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Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India

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ABSTRACT

Gujarat, a rapidly industrializing state in western India, is notorious for groundwater over-exploitation. A perverse link between energy subsidies and groundwater overdraft has left the state with a bankrupt electricity utility and depleted aquifers, especially since the late 1980s. Moreover, this perverse relationship has meant that groundwater irrigators have essentially held Gujarat's non-farm rural economy to ransom. Efforts to regulate groundwater overdraft since the early 1970s have been unsuccessful, as have attempts to charge a rational electricity tariff to groundwater irrigators. During 2003–2006, drawing upon a proposal outlined by researchers, the government launched the *Jyotigram* (lighted village) scheme, which invested US\$ 290 million to separate agricultural electricity feeders from non-agricultural ones, and established a tight regimen for farm power rationing in the countryside. By 2006, Gujarat covered almost all of its 18,000 villages under the *Jyotigram* scheme of rationalized power supply. With this, two major changes have occurred: (a) villages receive 24 h three-phase power supply for domestic uses, in schools, hospitals, village industries, all subject to metered tariff; (b) tubewell owners receive 8 h/day of power of full voltage and on a pre-announced schedule. The *Jyotigram* scheme has radically improved the quality of village life, spurred non-farm economic enterprises, halved the power subsidy to agriculture, and reduced groundwater overdraft. It has also produced positive and negative impacts on medium and large farmers, while notably harming marginal farmers and the landless, who depend for their access to irrigation on water markets which have become much smaller, post-*Jyotigram*. In addition, the water prices charged by tubewell owners have increased by 30–50%. We propose that the *Jyotigram* scheme, with some refinements, can be implemented successfully in other regions of South Asia facing similar challenges of groundwater governance.

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1. Groundwater irrigation and stress in Gujarat

Situated in the western-most part of India, the state of Gujarat, with a population of 51million, is enclosed on three sides by a 1600 km Arabian sea coastline. Geographically, the eastern mainland of Gujarat is humid in the south and semi-arid in the north. In the west, the Saurashtra peninsula is divided from the mainland by the Gulf of Kutch, which is separated from the mainland Gujarat to the east and Pakistan to the north by the low-lying desert called the Rann of Kutch. The state can be conveniently divided into four hydro-geological zones: (a) humid south Gujarat with alluvial aquifers; (b) semi-arid central and eastern Gujarat with alluvial aquifers in some parts and hard-rock aquifers in others; (c) arid north-Gujarat and Kutch with mostly alluvial aquifers, and (d) semi-arid Saurashtra with mostly hard-rock aquifers.

The state displays great variability in terms of its agro-meteorological and climatic conditions. Most of Gujarat, except some southern districts, represents one of the most water-stressed regions of India (Fig. 1). The hydrology of the state is characterized by wide spatial variations in rainfall (377 mm in Kutch to 1875 mm in the Dangs), and high year-to-year fluctuations in rainfall with the coefficient of variation ranging from 25% in Dangs to 80% in Kutch (IRMA, 2001). The state has a history of frequent droughts and famines. A famine Gujarat suffered in 1900 was so severe that a third of the population and most of the livestock perished (Yagnik and Sheth, 2005). Today, Gujarat is one of India's most rapidly growing states in industrial and economic terms. Yet, some 57% of the state's population is rural and more than 45% depends on agriculture for its livelihood. Even as the share of agriculture in the state's domestic product has declined to about 15%, the number of workers employed in agriculture has not declined as rapidly. As a result, the performance of the agrarian economy affects large sections of the population. Through the 1980s and 1990s, Gujarat's agricultural economy recorded a negative



Fig. 1 – Map of India showing the state of Gujarat.

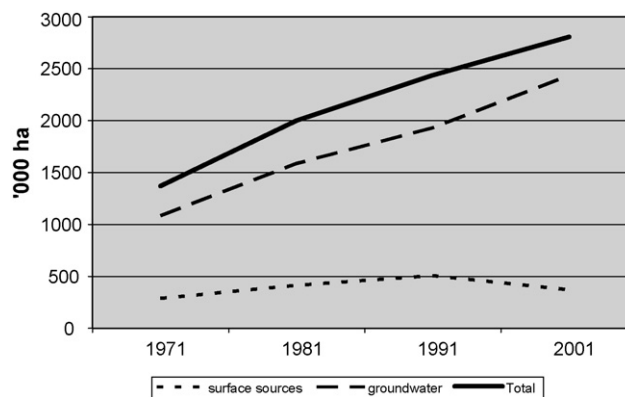


Fig. 2 – Trends in irrigation from surface and groundwater in Gujarat.

trend rate of growth, which has been a matter of great concern for the state's planners (Bagchi et al., 2005).

The state has several perennial rivers in the south. However, the colonial government, which built massive irrigation infrastructure in northwestern and peninsular India from 1830 through 1940, found the cost of irrigation schemes in Gujarat to be high and left the state's agriculture at the mercy of rains and groundwater irrigation. Being enterprising, many Gujarati farmers enthusiastically developed wells for irrigation. Their efforts have been enhanced over time by the availability of powerful diesel engines in the last years of the 19th century, and buried pipeline networks. Sophisticated water markets were established in central Gujarat in the early decades of the 20th century (Hardiman, 1998; Shah, 1993).

After India's independence in 1947, Gujarat invested heavily in canal irrigation projects. Yet, its agriculture continued to depend heavily on irrigation with wells and tubewells (Fig. 2). During the 1950s and 1960s, farmers used mostly diesel engines to pump groundwater. However, as rural electrification progressed, they began switching to submersible electric pumps, especially as diesel pumps were unable to chase declining water levels (Fig. 3). As a result, between 1971 and 2001, while the use of diesel pumps in irrigation increased by 56%, the use of electric pumps increased by 585%.

