Supply- and demand-side management of water in Gujarat, India: what can we learn?

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Abstract

Agriculture in Gujarat has grown rapidly over the last decade, driven at least partly by diversification to high value crops and dairying. High value agriculture requires better water control and offers higher returns for irrigation. Farmers, farm communities and the state government in Gujarat have responded to this requirement by implementing large-scale water supply and demand management projects like interlinking of rivers, the world’s largest popular recharge movement, electricity distribution reforms to limit use of subsidized energy for groundwater irrigation and rapid expansion of areas under micro-irrigation. Some of these programmes have already been declared successful and are being scaled up in Gujarat (like the Saurashtra recharge movement) and emulated elsewhere (like the Jyotirgram Yojana) without much critical scrutiny. Other programmes like the initiative to spread micro-irrigation have not received the attention they deserve from the research community in spite of their apparent success. This paper subjects the biggest on-going supply- and demand-side initiatives for water management in Gujarat to critical scrutiny in light of the recent data and tries to draw lessons for the state and other parts of India facing sustainable water management challenges.

Keywords: Aquifer recharge; Crop diversification; Demand-side management; High-value agriculture; Interbasin transfer; Supply-side management; Water scarcity

1. Background

Agriculture in Gujarat has grown rapidly at about 8% per year over the last decade (2000–01 to 2010–11) – almost three times as fast as the agricultural growth in the rest of India. A significant part of this growth is driven by rapid diversification of agriculture towards high value crops and allied activities like dairying is an important driver of this growth (Gulati et al., 2009). Food grains (cereals and pulses) accounted for less than one-tenth (9.86%) of the total value of output from agriculture and allied sectors


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in the state in 2008–09, compared to roughly 15% in 2000–01 and 20% in 1990–91. Nationally, this share was about 22% in 2008–09\(^1\).

High value crops and commercial dairy farming require better water control and offer higher returns on irrigation, even when not more water intensive. Gujarat, except its southern and central regions, is a water-scarce state with arid or semi-arid climate and frequent droughts. Its per capita annual renewable water availability is less than 60% of the national average of 2,000 cubic metres (IRMA, 2001) making water the major constraint to sustainable agricultural growth in the state.

Individual farmers, village communities and the government have all been highly active in developing the state’s water resources for agricultural use. Gujarat has one of the highest numbers of medium and large dams in India and the state is investing heavily in bulk interbasin transfer of water from the relatively water-rich southern Gujarat to the semi-arid northern regions. Spurred by financial support from local philanthropists, religious institutions and later the state government, farmers in Saurashtra and Kutch regions have built check dams and other small structures to recharge local aquifers on a scale not seen anywhere else in the world (Shah, 2000). In north Gujarat, where ever-receding aquifers make wells expensive and high-risk investments, farmers have come together to form tube-well companies to share risk and high capital costs (Dubash, 2002).

For decades, high investments, initiative and the institutional imagination shown in supply augmentation was not matched by initiatives on the demand side. In recent years, however, two large demand-side initiatives have caught policy makers’ attention: (i) power distribution reforms for rural areas through Jyotirgram Yojana (JGY) and (ii) rapid expansion of micro-irrigation through the Gujarat Green Revolution Company (GGRC).

Thus, the state of Gujarat has been at the forefront of experimenting with and implementing large public programmes to ensure that irrigated agriculture remains profitable and sustainable in the state even in its semi-arid and arid areas. A huge amount of public money is being spent on these initiatives. Programmes like the JGY and the Saurashtra recharge movement have already been declared a success and are being scaled up within the state and emulated by other states – all with scarce public resources. A critical review of these large public programmes of water supply and demand management in Gujarat may have useful lessons for other parts of India and the world. In this paper, we look at some of the largest supply- and demand-side interventions for agricultural water management in Gujarat using the latest data and observations from recent fieldwork by the author in July and August 2012.

Section 2 of the paper looks at water availability and the existing irrigation infrastructure of the state to highlight the potential and limitations for further development of water resources. Section 3 examines three large programmes, the Sardar Sarovar Project (SSP), the Sujalam–Sufalam programme and the Sardar Patel Participatory Water Conservation Scheme (SPPWCS), which are meant to increase water availability, while Section 4 explores two recent demand-side initiatives – the JGY and GGRC – which are meant to limit water use in agriculture. Section 5 summarizes our analysis and Section 6 concludes with some policy lessons.

\(^1\) These value shares are based on data on value of output of different agricultural commodities available on the website of Central Statistical Organization (CSO): http://mospi.nic.in/Mospi_New/site/home.aspx.
2. Irrigation infrastructure in Gujarat

2.1. Surface water

There are 185 river basins in Gujarat: 17 on the mainland, 71 in Saurashtra and 97 in Kutch with total surface water resources of 16,225 million cubic metres (MCM), 2,082 MCM and 206 MCM, respectively. Gujarat’s ultimate irrigation potential through surface irrigation, excluding the SSP, is estimated to be 2.15 million hectares (mha), of which 1.8 mha is from major and medium schemes and 0.348 mha from minor irrigation schemes. 85.5% of the ultimate potential (1.84 mha) has already been developed. SSP’s irrigation potential is assessed to be 1.8 mha, of which only 0.495 mha (<20%) had been developed by 2010. This means that most of the future increase in surface irrigated area in the state has to come from further development of the SSP to its design potential.

