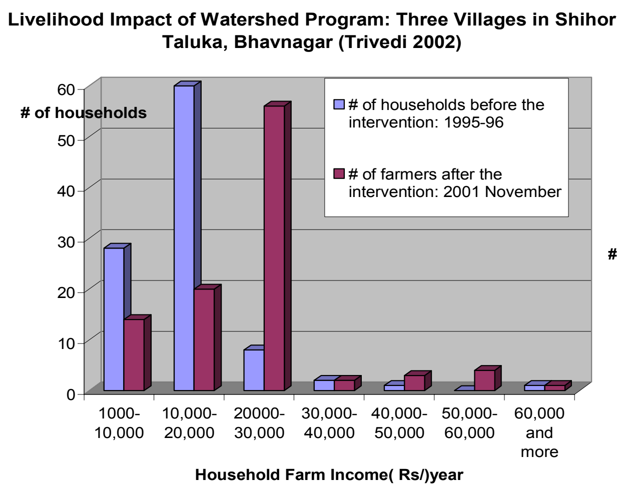

Figure 7

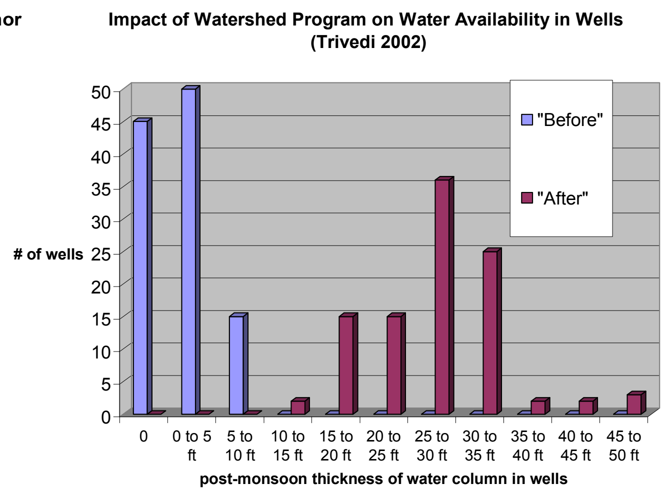

Figure 8

9 Vivekanand Research and Training Institute, a Kacch-based NGO which has done some pioneering experimental work in water harvesting and recharge.

One more example of the 'black-box' type study is Gohil (2002) who examines the household level farm income impact of water harvesting and recharge structures. He uses perception survey of farmers in Rajsamadhiala, a village celebrated for going overboard in water harvesting and groundwater recharge. This, somewhat naively asks each farmer in the village his net income from farming before and after the water harvesting movement. The survey was carried out with the help of the Sarpanch of Rajsamadhiala, who is one of the best-known protagonists of water harvesting and recharge. It is therefore not surprising that the increases in net farm income 'as revealed' by farmers are as impressive as figure 9 suggests. Based on what others have found about the increase in cropping intensity, crop yields and total farm income before and after decentralized WH &R movement, however, the numbers provided by Gohil on farm income before and after do not seem all that unrealistic. But, then, plausibility is no guarantee of accuracy.

Impact of Recharge Interventions on Household Net Farming Income/year-Rajsamadhiala (Gohil 2002)

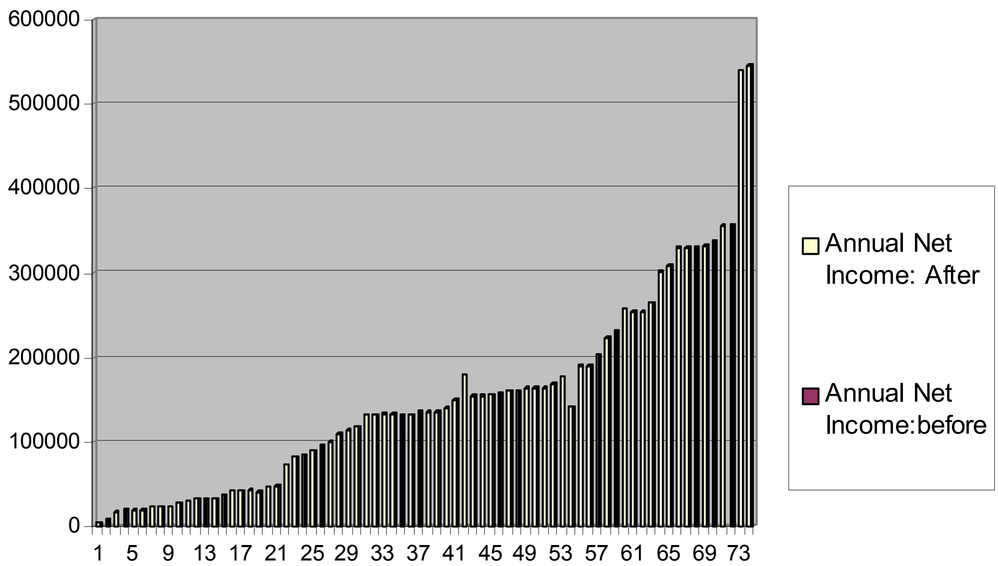

Figure 9

Coastal Aquifers threatened by Salinity Intrusion.

Impacts of groundwater over-draft—and of water harvesting and recharge structures--are dramatically different in weathered-rock areas of inland Saurashtra and alluvial aquifers of coastal Saurashtra. Gujarat has 1048 villages with more than 7500 ppm TDS in their groundwater; of these, 534 are on Saurashtra coast affecting 10.8 lakh people and 10.5 lakh ha of land. The latter areas have during 1970-90 witnessed massive and rapid saline intrusion in groundwater aquifers and pumping with saline groundwater has added large quantities of salts to top soils. In a coastal strip from Mahua to Kodinar, salinity ingress has all but wrecked the agrarian economy. Two of the 30 studies focused on understanding this immiserizing phenomenon. A study by Professor Ram—based on a survey of 100 farmers from 6 coastal villages of Sutrapada taluka in Junagadh district of Saurashtra—explores how salinity ingress progresses, and how communities a little inland, who are aware how the ingress is remorselessly proceeding to engulf them, feel paralyzed by their myopia, and unable to restrict their total pumping, end up hastening the disaster by over-pumping (Ram 2002).