By the mid-1980s, widespread groundwater depletion had become a matter of concern. A decade later, depletion assumed the proportions of a crisis in semi-arid alluvial North Gujarat and Kutch, and in hard-rock areas of Saurashtra. India's Central Ground Water Board assessed that out of Gujarat's 184 talukas¹, 31 were already withdrawing every year more groundwater than the long-term annual recharge creating a negative groundwater balance. Twelve more talukas were on the border-line, drafting 90% of the estimated 'safe yield'. Of the remaining, 69 talukas were drafting 65% of the 'safe yield' but experiencing rapid development of the resource. Fig. 4 shows the differing levels of groundwater development in the districts of Gujarat.

High fluoride concentrations and salinity levels in groundwater, the main source of drinking water supply, were

¹ A taluka is a sub-district administrative unit covering roughly 100–120 villages.

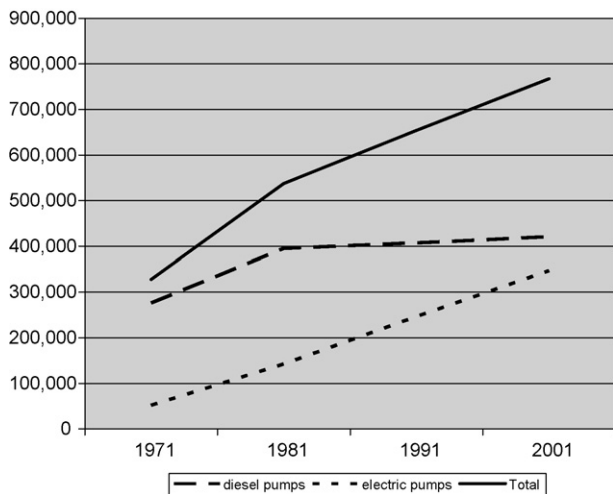


Fig. 3 – Trends in the number of diesel and electric pumps for irrigation in Gujarat.

detected in 16 of Gujarat's 25 districts in the early 2000s². In North Gujarat, groundwater tables had dropped so low that 'tubewell companies' of farmers replaced numerous individual-owned tubewells to share the large investment – and the risk of failure – associated with installing deep tubewells, fitted with 90 to 120 horsepower submersible pumps and buried pipeline networks for water distribution (Shah and Bhattacharya, 1993).

In search of effective policies for groundwater regulation, Gujarat's leaders and administrators have turned for guidance to experience in other countries. Global experience with groundwater regulation has been dominated by four *direct* policy instruments that seek to regulate the behavior of groundwater users (Shah, 2008).

- *Direct administrative regulation* involves laws or executive orders requiring the issue of licences/permits, prescribing the volume of groundwater the permit holder is entitled to extract, or specifying norms for the distance to be maintained between existing and new wells. Oman, Iran, Saudi Arabia, Israel, and China are among the countries that have experimented with such regulation (Shah, 2008).
- *Economic instruments* include charges and taxes levied on irrigation wells or the volume of water withdrawn, such as in China, under its 1994 Water Law (Wang et al., 2007), and in Mexico, under its Law of the Nation's Waters (Shah et al., 2004a; Scott and Shah, 2004; Sandoval, 2004) and in Israel (Feitelson, 2006). Jordan created a 'quasi water police' to measure withdrawals from irrigation wells, enforce pumping quotas and levy a volumetric groundwater fee (World Bank, 2000 World Bank and the Swiss Agency for Development Co-operation 2000).
- *Tradable water rights* for groundwater have been tried in the western United States and in Chile. By making these rights tradable, some countries have tried to create markets for

² http://cgwb.gov.in/gw_profiles/st_Gujarat.htm visited on September 25, 2007.

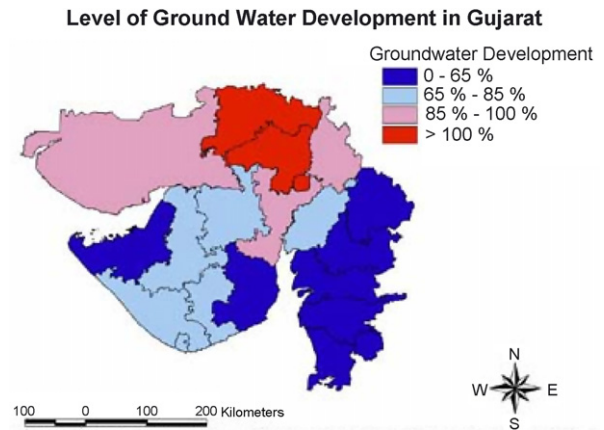


Fig. 4 – Level of groundwater development in Gujarat.

water rights that are somewhat different from the pump irrigation service markets found in South Asia (Shah, 2006).

- *Participatory aquifer management by groundwater communities* is based on the western United States experience with groundwater districts. This model has been tried in Spain and Mexico, where aquifer users are registered and organized into associations with a mandate to manage the aquifer on a sustainable basis (Sandoval, 2004; Villarroja and Aldwell, 1998).

These models have been widely discussed in Gujarat, especially during recent decades. Gujarat's policy makers explored several options for direct regulation of individual tubewell owners to reduce the stress on aquifers. In 1973, Gujarat's legislative assembly became the first among the Indian states to pass a groundwater act. However, the chief minister did not sign the act, due to concern regarding the administrative and logistical problems of enforcing an act pertaining to more than 300,000 dispersed owners of irrigation wells in Gujarat at that time. In 2001, Gujarat created a State Groundwater Authority to control and regulate groundwater use, and an effort to create a new law is underway. However, by 2000, Gujarat had more than 1.044 million irrigation wells (Government of India, 2005), and the logistics of enforcing a law pertaining to so many well owners scattered in the countryside will be substantial.