There are 21 major and 172 medium surface irrigation reservoirs (>10 MCM storage) in Gujarat with a total storage capacity of 16,062.28 MCM, which is 7.81% of existing live storage capacity of India. This number will rise to 8.15%, once the three major (Sardar Sarovar, Zankhari and Sidumber) and 18 medium-size irrigation projects, currently under construction, are completed. In water-scarce regions of north Gujarat, Saurashtra and Kutch, river basins are already over-appropriated (Table 1) and even for the state as a whole, the development level is quite high (~87%). Therefore, building new storage structures – small or large – may reconfigure the basins in terms of how the irrigated areas are distributed across the basin, but is unlikely to add to the total area irrigated (Kumar et al., 2008) unless there are significant efficiency improvements in water application. There is some anecdotal evidence that water from recharge structures built in the catchments of these over-appropriated basins is used more efficiently, as it is allowed to recharge aquifers and is then pumped (Shah, 2000). Better control and higher cost (of energy and time) associated with pump irrigation makes it more efficient than flow irrigation. However, we do not have good evidence of what happens to overall water use efficiency at the basin level.

Table 1. Number of medium and large dams and storage capacity by region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of dams</th>
<th>Total storage capacity (MCM)</th>
<th>% Appropriated (at 75% dependability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Gujarat</td>
<td>15</td>
<td>1,944.11</td>
<td>81.55*</td>
</tr>
<tr>
<td>South and central Gujarat</td>
<td>29</td>
<td>11,287.10</td>
<td></td>
</tr>
<tr>
<td>Kutch</td>
<td>20</td>
<td>300.47</td>
<td>145.86</td>
</tr>
<tr>
<td>Saurashtra</td>
<td>129</td>
<td>2,501.08</td>
<td>120.13</td>
</tr>
<tr>
<td>Total</td>
<td>193</td>
<td>16,062.8</td>
<td>86.76</td>
</tr>
</tbody>
</table>


3 The mainland includes districts of north Gujarat and central and south Gujarat.

4 This includes only reservoirs with live storage capacity greater than 10 MCM. Smaller reservoirs (capacity <10 MCM) account for just about 2% of India’s total live storage capacity.

5 Data for north Gujarat and south and central Gujarat are shown together in Table 1 and therefore it appears that river basins in north Gujarat are not over-appropriated. In fact all river basins in the region, except Watrak, are over-appropriated (Kumar, 2002).
2.2. Groundwater

Groundwater is becoming increasingly important for irrigated agriculture in Gujarat over time (Figure 1). Of the state’s gross irrigated area, 88% is irrigated from wells and tube wells. Whereas canals irrigate only 5.85% of net sown area (NSA) in the state, groundwater irrigates 25.7% of NSA (Shah & Singh, 2004). In Gujarat 36.19% of the NSA is irrigated. The total area as well as number of people benefiting from groundwater irrigation is much larger than canal irrigation. Ninety-five percent of Gujarat’s canal irrigation is concentrated in 20% of its talukas, mostly in south and central Gujarat, while groundwater irrigation is distributed more evenly (see Figure 2 in Shah & Singh, 2004) and the dependence on groundwater irrigation is higher in the water-scarce regions of the state.

Shah & Singh (2004) show that an additional hectare (ha) brought under canal irrigation has a larger impact on farm output per person and rural poverty compared to groundwater irrigation. Also land productivity is higher in talukas with high canal irrigation density than those with higher groundwater irrigation intensity. When canal irrigation is available, it has a higher productivity and poverty-reducing effect than groundwater irrigation. However, canal irrigation is limited to a relatively smaller area.

According to the data submitted by the four electricity distribution companies to the Gujarat Electricity Regulatory Commission (GERC), there were 0.89 million electrified agricultural wells in Gujarat in December 2011. There are another 0.24 million wells powered by diesel pumps. On average, every fifth operational holding in the state is equipped with a mechanized well and a large number of operational holders access groundwater through local water markets.

Unlike surface irrigation, there is not much scope left to bring more area under groundwater irrigation as almost 80% of the state’s groundwater irrigation potential of 2.55 mha has already been developed. The state’s utilisable annual groundwater recharge is estimated to be 15.02 billion cubic metres (BCM) while the gross annual draft for irrigation is around 10.49 BCM (CGWB (Central Ground Water Board),

Fig. 1. Decadal pattern in source-wise net irrigated area in Gujarat (’000 ha). Source: Graph plotted by the author using data from Directorate of Economics and Statistics, Government of Gujarat (several years).

6 A taluka is an administrative division below the district level. There are 226 talukas and 26 districts in Gujarat.
Gross annual draft already exceeds utilizable recharge in north Gujarat (Mehsana, Banaskantha, Patan and Gandhinagar) by about 40% and in Ahmedabad district, the annual draft is more than 90% of the utilizable recharge.

2.3. Reliability and drought proofing ability of irrigation

Gujarat is a drought-prone state. There was a drought declared in large parts of the state in 10 of the last 30 years (1985, 1986, 1987, 1998, 1999, 2000, 2001, 2002, 2003 and 2012). Therefore, it is important to Gujarati farmers that their sources of irrigation are resilient to variations in rainfall.