A more detailed investigation of impacts of saline intrusion is to be found in Mahua taluka in Bhavnagar district in a study by Professor Manoj Joshi (Joshi, Manoj 2002). Mahua used to be known as the Kashmir of Saurashtra but two decades ago. Groundwater depletion in its fragile coastal groundwater ecology resulted in saline intrusion; Mahua is now undergoing a gradual desiccation process. This study analyses the social impacts of salinity intrusion in Vadli and Khared villages of Mahua taluka. [10] Both the villages have hardly any irrigation; both get drinking water through piped group Water Supply Schemes. The 100 households surveyed represent a population of 906, around 10% of the total,

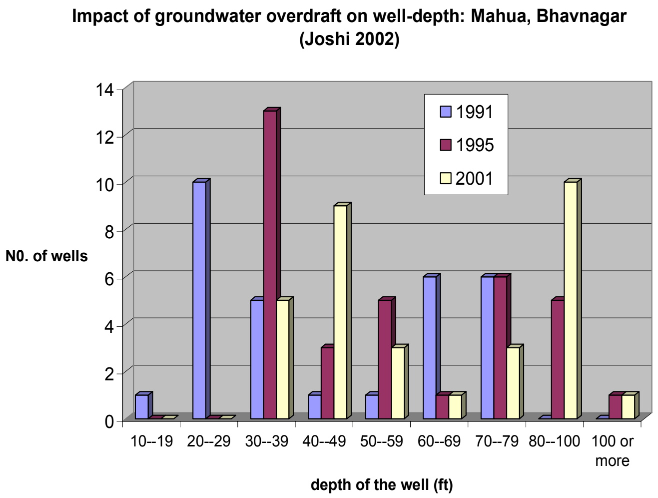

Figure 10

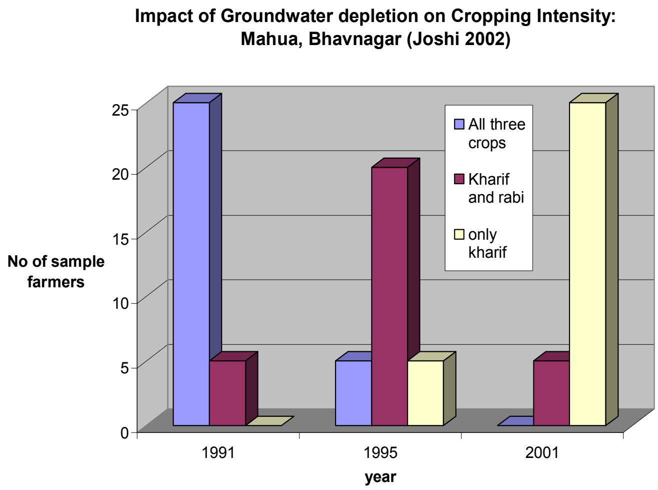

Figure 11

According to Joshi, life in these two villages has undergone massive change during the past decade. With relentless expansion of well irrigation, farmers have chased falling groundwater tables by deepening their wells repeatedly. In 1991, deepest wells in the two villages were 80 feet; but most were barely 30 feet deep. Come 2001, and a large proportion of wells were down to 100 feet and the modal depth around 50 feet. The impact of this chase has been fatal: until 1991, no well would remain totally empty during winter; today, most of them do; until 1991, most wells had a 10-20 feet water column during early winter; in 2001, none had (see figure 10). In 1991, most farmers interviewed by Joshi took three crops every year; in 2001, not one of them could do so; most are now down to rainfed kharif cultivation (figure 11). The agricultural economy of Vadli and Kharod has shrunk as rapidly during the decade of the 1990's as it had boomed during the 1970's and the '80's. Production of some of the key crops- groundnut, cotton, food grains, orchards fell to a small fraction of the 1991 levels. Household income from farming and dairying shrank, leaving the two

[10] Vadli has 68 wells, 50 hand pumps for domestic water supply and 2 check dams. However, all these are empty all through the year, barring 15 days after the last rains. Khared has 48 irrigation wells, 2 check dams and a tank; however, these too are all but useless. Vadli and Khared are thought to be experiencing extreme water stress; so that researcher expected to find large scale migration, school dropping out and water-related diseases. However, none of these hypotheses was validated.

villages impoverished in an absolute sense; in 1991, 2/3rd of the sample households earned over Rs 50,000 at 1991 prices; in 2001, 2/3rd earned less than Rs 30,000 at 2001 prices! Table 1 summarizes the averages computed by Joshi (2002) on a set of key impact variables for three benchmark years: 1991,1995, 2001. The pace of decline these two agrarian communities—and its wide ambit-- indicates the specter of salinity ingress that haunts coastal Saurashtra and many other parts of India's long coast-line. Not only field crops, but orchards, horticulture and livestock economy too have shrunk. Vadli and Khared represent a coastal strip that barely 20 years ago was fondly referred to as Saurashtra's 'Green Creeper" (*Lili Nagher).* Today, the region is a pale shadow of its former self.

Table 1: A decade of Decline: The Impact of Groundwater Depletion and Saline intrusion on the Economies of Vadli and Khared Villages of Mahua Taluka, Bhavnagar District.