There is also the question of "vote-bank politics." Over the years, groundwater irrigators in Gujarat have become a powerful pressure group that can mobilize large numbers of votes in the state's general elections around their common concern about irrigation. In India's parliamentary democracy, the ruling political elite can harm the interests of such powerful vote-banks only at the risk of undermining their political power. Finally, mounting evidence from countries like Spain and Mexico has shown that direct regulation of groundwater withdrawal by irrigators is difficult, even where they are far fewer and more visible than in India (Sandoval, 2004; Villarroja and Aldwell, 1998; Shah et al., 2004a). This has spurred a search for practical and politically feasible mechanisms for regulating groundwater withdrawals not by trying to change 'individual conduct' of countless farmers through law

and policing, but by modifying the ‘environment of conduct’ (Lowi, 1972). The remainder of this paper reports on one such innovative mechanism that Gujarat has tried in recent years, as the state has attempted to solve the twin problems of declining aquifers and a bankrupt electricity industry.

2. Metering and flat-rate tariffs

Until 1989, electric tubewell owners in Gujarat were charged for electricity based on metered consumption of electricity used for pumping groundwater. However, as electric tubewells increased to hundreds of thousands, meter reading and billing began to entail high transaction costs. Monitoring numerous dispersed metered tubewells also gave rise to rampant corruption and malpractice by farmers and the staff of the electricity board. Under the commercial metered tariff in force then, farmers had incentive to manipulate meters and readings. Some staff members of the electricity utility conspired with tubewell owners in such wrong practices, and collected bribes. Farmers sometimes also complained about the arbitrariness of the Gujarat Electricity Board (GEB)’s meter readers.

The problem was not confined to Gujarat. Other states of India also were contending with high transaction costs of metered farm power supply. A 1985 study by India’s Rural Electrification Corporation showed that metering, meter reading and billing costs accounted for more than 30% of the cost of supplying power to tubewells in Uttar Pradesh and Maharashtra (Shah, 1993). Uttar Pradesh switched from metered charges for farm power to a flat-rate tariff based on the horsepower of pumps, a system that eliminated meters and meter reading.

Comparative studies of Uttar Pradesh and Gujarat showed that flat-rate power tariffs induced tubewell owners in Uttar Pradesh to sell irrigation water to marginal farmers and sharecroppers at one-third the price charged by tubewell owners in Gujarat (Shah, 1989). Using these studies, researchers advised the GEB and government leaders of the equity benefits of a flat-rate tariff regime, but also emphasized the need to establish the flat-rate tariff at a level high enough to ensure average cost recovery. Researchers also highlighted the critical need for effective rationing of farm power supply in groundwater-stressed regions (Shah, 1993). Farmers also aggressively demanded the switch to a flat-rate tariff.

In 1989, the GEB changed from metered tariffs to flat-rate tariffs linked to the horsepower of pumps. As expected, the new flat-rate tariff system produced major beneficial productivity and equity impacts on smallholder irrigation. Since the marginal cost of electricity to tubewell owners was zero, they were induced to sell water to marginal farmers and sharecroppers who were unable to afford their own tubewells. Competition among sellers resulted in reduced prices of pump irrigation service in local, informal water markets, greatly benefiting the poor. The flat-rate tariff also expanded groundwater irrigation, increased the utilization of tubewells, and reduced the GEB’s cost of metering and billing for electricity used for tubewells.

However, the ill effects of the flat-rate tariff were substantial. Farmers had to pay electricity charges even during the monsoon, when they used little irrigation water. Most seriously,

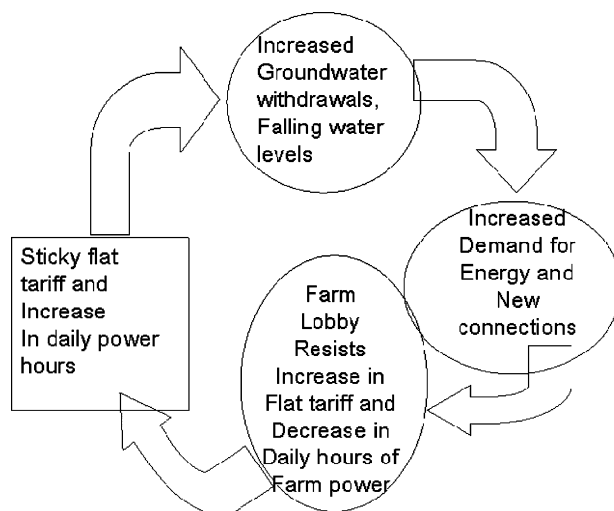


Fig. 5 – Vicious cycle of electricity subsidies and groundwater over-exploitation.

the flat-rate tariff could not be easily revised upward to recover the cost of increasing electricity use in groundwater irrigation. The GEB tried reducing power supply to agriculture to maintain the economic viability of its agricultural operations. However, farmer lobbies strongly opposed government efforts to increase the flat-rate tariff or reduce the daily hours of farm power supply, leading to mounting losses to the GEB on its agricultural account. By the mid-1990s, this electricity–groundwater nexus had become a vicious cycle (Fig. 5). Resisting any increase in the flat-rate power tariff or decreasing daily hours of farm power supply became a central agenda item, around which Gujarat’s farming classes mobilized support in the state’s mass politics.