The surface irrigated area in the state shrinks significantly in years of poor rainfall. This poor reliability in years of low rainfall is a major limitation of canal irrigation in Gujarat. **Figure 2** shows the net irrigated area by surface water for the four regions of Gujarat from 1971/72 to 2003/04, and **Figure 3** shows the groundwater irrigated area. The surface irrigated area has increased steadily in central and south Gujarat while there is no trend increase in other parts of the state. The graph shows wide year-to-year fluctuations in the surface irrigated area in the water-scarce north Gujarat, Saurashtra and Kutch. The irrigated area falls sharply in years of poor rainfall. The coefficient of variation in mean annual rainfall is higher in these low rainfall regions and they are more vulnerable to droughts. The large number of reservoirs (129 in Saurashtra, 15 in N. Gujarat and 20 in Kutch) built in these semi-arid and arid parts of the state are not able to protect farmers from an erratic monsoon. This becomes clearer from **Figures 4 and 5** where we juxtapose surface irrigated area in Saurashtra and north Gujarat with mean annual rainfall data in the respective regions. Regression of surface irrigated area against mean annual rainfall returns positive and statistically significant coefficients in all three water-scarce regions of the state (table not shown here, but can be furnished on request). Thus, except in the central and southern region, major and medium-size irrigation systems seem to be the farmers’ fair-weather friends in the state: they irrigate and offer high returns (higher than groundwater irrigation) when rainfall is good, but fail to provide even drought-proofing when the monsoon fails.

On the other hand, groundwater irrigated area has been increasing in all four regions of the state (**Figure 3**) and except in Saurashtra (**Figure 6**), the groundwater irrigated area is not significantly affected by inter-annual variability in rainfall. **Figure 3** shows the groundwater irrigated area. Even in water-scarce north Gujarat and Kutch, groundwater provides effective drought proofing because of deep alluvial aquifers. However, the situation is different in Saurashtra. Here both surface and groundwater irrigated areas fall sharply in years of low rainfall. In spite of its 129 reservoirs and nearly half a million (0.495 million in 2003) mechanized wells and tube wells, irrigated agriculture in Saurashtra continues to be vulnerable to weather. Unlike in north Gujarat and Kutch, even groundwater does not offer good buffer in Saurashtra because the hard rock aquifers there have limited storage capacity. They need to be replenished every year and, in fact, several times in a year. This is one of the reasons why there is a popular demand for a large number of water harvesting and recharge structures to be built in the region (Shah, 2000). These structures store additional water from high intensity rainfall events for future use. This water is often used for one or two crop-saving irrigations in the late Kharif or early Rabi seasons when the marginal value of irrigation is very high. Perusal of recent data shows that groundwater irrigated area in Saurashtra has become less sensitive to fluctuations in rainfall than in the past, while there is an opposite trend in the surface irrigation area. Both these trends may have resulted from construction of a large number of recharge structures in the upstream of reservoirs in the region. However, we need more years of irrigation data to make a definite statement.
Unlike many other states such as Bihar, West Bengal, or Kerala, Gujarat is relatively land rich\(^7\) and water scarce. Previously, we saw how, besides the SSP, there is not enough unutilized water left in the state to expand the net irrigated area, at least, not through conventional methods of building more reservoirs and sinking more wells. More than three-quarters of available run-off and recharge are already being diverted for irrigation and municipal uses. Many of the state’s river basins are over-appropriated.

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\(^7\) Average operational holding size in Gujarat at 2.33 ha is the third largest in India after Rajasthan and Punjab. According to 1995/96 Agricultural Census, Gujarat’s average operational holding was 1.9 times larger than the national average (2.62 ha vs. 1.41 ha). Only 30\% of Gujarat’s operational holdings are marginal compared with 62\% at the national level.
and groundwater over-exploitation is a serious problem in several districts. Outside the central and south region, surface irrigation systems fail to provide effective drought proofing in years of low rainfall and in Saurashtra, even groundwater irrigation is susceptible to the vagaries of monsoon. Given the limited availability of unutilized water resources and the low reliability of existing irrigation systems in the state, it seems that the main challenge that Gujarat’s irrigation managers face is to improve sustainability, reliability and productivity of irrigation. Meeting this challenge requires both supply augmentation and demand management.

Fig. 4. Net surface irrigated (’000 ha) area and mean monsoon rainfall (mm) in Saurashtra from 1971 to 2003. Sources: Irrigated area from Directorate of Economics and Statistics, Government of Gujarat (several years); rainfall data from Fishman (2011).

Fig. 5. Net surface irrigated (’000 ha) area and mean monsoon rainfall (mm) in north Gujarat from 1971 to 2002. Sources: Irrigated area from Directorate of Economics and Statistics, Government of Gujarat (several years); rainfall data from Fishman (2011).
3. Supply-side interventions

Using water from Narmada – the largest west flowing river in India – is the keystone of the government of Gujarat’s supply-side strategies to expand the irrigated area and improve reliability and sustainability of irrigation in the state. Narmada is a water-rich basin with an average annual run off of 41 km$^3$ and 75% dependable flow of 34.5 km$^3$, of which Gujarat’s allocated share is 11.1 km$^3$ although the state was able to utilize only 6.3 km$^3$ (or 57%) of its allocation until 2009/10 (Table 2 in IRAP (Institute for Resource Analysis and Policy), 2012). The strategy is capital intensive and sometimes technically challenging, but there is popular support and political will for it.