	Impact on a sample of 100 farmers interviewed from Vadli and Khared villages	1991	1995	2001
1.1	Production of wheat (qtl)	72.5	35	20
1.2	Production of Bajri (qtl)	59.50	45	34.4
1.3	Production of groundnut (qtl)	26	12	25
1.4	Production of cotton	13	4	3
2.1	Number of coconut trees	3550	1900	200
2.2	Income from coconut (Rs)	250,000	103,000	0
2.3	Number of Sapota trees	600	425	0
2.4	Income from Sapota sale	125000	56000	0
2.5	Income from vegetables	375000	195000	138000
3.1	% of households with nominal income less than Rs 30,000/year	13	43.3	63.3
3.2	% of households with nominal income between Rs 30,000-50,000/year	23.3	26.7	30
3.3	% of households with nominal income greater than Rs 50,000/year	63.3	36.7	6
4.1	No of buffaloes	66	30	42
4.2	No of milch cows	61	37	29
4.3	No of goat and sheep	1030	855	515
4.4	Milk production (kg/year)	45000	24600	23350

Manoj Joshi's study is made interesting by a companion study of the same terrain, in which V J Bhammar (2002) explored the impact of a *Bandhara* (stop dam) built by the government in Nikol village with the express purpose of staving off saline intrusion through artificial recharge of coastal aquifers. Over the past 3 decades, some 20 such *Bandhara's* have been constructed by the government, mostly under donor programs; yet, little is known about their social and ecological impact. Bhammar's study, though limited to just 4 villages (Vaghnagar, Naip, Sathara and Nikol Villages of Mahua Taluka), offers the first tentative evidence that we have been able to gather that suggests that these might actually be working. Mahua taluka has suffered seawater intrusion problem for a very long time. High-level Committees appointed by the State government recommended a *bandhara* scheme first in 1976 and then in 1978. Accordingly, a 3 km long stop dam was commissioned in 1998 at a cost of Rs

130 m. The dam—which has 305 meters of masonry component and 240 meters of earthen component-- has storage of 855 mcft. By reclaiming 3500 ha of saline land and irrigating 1600 ha, the Nikol *bandhara* held out the promise of alleviating the salinity problem faced by the four villages and revive their agrarian economy.

Did the project fulfill these hopes? Bhammar's study explores this question based on interviews with 100 households selected from the four beneficiary villages. In doing this, he employed five criteria: [a] the impact on crop yields; [b] impact on cropping intensity; [c] impact on farm incomes; [d] impact on soil salinity as perceived by farmers; [e] improved availability of groundwater, as revealed by farmers based on their perceptions. The results, based on information provided by a sample of 100 farmers, are set out in table 2.

Table 2: Socio-ecological Impact of Nikol Bandhara (stop dam) in Four Villages of Mahua taluka, Bhavnagar (Bhammar 2002)

	Impact Variable	**1996-97: "Before"**	**2001 November: "After"**
1.1	Yield of Bajri (qtl/ha)	107	116
1.2	Yield of Cotton (qtl/ha)	66.9	83
1.3	Yield of groundnut (qtl/ha)	68	77
1.4	Yield of onion (qtl/ha)	860	1233
1.5	Yield of wheat (qtl/ha)	55	101
2.1	# of farmers who grew kharif as well as rabi crops	0	100
2.2	# of sample farmers who earned up to Rs 20,000/year from farming	79	53
2.3	# of sample farmers who earned between Rs 20,000 and Rs 50,000/year from farming	21	23
2.4	# of farmers who earned more than Rs 50,000/year from farming	0	7
3.1	# of farmers who think salinity in their soil is 30% or less	0	56
3.2	# of farmers who think salinity in their soil is more than 30% but less than 70%	65	44
3.3	# of farmers who think salinity in their soil is more than 70%	25	0
3.4	# of farmers whose wells had less than 15 feet of water post-monsoon	78	21
3.5	# of farmers whose wells had more than 15 feet of water post-monsoon	0	57
3.7	# of farmers who think they face a drinking water problem:	97	3

Like other studies we have reviewed, Bhammar's results too need to be interpreted cautiously. For instance, his data on farm income-wise distribution fails to adjust for inflation; his conclusions on soil salinity are based not on soil tests in laboratories but by accepting farmers' own assessments; like-wise, his assessment of impact on groundwater availability, based wholly on farmer perceptions, too needs to be taken as tentative. Finally, a major limitation is that Bhammar's sampling scheme did not take into account the fact that household benefits might be strongly associated with distance from the stop dam; as a result, his assessment can provide a biased picture that is excessively rosy. But after all is said and done, his analysis offers a ray of hope to villages like Vadli and Kharod. William Barber, a World Bank hydrologist whom AKRSP had invited to advise on salinity ingress in late 1980's had left Gujarat after a doomsday prognosis. Barber asserted that complete secession of groundwater pumping for 30 years, nothing less, is what it would take to arrest salinity ingress in coastal Saurashtra. If Bhammar's assessment of the impact of Nikol *bandhara* is anything to go by, Saurashtra farmers may get away with a little less.

Impact on water table based on data on Static Water Level

A more interesting analysis that Gohil's paper (Gohil 2002) includes is based on observed values of water level changes in 30 talukas of Saurashtra in selected observation wells regularly monitored by the Gujarat Water Resources Development Corporation twice every year: once before the onset of the monsoon and then after its withdrawal. Figure12 plots the long-term average rise in static water level in wells in 30 talukas which indicate normal natural recharge averaged over a long period. Side