The flat-rate tariff, without effective rationing of farm power supply, led to a rapid increase in groundwater withdrawals and a lowering of groundwater levels. It also increased the demand for electricity connections for new tubewells. Falling water levels in turn required farmers to install bigger pumps, consuming more energy, which at commercial rates would make irrigated agriculture unviable in regions like North Gujarat. This led to further consolidation of tubewell vote-banks to protect the flat-rate tariff and hours of farm power supply. The GEB was one of the more solvent state electricity utilities in India until 1990; but a decade later, it was losing US\$ 550 million/year³ (EPD, 2007), with a good part of the loss attributed to farm power subsidies.

Despite farmer opposition, the GEB had no option but to gradually reduce power supply to agriculture. During the 1980s, Gujarat’s villages were able to obtain 18–20 h of three-phase electricity per day. This declined to just 10–12 h per day by 2000. The bargaining game between the political leadership and farm lobbies generally comes to a climax before the state’s assembly elections. While in many other states – such as Punjab, Andhra Pradesh and Tamil Nadu – chief ministerial aspirants won elections promising free farm power, in Gujarat, the least the aspirants were expected to do was to promise more farm power hours/day without raising flat-rate tariff. Being a

³ US\$ = Indian Rs. 40.

state utility, the GEB was forced to comply with pre-election commitments politicians made. However, the quality and timing of power supply deteriorated. Three-phase power supply came with low voltage, often during the nights and with frequent trips—all of which damaged motors and added to farmers' repair and maintenance costs of tubewells. Poor and inadequate power supply to villages became the key issue in Gujarat's mass politics.

Victims of this perverse game of bargaining were the non-farm rural electricity consumers. Since the 11 kV (kilo-volt) feeders serving tubewells were also serving non-farm rural users, the GEB had no way to ration power supply to tubewells without also reducing power supply to domestic and other rural users as well. Normally, single-phase or two-phase power that can run domestic appliances is provided 24 h but three-phase power required to operate tubewells, grain mills and other heavy equipment is restricted to 10–12 h per day. To evade this system of rationing, farmers everywhere in Gujarat began using phase-splitting capacitors (locally called *tota*) to convert two – or, sometimes, even single-phase power – into three-phase power to run their irrigation pumps. This created a new class of problems for the rural power system. It reduced the voltage downstream, affecting the village community, while tubewells continued to operate unhindered for 18–20 h per day. The rural society and its non-farm economy gradually became the hostage of the burgeoning groundwater economy of Gujarat. Power engineers consider capacitors to be the gateway to improved power factor (pf)⁴; but in rural Gujarat, farmers turned these into a tool for pilfering power.

The best way out of this complex situation, it was commonly argued, was to meter tubewells, provide 24-h quality power to farmers, and charge metered tariffs at cost. Shah et al. (2004b) had argued that, although correct in principle, taking this route in present conditions would resurrect the logistical problems of metering, which motivated Gujarat (and other Indian states) to implement flat-rate tariffs. They argued that this would attract strident farmer opposition on a large scale, and if the experience in other states was any indication, compromise the political prospects of a leader who championed it. Instead, Shah et al. (2004b) argued for a second-best solution of separating feeders, supplying power to tubewells from other rural feeders, and undertaking intelligent rationing of power supply to tubewells in a way that mimics a high-performing canal irrigation system.

In particular, suggestions included: (a) a flat-rate tariff on farm power use should be raised gradually to approach the average cost of power consumed by a tubewell; (b) low-cost off-peak night power should be judiciously used to minimize the average cost of farm power supply; (c) intelligent scheduling and management of rationed power supply to the farm sector should be the central elements of the strategy of effective co-management of groundwater and electricity use in agriculture. Shah et al. (2004b) anticipated that “farmers will no doubt resist such rationing of power supply. However, their

resistance can be reduced through proactive and intelligent supply management” by: (a) enhancing the *predictability* and *reliability* of power supply; (b) improving the *quality* in terms of voltage and frequency, and minimizing tripping; and (c) better matching of power supply with peak periods of moisture stress.

During 2001–2002, this proposal, henceforth referred to as the IWMI proposal, was shared with key policy makers in Gujarat government and the GEB. The IWMI proposal seemed timely since around then Gujarat was in the midst of major power sector restructuring exercise with a US\$ 300 million loan from the Asian Development Bank (ADB). Power generation and transmission/distribution were unbundled with the latter task taken over by five regional power distribution companies, each mandated to operate on commercial principles. The key impediment in the exercise was farm power. The ADB's answer, and conditionality, was metering of farm power supply. But in view of stiff farmer opposition, the government of Gujarat retracted from it, whereupon the ADB suspended the release of the loan installment. Instead of metering tubewells, however, in September 2003, the Government of Gujarat launched the *Jyotigram* scheme (JGS), which not only included key recommendations of the IWMI proposal but also went far beyond them, and unleashed a new wave of rural development in the state.

3. The *jyotigram* scheme

In Gujarati, *Jyotigram* means ‘the light of the village’. The basic idea is to improve quality of rural life through better power supply environment. The *Jyotigram* scheme (JGS) was launched initially in eight districts of Gujarat on a pilot basis but by November, 2004, it was extended to the entire state. By 2006 more than 95% of Gujarat's 18,000 villages were covered under JGS. This was an ambitious undertaking that involved laying a parallel rural transmission network across the state at an investment of US\$ 290 million. It involved complete rewiring of rural Gujarat, deploying 48,852 km of high tension lines and 7119 km of low tension wires, 12,621 new transformers and 1470 specially designed transformers (SDTs⁵), 1.2 million new electricity poles, 182,000 km of electricity conductors, 610,000 km of low tension PVC cables, and 30,000 mt of steel products. All this was aimed primarily at bifurcating, at the substation level, feeders supplying electricity to agricultural connections from those supplying rural commercial and residential connections. Meters on distribution transformer centers were also installed on both the sides of feeders to improve the accuracy for energy accounting.