3.1. The Sardar Sarovar Project

The SSP, built on the Narmada, has a design command area of 1.8 mha, of which only 0.495 mha had been developed up until June 2010 and only 0.253 mha of land was actually irrigated in 2010 (Government of Gujarat, 2011)$^8$. There will be a quantum jump in the irrigated area in Gujarat if the SSP command area is fully developed. It is a big ‘if’ however. The irrigated area from SSP increased only by about 0.1 mha between 2002 and 2010.

The command area development has stalled because it was envisaged in SSP’s planning that the state would build distribution systems up to minor canals while farmers will build sub-minor canals and field channels on their land with their own money and organization to bring water to their fields. Farmers, however, have refused to part with their land without compensation from the government and are reluctant to organize construction of the last mile of the infrastructure for themselves. Only 20,600 km of the 74,000 km sub-minor canals had been completed by May 2012. Instead of constructing sub-minor canals and field channels, farmers have invested in diesel pumps and plastic pipes to lift water from

$^8$ Irrigated area from SSP was 0.13 m ha in 2002, 0.153 m ha in 2007/08 and 0.253 m ha in 2010.
distributaries and minors. This has resulted in more efficient use of water, but at a higher cost and in smaller areas compared to the design command (Talati & Shah, 2004). Constructing the rest of the sub-minor canals and much longer field channels requires huge investment of money and effort in land acquisition by the government. The government has tried to rope in non-governmental organizations to persuade local communities, but there has been little progress. Planners of SSP had thought that the potential irrigation surplus would be incentive enough for farmers to organize and build the water distribution infrastructure in their villages. The potential surplus has been realized wherever farmers have irrigated from SSP (IRAP, 2012), but ironically the surplus has driven up land prices making farmers unwilling to part with their land.

3.2. River linking and interbasin transfer of water

Since the command area of SSP has not been fully developed yet and Madhya Pradesh – the upper riparian in Narmada – has not built its share of reservoirs on the river, there is surplus water in the system. The government of Gujarat is implementing river-linking projects to use this surplus water to recharge aquifers in depleted areas of the state and supplement water availability in major and medium irrigation systems with low dependability levels to improve their dependability. Water from Narmada is being used to fill 11 rivers of Gujarat that fall en route to the Narmada main canal. This initiative has revived some of these rivers that used to be dry for most of the year. The most striking effect is seen in Sabarmati River in Ahmedabad city where a riverfront development project is underway to capitalize on the aesthetic value created by the river flowing with water from Narmada.

A second and more ambitious interbasin water transfer project called Sujalam–Sufalam (richly-watered, richly-fruited) involves using excess water from Narmada and Mahi rivers to recharge aquifers and fill-in major and medium reservoirs in 10 districts of Gujarat (viz. Mehsana, Patan, Gandhinagar, Banaskantha, Sabarkantha, Ahmedabad, Panchmahals, Dahod, Surendranagar and Kutch) where water is scarce. This Rs. 62 billion (US$1.4 billion) scheme was launched in 2004 and it has three big components: (1) pumping ‘excess’ water from the Narmada canal into nine dams: Dharoi, Mazham, Meshwo, Vatrak, Hathmati, Goohai, Mukteshwar, Sipu and Dantiwada; (2) a 337.525 km long unlined spreading canal linking Kadana dam on the Mahi river to the Banas river crossing 21 rivers in north Gujarat to carry 700 MCM of water into these rivers and hundreds of ponds and recharge the aquifers in north Gujarat and (3) building 0.2 million farm ponds for aquifer recharge. The project aims to revive falling groundwater levels and mitigate the problem of fluoride contamination in 2,791 villages, nitrate contamination in 456 villages and salinity ingress in 92 villages of the state. It is also claimed that the rise in groundwater table would save 2,700 MW of electricity and Rs. 1,091 crores (US $227.9 million) in power subsidies to the farm sector every year.

There are few systematic studies of the actual impact of the project. In an early assessment, Ranade & Kumar (2004) argued that recharging aquifers in parts of north Gujarat that fall outside Sardar Sarovar irrigation project’s command area requires lifting water by about 75 m at a high energy cost and this may prove to be uneconomical unless farmers use this pumped water much more productively.

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10 These rivers are: Heran, Orsang, Karad, Mahi, Saidak, Mohar, Watrak, Sabarmati, Khari, Rupen and Banas.
Ranade & Kumar (2004) had done their analysis before the project started. I travelled to north Gujarat in 2007, 3 years after the project started and large parts of the spreading canal had been built and asked senior officials of the electricity utility company in north Gujarat (UGVCL) about the effect of Sujalam–Sufalam on electricity consumption for irrigation. They told me that they had not experienced any reduction in power use in the farm sector in the years since the project started. I could not ascertain other recharge benefits from the project either. In fact, the project was mired in controversy owing to the alleged incidence of corruption (Indian Express, 2008)11 and structural problems. Soon after the water was released into the spreading canal, it started crumbling at several points of its 337 km stretch, not being able to handle the deluge of water entering it. Portions of the canal caved in and the canal suffered severe damage on its lining wall and approaches. In a repeat visit in July 2012, I found that the canal was largely in disuse and was widely considered as a failure by farmers and even government officials.