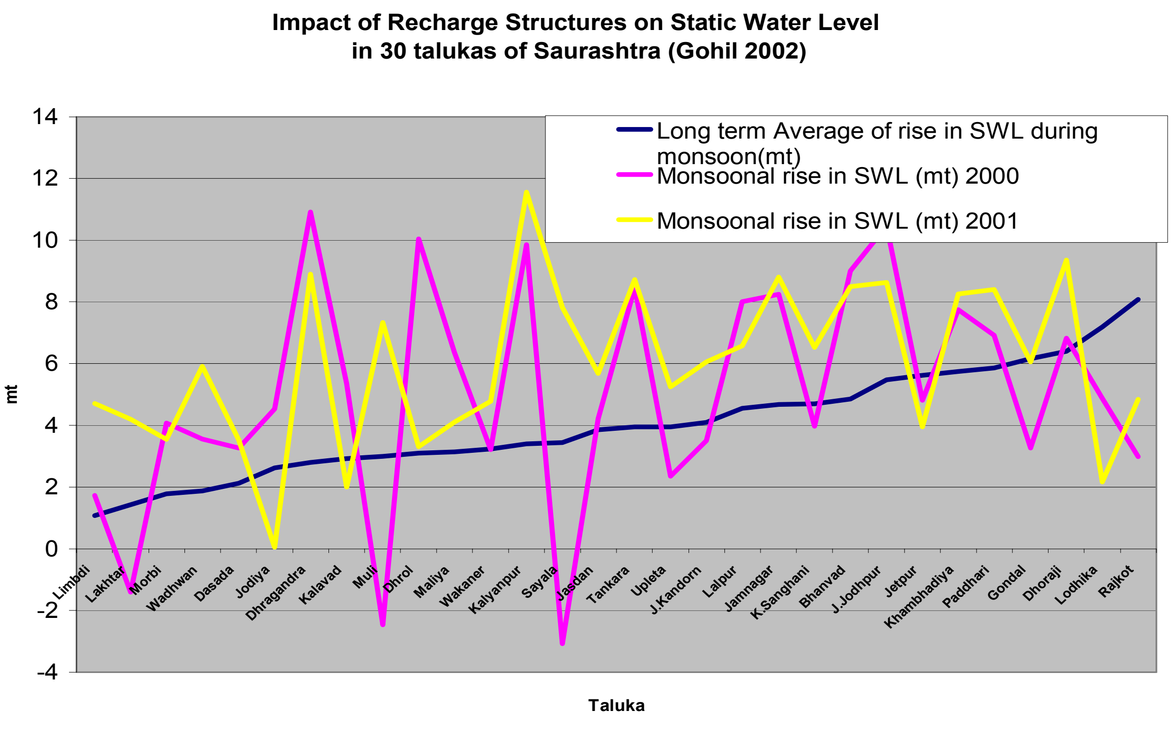

Figure 12

by side, it shows rise in SWL during July 2000 and July 2001, years that should show if a decade of decentralized water harvesting and recharge work has produced any real time recharge. If figure 12 were to be believed, there is strong evidence that SWL rise resulting from monsoonal precipitation is noticeably higher in 22 of the 30 talukas when compared to long term SWL rise. The effect was more pronounced in 2001 July than in 2000 July. This differential recharge performance can be explained either by higher rainfall in these two years, or improved 'recharge rate' or a combination of both.

Now, figure 13 plots three sets of rainfall data for the 30 talukas: long term average, and rainfall during July 2000 and July 2001. These show that barring 5 talukas, the remaining received less rainfall than the long-term average. Thus higher than normal rainfall during 2000 and 2001 does not seem to underlie the higher rise in SWL during 2000 and 2001 relative to the long term average. The only explanation left is improved recharge rate as a result of water harvesting and recharge activity.