Fig. 6a and b show the changes that took place at the feeder level. Before the JGS, at the lowest level, 11 kV feeders served a group of 2–5 villages wherein all connections in these villages (domestic, agricultural as well as commercial) were served through this feeder (see Fig. 6a). With JGS, the feeders were bifurcated into agricultural and non-agricultural feeders (Fig. 6b). This meant that certain feeders only served farm

⁴ Motors running irrigation pumps have a pf of 0.7–0.8, which the use of a capacitor can raise to 1. A 100 kVA transformer can be connected to 26 motors of 5 hp with capacitors instead of 18 without getting overloaded. Capacitors improve the voltage and reduce the load on the transformer and in general curtail power loss in distribution. See, PRAYAS (2004).

⁵ These were equipped to shut off power supply on the entire feeder if the load increased above a minimum prescribed level, making it easy for GEB staff to identify illegal power use.

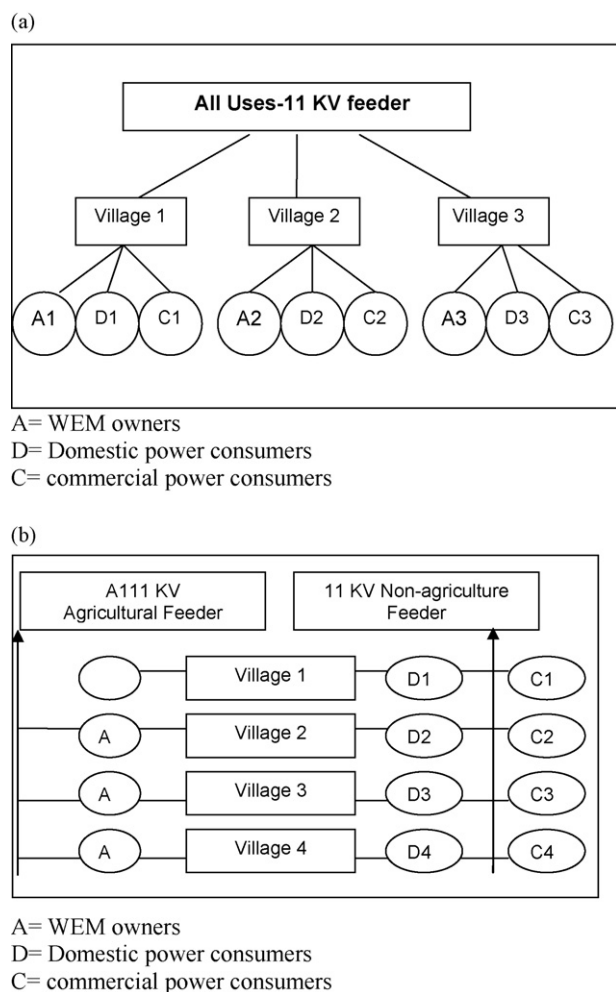


Fig. 6 – (a) Electricity network before JGS. (b) Electricity network after JGS.

tubewell connections while the rest served only domestic and commercial customers. Meters on agricultural feeders were meant to identify the source of any *significantly-greater-than-expected* demand.

In rural Gujarat, thus rewired, two changes occurred in JGS villages: (a) the villages began receiving 24 h three-phase power supply for domestic uses, in schools, hospitals, and village industries; (b) farmers began receiving 8 h per day of three-phase power supply, but of full voltage and on a pre-announced schedule, after which power supply was discontinued on those feeders making it impossible for tubewell owners to use capacitors. Every village receives agricultural power during the day and night in alternate weeks that are pre-announced.

4. Results

The Jyotigram scheme is described by the government of Gujarat as a win-win solution. Studies by Institute of Rural Management Anand (IRMA, *in press*) and the Ahmedabad based Centre for Environment Planning and Technology

(CEPT, 2004) describe many ways in which the JGS has improved village life. However, neither study describes the new dynamic that the JGS has generated in Gujarat's agriculture and its groundwater economy. In early 2007, we undertook a quick assessment of the impacts of the JGS in 55 Gujarat villages spread over 10 districts. The study emphasized impacts on Gujarat's groundwater economy. The individual case studies developed by local researchers can be obtained by writing to p.reghu@cgiar.org.

We summarize the case studies to provide a preliminary assessment of JGS impacts and highlight its lessons for co-management of electricity and groundwater. Our findings regarding the quality of rural life, and the non-farm economy are in agreement with the highly positive assessment of IRMA and CEPT studies (cited earlier). Therefore, we present our findings on these aspects in a summary form but discuss in greater detail the agrarian impacts of JGS that have so far remained unexplored. The most important is the impact on the nexus between electricity supply and groundwater irrigation.

Given the objectives of improving rural power delivery and enhancing the viability of GEB, the JGS has proved an outstanding intervention. During the past 5 years, Gujarat has emerged as one of the best performing states in the management of its power sector. The Gujarat Electricity Board has been rapidly improving its financial situation, with its annual losses falling from US\$ 550 million in 1999–2000 to US\$ 119 million in 2002–2003. In 2006, it posted a modest profit of US\$ 50 million. This is undoubtedly the result of reforms on several fronts and intensive monitoring of power pilferage. However, reforms of the electricity–groundwater nexus through the JGS have contributed to improving the finances of the GEB. The farm power tariff, which had stagnated at Rs. 350 (US\$ 8.75) and Rs. 500 (US\$ 12.5)/horsepower/year for pumps of less and more than 7 horsepower, respectively, has been raised to Rs. 800 (US\$ 20)/horsepower/year.