Even as the interbasin transfer of water through the unlined canal has faltered, the Rs. 30 billion (in current 2002 prices) project diverting water from the Narmada main canal to fill nine medium and large reservoirs in north Gujarat12 and 5,000 village tanks using a network of pipelines is being implemented. This project is not only capital intensive, but also highly energy intensive, as large volumes of water have to be lifted by a height of about 75 m to reach the reservoirs in north Gujarat.

I did a short fieldwork along the Piaz-Dharoi (PD) pipeline – one of the six pipelines in the project – in July 2012. This pipeline lifts or 4.96 cumec (cubic metres per second) (175 cusecs (cubic feet per second)) of water from Narmada main canal near Kalol in Gandhinagar district and puts it into the Dharoi reservoir in Banaskantha district. Eighteen pumps (with a total capacity of 16,200 KVA (kilovoltamps) or 12.6 MW) work day and night to lift the water13. The energy cost of pumping water alone comes to about Rs. 1.00/m³ at current electricity prices, which is close to what farmers in north Gujarat pay for irrigation water (see Table 2 in Kumar et al., 2011). The total cost would be much higher. Such high costs can be justified only if this water is used efficiently.

Of the total 4.96 cumec water lifted from this pipeline, 0.85 cumec is used to provide clean, treated drinking water to villages in Kalol, Mansa and Vijapur talukas – all areas where groundwater has a high fluoride concentration and high total dissolved solids (TDS). Improvements in public health from clean drinking water will form a big fraction of the total benefits of this project, although less than 20% of total water is used for this purpose.

A fraction of water from the pipeline is used to fill 32 large ponds and work is in progress to link three more ponds to the system. Villagers can lift water directly from these ponds for irrigation by paying an irrigation fee of Rs. 506/ha/season. This is too low a price for water that is being delivered at such high cost even if we factor in the pumping costs to the farmer. Most of the irrigation benefits, however, will accrue from recharging of aquifers. In my fieldwork in villages in Vijapur taluka in Mehsana district, I found that there was a great demand from different villages to fill up their village ponds with water from the PD pipeline to recharge their aquifers. In one village, Chadasan, farmers told me that they

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12 These reservoirs are: Dharoi, Hathmati, Guhai, Mazam, Meshwo, Watrak, Mukteshwar, Sipu, Dantiwada.
13 There are three pumping stations along the pipeline: one in Piaz near Gandhinagar, another in Lodha in Mehsana district and the third in Rampur. Each pumping station has eight pumps of which six are pumping water at any given time. Each pumping station is also equipped with a water filtration plant for drinking water.
have been petitioning the irrigation minister repeatedly to link their village tank to the system. They even got their pond deepened using their own resources to facilitate the process. Given the high demand for water from the pipeline, the government has proposed that villages that bring all the entire cropped area under micro-irrigation will get priority. The government will provide 80% subsidy for micro-irrigation systems (MIS).

In a setting where the government cannot institute property rights for groundwater, charge a volumetric price, or even raise electricity tariffs, it seems to be a sensible step to encourage farmers and village communities to switch to micro-irrigation to increase water productivity and water use efficiency, especially when water is being brought to the fields at such high costs to the taxpayer. Increasing the area under high value crops and mainstreaming precision irrigation technologies may make this expensive scheme of interbasin transfer of water economically viable in future. Even then the taxpayer will continue to bear the high operational costs of water transfer because it is unlikely that farmers will pay for it.

3.3. Sardar Patel Participatory Water Conservation Scheme

While the first supply-side programme that we discussed involves interbasin transfer of large volumes of water, the second, the popular recharge movement of Saurashtra, is built on the slogan of keeping village water in the village. Both programmes seek to reconfigure water-scarce reverse basins of the state, but use very different approaches and scales of activity.

In the late 1990s, a decentralized movement for water harvesting and groundwater recharge started in Saurashtra and Kutch in response to the water scarcity and drought proneness faced by the region. Initiated by local grassroots organizations and funded by local communities and philanthropies, the movement soon acquired a scale and broad-based support not seen before. While the government had taken years to build only 2,500 check dams in the state, the people built thousands in a few months. Swayed by popular support and demand, the state government launched the SPPWCS in January 2000, with simplified procedures for approval of projects and release of funds and 60% capital subsidy for construction of check dams14. The scheme received an overwhelming response. More than 45,000 structures had been built under the scheme up until June 2007. Altogether, 90,000 check dams have been built in Gujarat under different government schemes along with 35,000 bori bundhs and 1.71 lakh farm ponds. Of the 90,000 check dams, about half (44.3%) have been built in seven districts of Saurashtra (Amreli, Bhavnagar, Jamnagar, Junagadh, Porbandar, Rajkot and Surendranagar) alone.