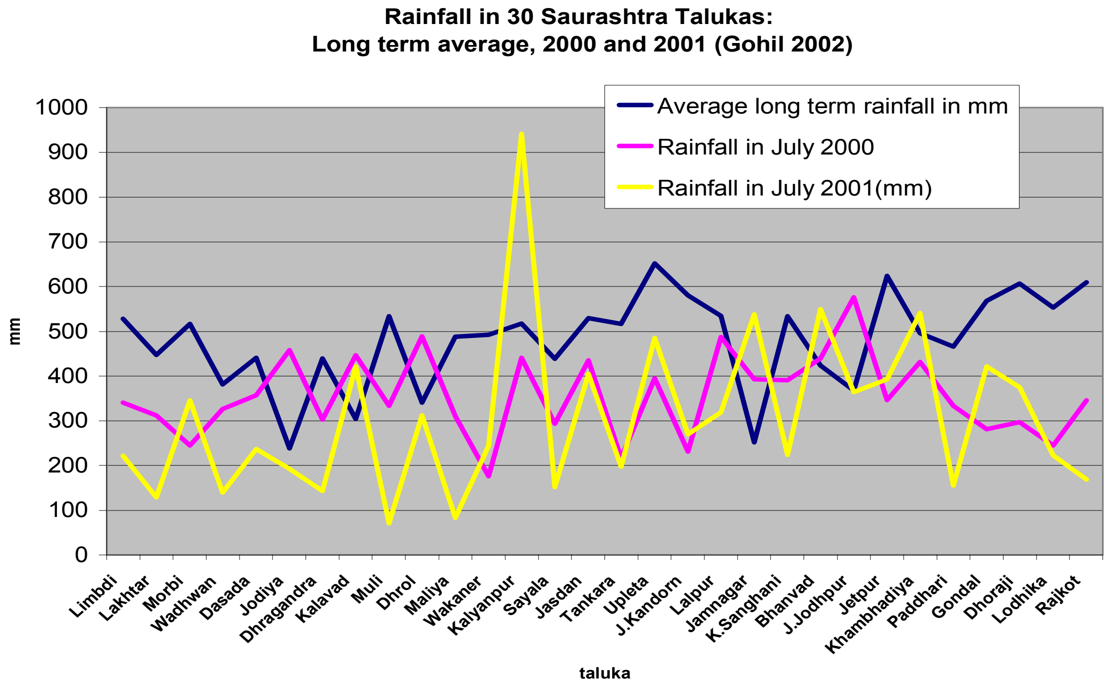

Figure 13

Figure 14 shows the same data for 30 talukas in Gujarat map. The first pair shows the long term average; and the next two pairs show the rainfall and SWL changes during the monsoon during 2000 and 2001 respectively. The long-term average maps show lower SWL rise despite higher rainfall. The latter maps show that during 2000 and 2001, although rainfall has been less than average, groundwater availability at the end of the monsoon is better in most talukas. Many critics believe that impacts of water harvesting and recharge movement are localized. But the GWRDC data offered by Gohil (2002) suggest these impacts are widespread and region-wide. These data suggest that because of water harvesting and recharge structures, post-monsoon static water tables in the 30 talukas tend to be higher by an average of 1 to 2 meters. If we apply this to all of Saurashtra, and take a specific yield of 15%, then we can say that the recharge movement makes 1.3-1.4 km^3 of additional groundwater (60000 km^2* 1.5*0.15) to Saurashtra after the monsoon. These also put in better perspective the significant biomass difference discernible in remote sensing images developed by Yan Chemin of IWMI for December 1989 and December 1999 using NOAA images (figure 15 below).