Agricultural power subsidies were a major burden on Gujarat's electricity industry. They remain an issue, but the JGS has created an effective mechanism to 'manage' farm power subsidies within acceptable limits. As the IWMI proposal had noted, the pre-JGS power tariff policy created large power subsidies and gave the government no control over the volume of electricity used by tubewell owners, who exceeded their allotments using illegal phase-splitting capacitors. With effective power rationing in place, the JGS has transformed a degenerate flat-rate tariff into a rational flat-rate tariff, with the government having firm control of the total volume of farm power supply.

Estimates of groundwater use in agriculture are not available. However, as more than 70% of groundwater withdrawal in Gujarat occurs through electrified tubewells, electricity consumption by tubewells provides an accurate estimate of aggregate groundwater withdrawal. Government data suggest that farm power use for tubewells has declined from more than 15.7 billion kWh/year in 2001 to 9.9 billion kWh in 2006, a nearly 37% decline (Government of Gujarat, 2007). As a result, the aggregate farm power subsidy has declined from US\$ 788 million in 2001–2002 to US\$ 388 million in 2006–2007 (Fig. 7). A portion of the decline in agricultural power use might be caused by two successive good monsoons

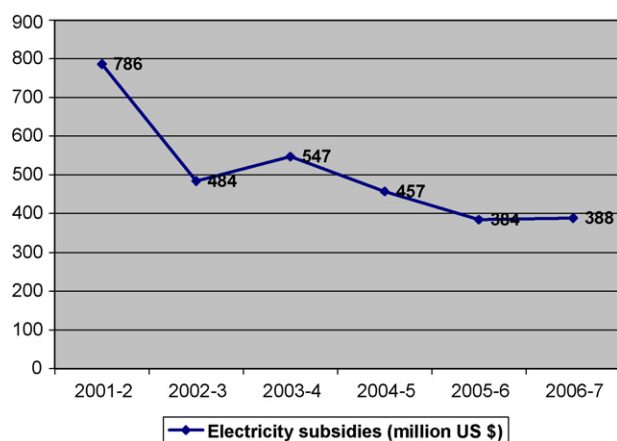


Fig. 7 – Reduction in Gujarat government's electricity subsidies (million US\$).

in 2005 and 2006, but evidence suggests some decline in areas irrigated by tubewells. The most prominent indicator is the declining trend in Gujarat's once vibrant groundwater markets.

The JGS has produced significant socio-economic impacts on diverse groups of stakeholders. An accurate quantitative assessment of these impacts is of considerable importance, but would require a larger empirical effort than our preliminary assessment based on village studies.

By far the most significant impact of the JGS has been improving the quality of life of rural people who had never experienced uninterrupted 24 h, three-phase power supply, as noted in all of the 55 villages we studied (Table 1). Freedom from pre-announced power outages, voltage fluctuations and frequent tripping has improved the well being of rural people everywhere in the state. Rural women now find it easier to organize their daily lives. Before JGS, livestock keepers were obliged to complete the milking and feeding of cattle very early in the morning before the power supply was withdrawn. Now they enjoy greater convenience and flexibility in performing these tasks. School teachers and students can use laboratory

equipments, computers, television sets more than they could do before due to long and frequent interruptions in rural power supply. Especially during Gujarat's hot summer, the inability to operate ceiling fans made the afternoon heat insufferable in schools, shops, workshops, homes and rural hospitals. The JGS has greatly improved this situation.

The JGS also has modified migration. Prior to implementing the JGS, many wealthier, rural families migrated to towns, where the power supply was better. This temptation, especially among the young, has declined as village life has become more comfortable with implementation of the JGS. Improved power supply has led to improved services such as drinking water supply, street lighting and telecommunication. The JGS paved the way for better functioning of schools, primary health centers, dairy cooperatives and other village institutions. It has also enhanced access to television, radio, kitchen gadgets and fans. Women we interviewed in many villages have begun using the time saved from household chores to generate supplemental income.

Pre-JGS, Gujarat's rural non-farm economy was made to pay for the faults of the groundwater irrigators, even though the former paid commercial electricity charges based on metered consumption. Because all three-phase power users were supplied by the same feeders, it was impossible for the GEB to ration power for tubewells without also rationing it for rural, non-farm commercial users. By freeing the non-farm rural economy from compulsory power rationing, the JGS has given a strong impetus to existing and new non-farm economic enterprises generating new livelihoods and jobs. It has reduced the cost of non-farm businesses such as flour and rice mills which now do the same amount of work by consuming less power because they receive full voltage, uninterrupted three-phase power supply. Flour mills were running at great cost with diesel engines pre-JGS. Now they use electric engines. Shops, especially those vending perishable food items, telephone exchanges and call booths, computer training centers had to make significant investment in invertors or generators, which are no longer needed. Commercial establishments can operate in a continuous manner.

In many areas, diamond polishing units have been shifting to villages to save on expensive space in towns, creating new employment for village youth. Many women, unable to commute to urban centers of the diamond polishing trade, have now begun to work in newly opened diamond cutting/polishing units in their own villages. The JGS has given impetus to tailoring, knitting, vending cool drinks, welding, small oil mills in villages. According to a local leader in Bhavnagar district, "thanks to JGS, our villages have witnessed more progress and better incomes during the last 3 years than in 50 years before". According to another, "JGS has good and bad things for farmers; but it has only good things for the village as a whole".