Experts disagree on the impact of the large number of recharge structures built in Saurashtra. Some hydrologists (Kumar et al., 2006, 2008) argue that water harvesting in water-scarce regions like Saurashtra does not offer any potential for groundwater recharge or improving water supplies at the basin level. They cite many check dams as drawbacks to water-harvesting structures. (1) Water-harvesting structures have a negative downstream hydrological impact in closed basins, especially in the years of low rainfall when little run-off is generated. (2) Given the high inter-annual variability in rainfall and the nature of aquifers in Saurashtra, these structures are unlikely to provide effective drought proofing and have

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14 The scheme provided an 80% subsidy in tribal areas. From April 2005, the subsidy has been increased to 80% throughout the state.
high costs for every cubic metre of additional water stored. A typical hectare of an aquifer in Saurashtra can absorb and store at most 400–500 m³ of water, which is a small fraction of the total water needed to irrigate a crop. If more water is used to recharge using current methods, aquifers in much of Saurashtra would not be able to hold that water and it would reappear on the ground as ‘rejected recharge’ (R Sakthivadivel, as cited in Shah & Desai, 2002). (3) Storing water in a large number of check dams, instead of a few larger reservoirs, leads to greater loss, owing to evapotranspiration, and is therefore inefficient.

On the other hand, proponents of water harvesting and recharge argue that the recharge movement in Saurashtra and Kutch is ensuring the security of the kharif crop through supplemental irrigation in later stages. They also find evidence of significantly higher availability of groundwater after the withdrawal of the monsoon, roughly of the order of 1–1.2 km³ in Saurashtra (Shah & Desai, 2002). An independent evaluation of the check dams in Gujarat was carried out in 2002 by the Indian Institute of Management (IIM), Ahmedabad (Shingi & Asopa, 2002) using data collected from over 100 check dams in Saurashtra and concluded the following. (1) Localized rainwater-harvesting systems in the form of check dams in Saurashtra contain a proven solution to the water crisis that is simple, based on local skills, is cost-effective and environmentally friendly. (2) It is economically and financially very sound with a short payback period. It helps women and promotes people’s participation. Given all these positives, they recommended that ‘the rainwater-harvesting efforts initiated with the people’s participation and support from SPPWCP should be relaunched and implemented on a larger scale’. The detractors argue that farm-level analysis of the benefits of a water-harvesting structure, as did the above study, ignores the downstream impact of such structures in the river basin (Ray & Bijarnia, 2006).

Thus, we find that there are contradictory views among experts on almost every aspect of check dams and other water-harvesting structures: their downstream impact, their effectiveness in drought proofing, their cost-effectiveness and even their non-productive social impacts, and both sides present empirical data in support of their contention. However, most of these studies are based on recall data and this author could not find any rigorous technical or economic study of the impact of water harvesting in Saurashtra. While the debate among the experts continues in an atmosphere of limited empirical data and lack of rigorous observation, the local community continues to build new structures with support from government. In fact the government has increased incentives for building more recharge structures by raising the subsidy from 60 to 80% in the fourth phase of SPPWCs even though the biggest objection to the project has been its likely negative effect on major and medium reservoirs owned and operated by the government.

4. Demand-side intervention

While supply-side interventions try to augment the available water, demand-side efforts are aimed at improving water use efficiency. There is a general agreement that effective demand-side measures are essential to ensure the long-term sustainability of irrigation in Gujarat. Supply-side measures require engineering interventions while demand-side measures mostly involve changing incentives (pricing and allocation rules) and fostering innovations (new technologies/practices). Here we will discuss two demand-side policy interventions – one indirect (JGY) and one direct (incentives for micro-irrigation) – by the government of Gujarat to improve water use efficiency in irrigation.
4.1. Jyotirgram Yojana

There are 0.89 million electrified irrigation wells in Gujarat that consume nearly 30% (13.24 billion kWh of a total consumption of 43.62 billion kWh) of the total electricity consumed in the state and pump more than 90% of the total groundwater used for irrigation. Farmers in Gujarat receive 8 hours of power every day. The rationing of hours of power supply serves to limit the total energy use in the farm sector, the total subsidy that irrigators receive and indirectly the total volume of groundwater pumped for irrigation, provided it is not accompanied by an increase in the connected load (Kumar, 2005). The Jyotirgram scheme was implemented between the years 2004 and 2007 to make sure that rationing the power supply to the agricultural sector is effective in controlling energy use and that this rationing does not have negative effects on non-agricultural users of power in rural areas. A separate wire network was laid for electric wells in all 18,000 villages of the state at a cost of US$0.29 billion (Rs. 1,290 crore) for this purpose. Now, non-agricultural users in rural Gujarat receive a 24-hour power supply while farmers get 8 hours of daily power supply at full voltage on a pre-announced schedule. Unlike the past, now farmers cannot use capacitors to use electricity beyond their designated hours.

An early assessment of JGY by Shah & Verma (2008) reports government figures that show a decline in electricity use for irrigation from 15.7 billion units in 2001 to 9.9 billion units in 2006, a reduction of 37%. Authors attribute a part of this decline in energy use to good monsoons in 2005 and 2006, yet they find ‘unmistakable evidence of tube well irrigation shrinking’ in these data owing to implementation of JGY.

The ‘unmistakable evidence’, however, disappears when we look at the more recent data on electricity used for irrigation in Gujarat and compare them with data before Jyotirgram (2003/04). We find that the electricity sales to pump owners increased from 11.61 billion units in 2003/04 to 13.24 billion units in 2010/11 (Figure 7), an increase of about 15% in 7 years. The actual increase in agricultural use of electricity may be even higher because earlier the measurement of power consumption was flawed and the utility tended to overestimate it in order to claim a higher subsidy refund from the state government. The accounting of power use has improved with the implementation of JGY, a significant contribution of the scheme. The total number of agricultural connections has also increased from 0.6 million to 0.89 million in this period – an increase of 50%. This means that after JGY, the number of pump sets has increased while the annual electricity use per pump has decreased from 19,000 units to 15,000 units. Therefore, a survey of a few pump owners may indicate a decline in energy and water use, but the aggregate picture is the opposite.