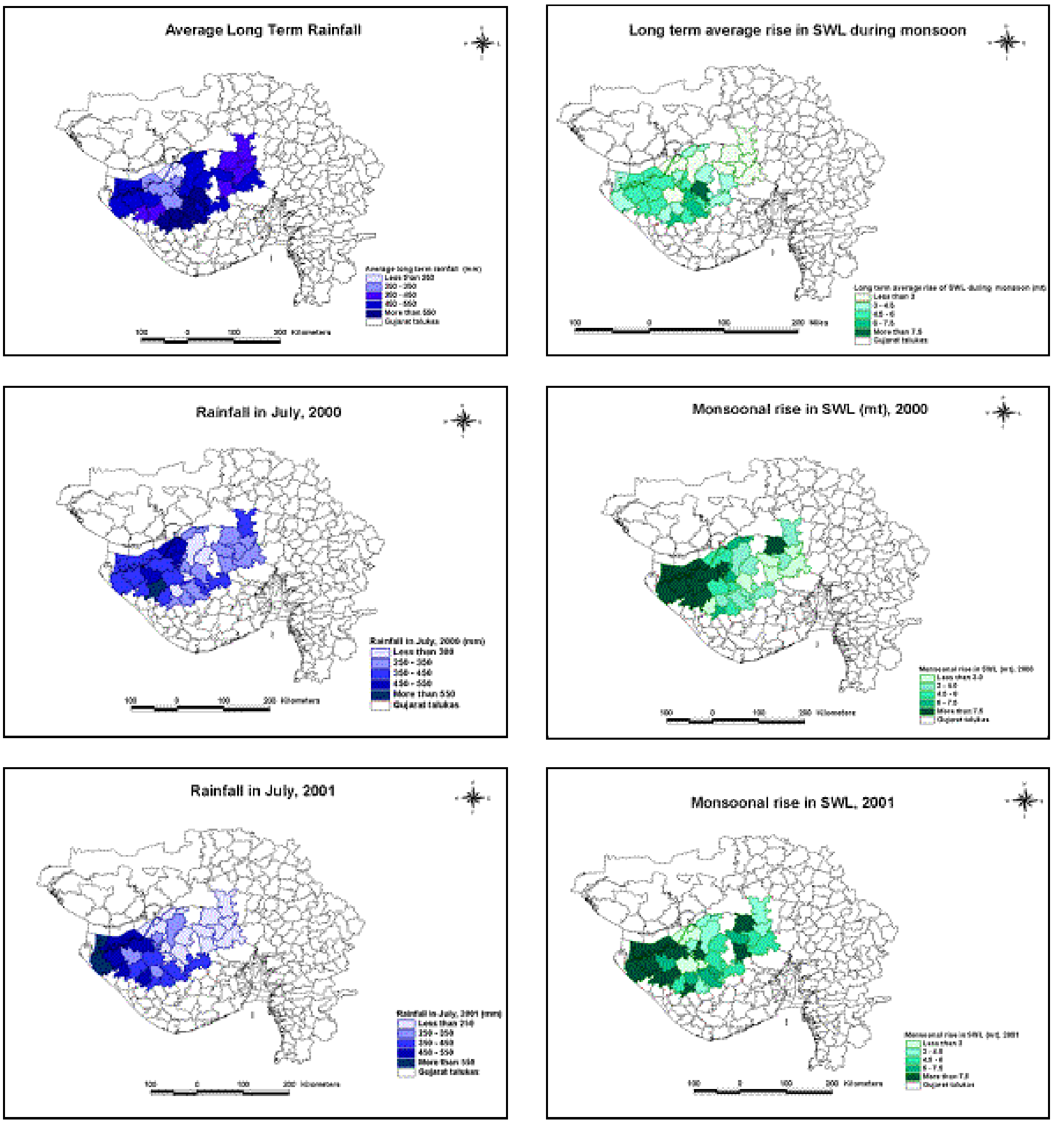

Figure 14

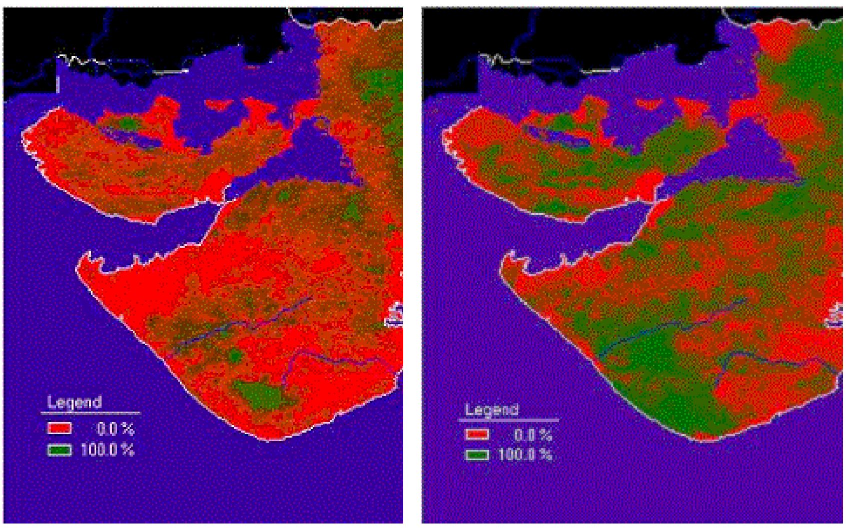

Figure 15

IV. Water-economizing Behavior

All in all, there seems growing evidence that the recharge movement is indeed helping augment groundwater supply that can assure kharif crop security—and more—in much of Saurashtra and a good deal of Kutch. Many NGOs and activists working for water harvesting and recharge programs in Saurashtra and Kutch however are beginning to get disillusioned. In a recent workshop on Kutch organized by OXFAM and UNDP in Ahmedabad (February 2, 2002), R K Sama of Vivekanand Research and Training Institute, who has personally overseen the construction of over 500 recharge structures in Kutch lamented that the more water we harvest and recharge, the longer the tube wells are pumped, and we are back to square one. More, in many situations, the water harvested by community effort and resources is usurped by a few powerful and resourceful farmers to expand their irrigated farming. He asserted results of studies show benefits of watershed development activities are often captured by only 10-12% of the farmers covered. But the greatest benefit that water harvesting confers is that the security of kharif crops restores the farmers' seriousness towards their farming and their land. In Saurashtra as well as Kutch, wherever recharge movement has produced results and helped farmers to save their kharif crops from early withdrawal of monsoon, there is a subtle shift in the mindset of the farmers. Water as a gift of God is no longer the ruling idiom; farmers are increasingly realizing that water—like other resources—needs to be 'produced', planned and husbanded. If this is true, then, the water harvesting movement has guided Gujarat into the first steps of groundwater *demand* management.

In a recent workshop organized by Aga Khan Rural Support Program, Ambuja Foundation and Gujarat Agriculture University, some 60 progressive and reflective farmers from Saurashtra exchanged experiences about sustaining agriculture in the face of groundwater depletion, and about growing high-value crops with less water. These discussions suggested some water-economizing behavior amongst farmers. Shifting to water-economical crops from water intensive ones is the most common form that water economizing assumes; however, other instances were presented too. Some farmers who tried Bt cotton—illegally, as it were-- found it yields 1000 kg/ha on just 1 or 2 irrigations. In many parts of Saurashtra, alternative furrow irrigation is rapidly becoming popular amongst progressive farmers; this results in 50% cut in pumping per acre without any sign of moisture stress in unwatered furrows.[11] Cotton, groundnut, wheat and orchard crops seem to do well with alternate furrow irrigation; but we met farmers who use it successfully on vegetable crops such as brinjal and tomato, too. Another practice which is gaining some popularity is reducing the length of the furrow. In groundnut fields, typically, farmers use long furrows that cut across the width of the entire field. Since it takes a long time for water to reach the other end of the furrow, much over-irrigation and seepage losses occur at the source-end. One answer many farmers are trying out is of limiting the length of the furrow; some others are trying out irrigating in '*kyari'* to ensure quick and uniform spread of water. One farmer explained how dragging a heavy sack filled with limestone and ash along the furrows made them smoother making water travel faster. Especially in vegetables (such as brinjal, tomato, kareli, coriander, chili) grown as a cash crop, farmers increasingly synchronize application of input and water with the market conditions; when the market is dull or glutted, 'survival inputs'—including irrigation-- are

[11] This is similar in some ways to alternative wet and dry irrigation approach that is gaining popularity amongst paddy farmers in China.

provided; these crops respond quickly to input application; so as soon as the market looks up, farmers raise the input levels to cash in on the market opportunity.

Amongst more progressive of the Saurashtra farmers at least, there is growing awareness that in sustaining profitable agriculture under water stress, the ball-game they need to master is of managing root-zone moisture levels. These farmers are now trying out new methods to do this better. Farmers distinguish between moisture needs of fibrous roots and deep roots. Many farmers have begun trying out the '*nik padhdhati*' (deepened furrow irrigation) for orchard crops—where furrows are dug up 50-100 cm, and fruit trees are planted inside so that their roots can get the required moisture. An increasingly popular technique of maximizing moisture productivity is of 'relay cultivation'. In this, a rain fed or water-economical crop is planted in an irrigated crop when it is maturing. Typically, in Saurashtra, farmers relay-plant tuwar or arhar or fodder jawar or maize in a ground nut field in 3:1 ratio, or two rows of til with one row of *tuver,* or *ajmo* and find the total value of output rising significantly without any additional irrigation since the relay planted crop germinates from soil moisture retained from irrigation provided to the main crop. Many have found mulching very useful for moisture retention, especially when mulch material is mixed with sand, but mulching encourages pests; to counter these, they successfully tried pasting the stem with mud before mulching which seems to check pest attack. Table 3 lists a set of on-farm water economizing practices that are slowly gaining ground amongst the progressive and forward looking farmers in Saurashtra. Perhaps, the next wave needed here is in wide-scale propagation of these and others which can help this region's agriculture flourish in the face of its scarce water resources.