In most districts, electronic and electrical repair shops experienced major improvements in efficiency and speed. Welding machine owners and tire puncture shops improved their businesses substantially. Rural demand for electronic products – TV sets, DVD players, tape recorders – increased rapidly. Cold drink and frozen food shops have experienced 10% to –20% increases in business, especially during the summer. Tailors have improved their productivity and income

Table 1 – Impacts of the Jyotigram scheme on different stakeholder groups

| Stakeholder group | Positive (+)/negative (–) |
|--|---------------------------|
| Rural housewives, domestic users | + + + + + |
| Students, teachers, patients, doctors | + + + + + |
| Non-farm trades, shops, cottage industries, rice mills, dairy co-ops, banks, co-operatives | + + + + + |
| Pump repair, motor rewinding, tubewell deepening, etc. | – – – – – |
| Tubewell owners: quality and reliability of power supply | + + + |
| Tubewell owners: number of hours of power supply | – – – |
| Water buyers, landless laborers, tenants | – – – – – |
| Groundwater irrigated area | – – – |

by as much as 40% by attaching electric motors to their sewing machines. Housewives, students, commuters, non-farm workers, and cottage industry owners are unreservedly positive about the beneficial impacts of the JGS.

Tubewell owners' reactions regarding the JGS have been mixed. They have welcomed five important changes that the JGS has brought about:

- (a) *Continuous power supply*: Before JGS, frequent interruptions in farm power supply made it impossible for farmers to maintain their irrigation schedules, led to wasted water and power, caused wear and tear of pumps and motors; and imposed idle time on them, their water buyers and hired laborers during power outages. By providing power with greater continuity and fewer interruptions, JGS has eased these problems.
- (b) *Power at full voltage*: Before JGS, low and fluctuating voltages, in part due to rampant use of phase-splitting capacitors by farmers themselves, resulted in frequent burn out of motors, and high wear and tear. Post-JGS, it is technically impossible to use capacitors because power is shut off on agricultural feeders after they receive their 8-h ration. In addition to improving voltage, this has helped improve order and discipline in electricity use in agriculture.
- (c) *Reliability and predictability*: Before JGS, farmers could never know in advance precisely when power would be supplied and withdrawn. Tubewell owners and their customers were always in a state of anxiety, waiting all day for power to arrive so they could begin irrigation. They used automatic switches that turned tubewells on as soon as electricity was received. With JGS, farmers receive their ration of 8 h of power during a fixed time schedule, known to everyone, during day and night in alternate weeks, making irrigation scheduling easier for tubewell owners and their customers.
- (d) *Externally imposed restraint*: Some farmers grudgingly recounted that, by limiting collective groundwater withdrawal in a *uniform* and *arbitrary* manner, the JGS effectively has ended the common-property externality inherent in groundwater irrigation. Similarly, many farmers felt guilty about the use of capacitors but used them simply because everyone else did so. With JGS, no farmers use capacitors.
- (e) *New connections*: With JGS, the Government of Gujarat lifted the embargo on new tubewell connections and began offering new connections in a planned manner, depending on the availability of groundwater and power.

There were several aspects of the JGS about which tubewell owners were unhappy. Particularly dissatisfied were tubewell owners in groundwater-abundant areas of central and southern Gujarat who were earlier able to operate their tubewells for up to 18–20 h daily using capacitors. Now they receive electricity for only 8 h. Vibrant water markets have been central to Gujarat's groundwater irrigation economy and essential for the viability of tubewell investments now for eight decades effective power rationing limits the ability of some tubewell owners to generate water supply for sale in market transactions.

Some farmers we interviewed were bitter about promises not kept, suggesting they still face frequent power interruptions, lower than full voltage, and they receive power for only 6–6.5 h per day. Some farmers described problems with the supply of power at night in alternate weeks, noting that night irrigation is inconvenient and hazardous, and that finding labor to work in the fields at night is difficult. The crucial issue for many, however, is effective rationing. Many farmers stated "it is unfair on the government's part to divert agricultural power for residential users. Agriculture is the backbone of the village economy. When agriculture itself is threatened, how can a village enjoy better life?" In sum, our assessment is that tubewell owners' dissatisfaction with effective rationing is muted by better quality, voltage and reliability of power supply.

Major improvements in the quality of agricultural power supply made possible by implementing the JGS are evident in the rapid decline in rural Gujarat's pump repair and motor rewinding trade. That industry had benefited from the frequent power interruptions and voltage fluctuations that increased the burning of motors and wear-and-tear in pumps. The industry also helped tubewell owners install the illegal capacitors.

5. Discussion

The JGS has negatively impacted water-buying marginal farmers, tenants, and landless farm laborers. This large portion of Gujarat's agrarian poor has always depended on tubewell owners to sell them reliable pump irrigation at an affordable price. Ironically, these poor farmers benefited indirectly from illegal use of electricity before the JGS. With the sharp reduction in pump irrigation sales after the JGS, the agrarian poor of Gujarat are in deep distress. We encountered only three situations where this did not happen. First, in water-stressed hard-rock areas like Bhavnagar where, due to limited availability of water in wells, water markets were absent even before the JGS. Small and marginal farmers in such areas have always operated in rainfed conditions. Second, in canal commands where widespread canal irrigation, high tubewell density, high water tables and good well yields combine to make 8 h of power sufficient for meeting a village's irrigation demand, farm power rationing has not had a significant adverse impact on water buyers. In such areas, even after the JGS, the terms of sharecropping here have remained largely unchanged, indicating that landowners have absorbed the JGS shock. Third, in the prosperous and groundwater rich South Gujarat where most farmers had their own electrified tubewells, water markets were always limited. After the JGS, irrigation water sales declined, but we did not observe any notable increase in water prices.