It seems that the politically well-organized farmers of Gujarat allowed JGY to be implemented only after the scheme’s potential to enforce strict rationing was blunted by releasing new connections, allowing farmers to pump more water with the same hours of electricity. JGY may have resulted in a better power distribution system in rural Gujarat, better energy accounting, reduced negative externalities in non-agricultural sectors and more farmer satisfaction owing to improved quality of power supply, but it did not lead to reduction in agricultural use of power or groundwater in the state as was claimed in some of the early quick assessments of the scheme.

The ‘grand promise’ of JGY to ‘transform a degenerate power-pricing-cum-supply regime into a rational one’ has been repeated in a number of research publications (see Shah & Verma, 2008; Shah et al., 2008; Mukherji et al., 2010). These studies claim that JGY enabled government of Gujarat to enforce rationing of electricity use and control the size of the farm power subsidy and the amount of water pumped and it turned the tables on tube well owners who now have to manage with the power they get. Enthused by these
positive reports of the ‘breakthrough’ achieved by JGY, many other state governments in India (e.g. Karnataka, Madhya Pradesh and Andhra Pradesh) are now trying to implement a JGY-like feeder separation scheme at high costs. GERC’s own data, however, tell a more sobering tale. JGY did not manage to reduce overall energy (or water) use in agriculture in Gujarat. Shah & Verma (2008) claim:

*Gujarat under the JGS has shown that effective rationing of power supply can indeed act as a powerful, indeed all powerful, tool for groundwater demand management.*

In fact, the experience of JGY in Gujarat shows that it is difficult to enforce a groundwater management regime on a community of well-organized farmers through technological fixes like JGY. JGY may provide the technological ability to enforce rationing electricity use, but the actual use of this capability would require political concession from farmers. Top-down technological fixes for reducing water use are unlikely to work when water is a critical input and its users are politically powerful.

4.2. Gujarat Green Revolution Company: the spread of micro-irrigation

The government of Gujarat is aggressively promoting micro-irrigation in the state with financial assistance from the central government. In 2005, the state set up a special purpose vehicle called GGRC to act as a nodal agency to promote MIS. GGRC has helped to install MIS on more than 0.42 mha of land since 2006/07 and the demand is rapidly increasing (Figure 8). Covering nearly 5% of NSA and 15% of net irrigated area under micro-irrigation in just 5 years is a significant achievement, especially given that not much was achieved in the two decades before GGRC, in spite of high rates of subsidy.

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15 Figures for year 2005–06 are not available.
Studies by IWMI in Gujarat and Maharashtra (Namara et al., 2005) and Madhya Pradesh (Verma et al., 2004) show that farmers adopt micro-irrigation, not to save water, but to bring greater areas under irrigation or to provide more water for their irrigated crops. As a result, the adoption is more likely when water is scarce relative to land, that is, when there is not enough water to irrigate all the available land. This is the situation in Saurashtra and north Gujarat and data from GGRC show that indeed there is greater demand for MIS in these two regions (Table 2).

We can expect even more expansion in area under micro-irrigation as water scarcity increases. Expansion of areas under high-value crops like cotton and fruits and vegetables, which require better water control, will also encourage greater adoption of micro-irrigation devices. Water buyers and part owners of tube wells (mainly in north Gujarat) outnumber pump owners in Gujarat. Adoption of micro-irrigation devices is difficult for them because they do not get water at a high enough pressure in their plots and cannot afford to irrigate as frequently as is often needed with the adoption of MIS. This is a major constraint in the expansion of micro-irrigation in several parts of Gujarat, especially the water-scarce northern parts of the state (Kumar, 2007).

While growing water scarcity and an increase in cultivation of high-value crops that offer higher returns to irrigation have helped spur the use of micro-irrigation in Gujarat in the last 5–6 years, the state government’s initiative and judicious policies have also played a role in creating demand and ensuring that this demand is met.

### 4.2.1. What is Gujarat doing better in promoting micro-irrigation?

The government of Gujarat created a single nodal body, the GGRC, to spread micro-irrigation. GGRC processes farmers’ applications for subsidy and monitors the installation of MIS. This single-window system has accelerated the installation of MIS and reduced the transaction costs of getting the subsidy. All farmers, small and large, are eligible for subsidy and they can avail the subsidy on as much land as they own. A third party does

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16 A recent study by Kumar et al. (2010) shows that use of micro-irrigation in north Gujarat also led to real water saving at the farm level, besides other benefits of increasing yield, profits and water productivity.
physical verification and trial run of the system at all installation sites. Further, the local agricultural university audits the inspected sites of the third party. Two reputable academic institutions, Center for Environmental Planning and Technology (CEPT) and Gujarat Engineering Research Institute (GERI), are designated to inspect the factories of manufacturers and the quality of their components. Finally, there is a high level of transparency with farmer-level data available on GGRC’s website for anyone to verify. GGRC requires that micro-irrigation installers also offer extension services to farmers. There are strict norms regarding number of extension workers to be deployed per hectare of land and number of expert visits to installation sites.