Table 3:Water-economizing On-farm Irrigation Practices in Saurashtra

Traditional Practices	Emerging New Practices	Likely impacts
Planting of crops along the slope	Planting across the slope; slope converted into terraces	Rain water conservation; arresting soil erosion
Long furrows a general practice	Shorter furrows coming in use; 'nik' method of deepening the furrows and planting tree crops in it, or kyari's becoming popular.	Even spread or water; minimizing seepage
Mono-cropping; inter-cropping	Relay cropping of groundnut, cotton and castor with pulse and grain crops; of cotton with groundnuts, castor with groundnut, castor with fodder maize followed by wheat	Making best use of soil moisture
Flood irrigation of orchards	'Ring' irrigation of mangoes and other orchard crops; drip irrigation	Reducing water use per tree
Furrow irrigation	Use of hose pipe and cement pipe to transport water from well-head to furrows.	Minimizing seepage losses
Flood irrigation of each furrow	Alternate furrow irrigation, especially of cotton	Cutting irrigation water use by 40-50%
Little effort to reduce non-beneficial evaporation from furrows	Mulching gaining popularity; smoothening and hardening the surface of furrows and filling up cracks to minimize loss of irrigation water. Some farmers inter-cultivate and mulch to get the same effect	Root-zone moisture management
Obsession with chemical fertilizers	Renewed focus on organic manure as a method of soil nutrient and moisture management.	Root zone moisture management

Excessive dependence of wheat, cotton and oilseed crops	Gradual switch to orchards of mango, amla, aritha, sapota, ber, guava, promegenate, custard apple, lemon and to vegetable gardens and jojoba	Improving cash per drop; stabilizing farm incomes during drought
Irrigation directed to maximizing output	Irrigation and other inputs applied to maximize vegetable and fruit output to beat market glut.	Improving cash per drop; increasing supply to match market demand; fighting market glut
Over-irrigation of wheat, cotton and groundnut common	More farmers irrigate at crucial stages of plant growth to overcome moisture stress.	Improving crop per drop.
Irrigating directly from the well	Irrigating from an over-head or ground-level tank filled up with water from wells	To stop having to over-irrigate due to power supply uncertainty
Traditional HYVs	Genetically engineered new varieties such as BT cotton	Resistance to drought; high crop per drop.

Reflective amongst the Saurashtra farmers—some of whom were present in the Kodinar workshop—engage in continuing experimentation in water saving. Several mango orchard owners have been trying out continuous watering only alternate rows, and have found increased mango yield with lower water use. Others have tried groundnut meal and castor bran as manure that improves moisture retention of soils in the root-zone. Some others—facing extreme water stress—have successfully used 'matka' irrigation for a sapota plantation, orchards and vine crops. One farmer found he saved 75% on water in sugar cane by switching to *nik* method for irrigating it.

However, two aspects of this emerging water-economizing consciousness are note-worthy; first, almost all efforts are aimed at improving or protecting crops in the face of uncertain water supplies; second, there is no move anywhere for the community to bring a modicum of discipline or order or programming in the way members appropriate groundwater. One participant pointed out an unusual case of Gardar Vadi village in Ahmednagar district in Maharashtra where all bores have been sealed with cement and concrete at a uniform depth of 125 feet so that there is no competitive deepening. However, this remains a lone case in Maharashtra and there is nothing approaching it in Gujarat, barring some interesting applications of drip and sprinkler technologies.[12] In Rajapara [2] village of Talaja taluka, some progressive farmers have established a community sprinkler system which apparently has yielded good benefits in terms of total output and water savings.

Drip irrigation is considered particularly useful for irrigating orchard crops with saline water because it spreads salts over a larger area in the root zone. However, while many other water-economizing practices are gaining ground, the adoption of drip irrigation is not as rapid and widespread as it might. Lured by subsidies and hard sell from companies, many farmers by the system but fail to use it. In Talala area in Junagadh, for instance, many mango farmers installed a drip system but later removed the drippers and installed taps instead because they have been used to filling up the *'khamna'* (ring around the tree).

[12] Gardar Vadi village has a mango-based economy. A lone trader export-markets the mango produce of all of the village's farmers and delivers a significantly higher price than they can ever imagine. As a consequence, this trader has acquired a unique position of informal power and has been able to enforce a series of diktats—including the sealing of all bore holes at 125'—to transform Gardar Vadi into an environmentally ideal village. Exceptional this case may be; but this exception proves the rule that farmers need to be either bribed or coerced into accepting norms yielding collective good.

On paper, adoption figures for drip and sprinkler irrigation are impressive for Saurashtra; but their actual use is limited. Farmers have misconceptions: they think sprinkler-irrigated land tends to harden up; they also detest the hassle of repeated shifting around of the system. Some are deterred by the rat menace; and others believe sub-surface drippers get choked by roots growing into them. But the real barrier to wide-scale adoption seem to be the irrigation equipment companies which seem interested in skimming the subsidy cream more than saving water or helping farmer produce more. Many farmers get lured by free pipes the companies offer; farmers sign on the dotted line and Companies claim subsidies in tens of thousands against pipes that cost Rs 4-5 thousand they provide to farmers.

Concluding Remarks

We began this analysis with four questions: First, in principle at least, can decentralized water harvesting and groundwater recharge result in net improvement in *basin* or *region* level welfare? If not, is there emerging evidence of the movement waning, and people getting disillusioned, now that it has operated in a hyper-active mode for over a dozen years? Has the decentralized water harvesting and recharge movement stayed just that—water harvesting and recharge movement—or has it marked the first step to decentralized water resource management by communities? And, for populous, water-scarce countries like India, does Saurashtra represent a quirky exception or the harbinger of a broader, mainstream trend? If so, what might be its wider implications?

The evidence we reviewed offers some tentative answers: [a] Decentralized groundwater recharge can at least ensure security of the main kharif crop for most farmers in Saurashtra and Kutch; and if a large number of people are adversely hit by this activity—including towns people—there seems no significant sign yet of any big time opposition to water harvesting; [b] there seems little evidence of the waning of people's faith in the power of decentralized water harvesting to improve their livelihoods; [c] there are some early signs of an emerging consciousness of the need for water demand management, especially in agriculture; but this is essentially in response the need to save crops from declining well yield. There is no clear answer to the last question since Saurashtra and Kutch are different from other parts of Gujarat and Western India in several aspects of their socio-ecology.