In most other areas, our researchers found that marginal farmers and landless laborers were negatively impacted by the JGS in several different ways: (a) groundwater markets declined, restricting the buyers' access to irrigation; (b) pump irrigation prices in cash sales increased by 40–60%; (c) landless laborers cultivating leased land faced reduced availability of irrigation as well as lower returns on lease farming; (d) they also faced reduced opportunities for farm work as the irrigated

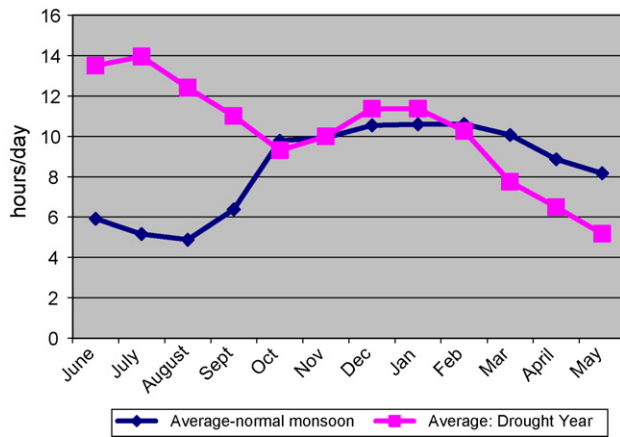


Fig. 8 – Aggregated preference of farmers about daily power supply during different months.

area declined; (e) resourceful and educated farmers used the JGS to move from farming to more remunerative non-farm trades; however, migrant tribal laborers, *Harijans*⁶ and low-caste households dependent on farm labor and share cropping are also the least equipped to benefit from non-farm trades where the JGS has opened up new opportunities for growth and prosperity.

This misery of the agrarian poor can be reduced somewhat by targeting maximum power supply during periods of peak irrigation demand, while reducing the power ration at other times. The IWMI proposal mentioned earlier had argued that farmers' derived demand for power is unlike that of domestic or industrial users who need 24 h daily power supply. Farmers in India need power most on 30–40 days of the year when their irrigation need becomes acute. A farm power regime that supplies maximum power to agriculture on those carefully selected 30–40 days and reduces daily power supply during the rest of the year to a maintenance ration of 3–4 h would help farmers. Instead, under the JGS, the GEB provides farmers a fixed ration of 8 h of power per day during winter and summer, when they need irrigation most as well as during monsoon when they need no irrigation.

Under the JGS, the government has committed to supplying 2880 h of farm power/year. There are many ways this same quota can be delivered to maximize its beneficial impact on the agrarian poor and on agriculture as a whole. In order to understand farmers' preferred season-adjusted power supply schedules, in our second round of enquiry, we asked our respondents to allocate an annual ration of 3000 h of farm power (@8.30 h/day) over the 12 months. The responses we received showed considerable variation across districts. However, everywhere, our respondents allocated more hours during November through March than in other months. Aggregating the preferred schedules provided by all respondents suggests two distinct patterns displayed in Fig. 8: (a) in a year of normal monsoon, farmers would like power-hours reduced during the rainy season (from June to October) and

increased to 11–12 h/day during the winter season (November to February) and 8–9 h/day during summer (March to May); (b) during a drought year, however, farmers would like 12–13 h/day during the monsoon season itself, 9–10 h/day during the winter season and a much smaller ration during the summer months.

6. Conclusion

In our assessment, the JGS has helped to establish real-time co-management of electricity and groundwater irrigation in Gujarat. It has liberated the domestic and non-farm rural electricity supply from a perverse political economy of farm power subsidies. Its highly beneficial impacts on rural women, school children, village institutions and the quality of rural life are evident. The stimulus the JGS has provided to rural non-farm economy too is already evident; but all indications suggest that this stimulus will become stronger over time. Thanks to the JGS, Gujarat has made significant progress in placing its electricity industry on a financially viable footing in just over 5 years. Thanks also to the JGS, Gujarat now has a form of switch-on/off groundwater irrigation economy.

In India and elsewhere, governments have tried, often in vain, to manage groundwater demand by making laws that are unenforceable, or by administrative regulation of irrigation wells. In comparison, Gujarat under the JGS has shown that effective rationing of power supply can indeed act as a powerful tool for groundwater demand management. The JGS can be used to reduce groundwater draft in resource-stressed areas and to stimulate it in water-abundant or waterlogged areas; it can be used to stimulate conjunctive use of ground and surface water.

Electricity supply policies can now also be used to reward 'electricity feeder communities' of tubewell owners that invest in groundwater recharge and penalize villages that overdraw groundwater without showing restraint. A significant breakthrough achieved is the control that the government now has on the size of the farm power subsidy: before the JGS, capacitor-using tubewell owners subject to flat-tariff availed of all the power they wanted while the government and electricity board remained mute spectators. Now, things have changed; tubewell owners have to manage with the daily power ration they are provided. In this sense, the JGS has transformed what was a degenerate flat-rate power pricing regime into a rational one.

The principal limitation of the JGS is that the major burden of reduced power subsidy and groundwater overdraft is borne largely by marginal farmers, and landless because of the decline of water markets and of groundwater irrigation itself. There seems no simple way of eliminating this completely except by increasing hours of power supply – and subsidy – that tubewell owners everywhere have been demanding. However, the JGS can significantly reduce the misery of the agrarian poor by adjusting the schedule of power supply to match peak irrigation periods, especially for winter season. Providing the daily power supply in two or more installments to respond to the behavior of wells in hard-rock areas can further help the poor. Charging a common flat-rate tariff to all tubewells regardless of whether metered or not can also

⁶ The former untouchable castes in the bottom run of India's ancient caste hierarchy.

stimulate metered tubewell owners to share irrigation with the poor.

Metering electricity use by tubewells and charging farmers at near commercial rates based on power consumption is ultimately the ideal solution to South Asia's perverse electricity-groundwater nexus. However, doing this will remain a politically sensitive issue. Until such time as public systems find a feasible way of meeting this challenge, the JGS offers a practical way forward that can restore health to the finances of power utilities and provide the governments effective tool to control and manage agricultural groundwater demand in these populous agrarian economies.

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