Thus, the government of Gujarat has simplified the process of accessing the subsidy for farmers and manufacturers, removed the need for targeting of subsidies, ensured that there is competition among manufacturers by allowing farmers to choose between approved brands, ensured quality of components and installation by instituting third party audits, arranged for post-installation extension support for farmers and created a transparent system for verification and monitoring.

5. Key findings from our study

Except for its central and southern parts, Gujarat is a water-scarce state. Aquifers are already highly developed and most river basins are over-appropriated even though only one-third of the NSA is irrigated. Expanding the irrigated area and sustaining irrigation on already irrigated lands is a challenge. The government of Gujarat is trying to meet this challenge mainly by building new infrastructure like river linking schemes and thousands of small recharge structures. These infrastructure projects have high capital cost and sometimes even high operating costs. The high investments and costs can be justified only if the water use efficiency increases significantly. The state, however, is not able to institutionalize measures like water pricing, volumetric allocation of water, property rights in water, subsidy reduction on power supply for irrigation, and so on, to increase water use efficiency for political and logistical reasons. Thus constrained, it is aggressively promoting MIS and has tried to enforce rationing of electricity use for irrigation. Some of these supply- and demand-side efforts have already been declared a success and are being scaled up within the state and emulated elsewhere, but our review of literature and the recent data show that these success stories are built upon doubtful evidence and superficial analysis. More rigorous impact evaluation of these large public schemes is needed to inform the policy process.

Table 2. Spread of micro-irrigation in different regions of Gujarat in 2011–12.

<table>
<thead>
<tr>
<th>Region</th>
<th>Region’s share (%) in Gujarat’s total NSA*</th>
<th>Region’s share (%) in total area under MIS in Gujarat</th>
<th>% of NSA in the region that is covered under MIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Gujarat</td>
<td>21</td>
<td>29.33</td>
<td>5.95</td>
</tr>
<tr>
<td>South and central</td>
<td>33</td>
<td>26.1</td>
<td>3.40</td>
</tr>
<tr>
<td>Gujarat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saurashtra</td>
<td>40</td>
<td>40.77</td>
<td>4.45</td>
</tr>
<tr>
<td>Kutch</td>
<td>6</td>
<td>3.80</td>
<td>2.54</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>4.3</td>
</tr>
</tbody>
</table>


NSA = net sown area; *This is approximate and it varies slightly from year to year. MIS = micro-irrigation system.
6. Conclusion

Gujarat’s agriculture has grown rapidly in the last decade in spite of growing water scarcity. Indeed our surmise is that water scarcity could be one of the main drivers of agricultural growth as is apparent from the fact that the growth is seen mainly in water-scarce regions of the state. Unable to intensify land use owing to lack of sufficient irrigation water, farmers here have adopted the path of diversification into high value crops (Table 3) and dairying.

Diversification of agriculture may enhance the demand for water (as in dairy) or it may reduce overall water demand (as in cotton and castor). While the implications of diversification for overall water use are not clear, what is indeed clear is that farmers will demand more reliable and flexible supplies of irrigation water in the future. This will offer both challenges and opportunities. The challenge is to provide high quality irrigation on demand by reconfiguring existing irrigation systems and taking care of the long-term sustainability issues. The opportunity lies in the fact that diversified agriculture would also mean more income per drop of water, which means that farmers might be willing to pay higher prices for a reliable and flexible supply of irrigation water.

Demand for irrigation is already on the top of the agenda of farmers in Gujarat and this is unlikely to change in the near future. Increased demand for better water management and the ability to pay for better services makes it probable that agriculture in Gujarat will follow the growth trajectory charted by high value agriculture practiced in the north China plains. In north China, as in Gujarat, farmers have responded to water scarcity by diversification of agriculture on the one hand and adopting better and water-saving irrigation technologies on the other (Shah, 2006).

Fortunately, for a variety of reasons, the political leadership in Gujarat is keenly attuned to farmers’ demands. The keen interest of the political leadership, the strong power of the farming lobby and an increased stake of the agro-processing and dairy sectors in water economy makes it likely that the state of Gujarat will keep investing in the water sector in ways that fulfill the demands of the farmers.

However, analysis of the last three decades of irrigation data suggests a need for rethinking of the state’s water policy. Barring south Gujarat, agricultural use of water reached or crossed sustainable limits long ago (Kumar & Singh, 2001) while more than 60% of the state’s NSA still remains rainfed. Expanding the irrigated area to more parched lands (outside the Sardar Sarovar command area) will require a new strategy; building new dams and sinking new wells is not going to work. As irrigation expands to hitherto un-irrigated areas in the catchments, river basins and irrigation systems will be reconfigured creating new challenges, both hydrological and political.

Finally, even as access to irrigation remains limited in Gujarat – only one-third of land is irrigated and only one in five of farmers in the state own tube wells – the value added by irrigation is rapidly rising. This means that irrigation rent is likely to rise and the inequality between farmers who have direct access...
to irrigation and those who do not have it (share croppers, water buyers, small and marginal farmers) may increase in the future. While this paper has not looked into this aspect, nevertheless, inequalities stemming from unequal access to water resources in a high growth environment would be a legitimate topic of research in the future.

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