There is evidence that recharge movement has produced broad-based positive impacts. The primary benefit is ensuring the security of the kharif crop which, farmers in Saurashtra and Kutch are unsure of in 3 years out of five because of frequent early withdrawal of monsoons. The water harvested and available close to the point of use has ensured that the kharif crop is saved from moisture stress towards the close of the season; and social value of this benefit is indeed great. This is enough to induce farmers to take farming seriously again, to invest in land care, as also in inputs. Water harvesting and recharge works also alter the micro-ambiance, helps establish vegetation and increase biomass.

There is much discussion of up-stream/down-stream inequities. In contrast, some suggest we need to focus on overall welfare of the state. MS Patel, Gujarat's Secretary of Water Resources, and a big supporter of decentralized recharge works, is one of the exponents of this view. According to Patel, of the 6.4 m ha of total land mass in Saurashtra, 4.2 m ha is under cultivation. Its 120 dams irrigate 3.5 lakh ha; Narmada is expected eventually to irrigate 4.5 lakh more bringing the total irrigated area to 8 lakh ha. As of now, groundwater irrigates 12 lakh ha. Still, 22 lakh ha is totally rainfed, limited to a single kharif crop. These farmers can be stabilized only if the kharif crop is secured—which can be done only through WHSs. In the 22 lakh ha of rainfed area, annual agricultural output is only Rs 1000-1500 crore; this, according to him, can go up to Rs 5000 crore with kharif-crop security. Patel also believes that the real water use efficiency issue in Saurashtra is not storing water in big versus small reservoirs, but in reservoirs versus aquifers. The water lost by evaporation from 2200 m m^3 of water stored in reservoir is 600 m m^3 which is greater than the total domestic water requirement of Saurashtra estimated to be 500 m m^3.

According to Patel, the big answer to Gujarat's water problems is check dams and more check dams. At a rate of 1 check dam per km^2, there is room to build nearly 50,000 in Saurashtra alone. Against this, Saurashtra has built less than 20,000, and that too, mostly in the central uplands; there is room and need for many more.

Annexes

Annexure 1: List of ITP-SPISER Studies on Gujarat Groundwater Economy

Sr. No.	Author	Title of the research proposal
1	Mahesh V. Joshi, Prof. Economics, Saurashtra University, Rajkot	Water crisis and water conservation in Saurastra
2	V J Bhammar, Sri Parekh Science, Arts and Commerce College, Mahuva, Dist. Bhavnagar	Impact of Bandhara Scheme on agricultural development
3	B M. Jani, Prof. Economics, Saurashtra University, Rajkot	Techno economic analysis of groundwater resources in Rajkot districts
4	Rohit J Desai, Lecturer in Economics, Arts and Commerce College, Khedbrakma, Dist. Sabarkantha	Estimates of groundwater in Sabarkantha district
5	Ashok B. Trivedi, Smt. H B. Sanghvi, Mahila Arts & Commerce College	Impact of watershed development on agriculture development
6	Premji M Patel, Sardar Patel Institute of Economic and Social Research, Thaltej Rd., Ahmedabad	Scarce area of water and water- shed – A Study
7	M G Sheikh & D R. Vajani, Sri K R Desai Arts and Com.College, Zalod, Dt. Dahod	Impact of over extraction of groundwater on village economy
8	Rajesh R Modi, Lecturer in Economics, Smt. V P Kapdia Mahila Arts College, High Court Road, Bhavnagar	Impact of groundwater irrigation on agriculture economy – A Case Study
9	K R Ram, Lecturer in Economics, Adivasi Arts and Commerce College, Santrampur, Dist. Panchmahal	Impact of over extraction of groundwater on rural economy
10	A D Gohil, Chotunagar Society, Raiya Road, Rajkot	Impact of water conservation and groundwater activity in Saurastra region
11	Ms. Swati Dave and Ms. Ila Shah, Sardar Patel Institute of Economic and Social research, Thaltej Road, Ahmedabad	Drinking water management distribution in Shilaj Village
12	Dilip H Parikh, Sardar Patel Institute of Economic and Social research, Thaltej Road, Ahmedabad	Rapid urbanization and problems of water
13	R.R.Bhatnagar, Sardar Patel Institute of Economic and Social research, Thaltej Road, Ahmedabad	Impact of excessive fluoride in groundwater on human beings and animals
14	Jayashree Soni, Centre for Social Studies, South Gujarat University Campus, Udhna-Magdalla Road, Surat	Water Scarcity and gender dimension
15	D.M. Rohit, Lecturer Adivasi Arts and Commerce College, Santrampur, dist. Panchmahals	Interlinkage between groundwater irrigation and rural electricity supply
16	Ms. Misha V Vyas and Bhavesh N Desai, Deptt. Of economics, Bhavnagar University, Bhavnagar	Impact of groundwater irrigation on agricultural economy with special reference to Mehsana dist.
17	Tushar R. Hathi, Somnath Society, Rajkot	Participatory role in water conservation and groundwater recharge-Issues and impact
18	H.T.Patel, Sardar Patel Institute of Economic and Social research, Thaltej Road, Ahmedabad	Impact of groundwater irrigation on agriculture economy
19	Paresh A. Raval, Deptt. Of Civil Engineering , Govt. Polytechnic,	Conjuctive use of surface and groundwater

	Ahmedabad	
20	Rema J. Shah, Head, Deptt. Of economics, Mahila Arts and Commerce College, Dhansura	Impact of groundwater irrigation on agriculture economy – A Case Study
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