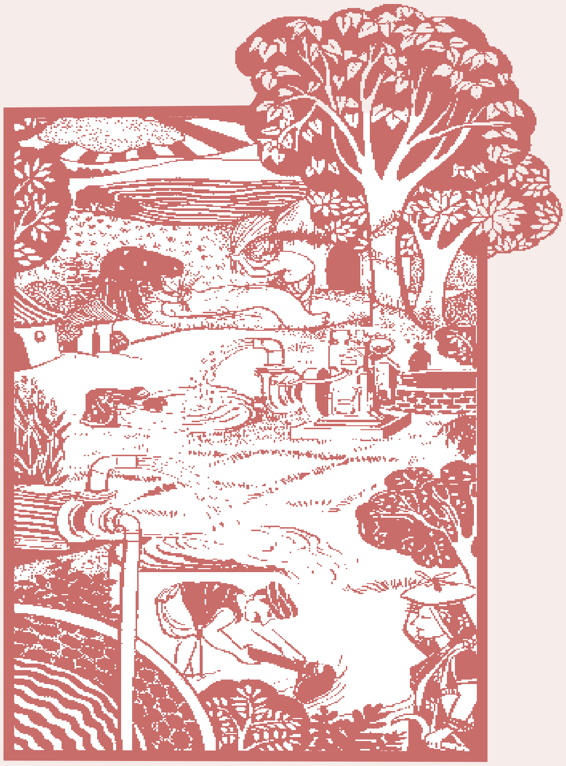

In this Highlight, we examine historical antecedents of energy-irrigation nexus in India and find that its genesis lies in policy decision taken over two decades ago to supply unmetered electricity to farmers. This has led to a number of problems, most important of which is lack of appropriate incentive to all the players including farmers and utility officials to minimize perverse impacts and to ensure efficient use of power and groundwater. This in turn has led to a crisis in all three sectors - energy, groundwater and agriculture. In response, different state governments have tried different solutions to reduce negative impacts of this nexus. In this Highlight, we arrive at a broad typology of these solutions and conclude that text-book solutions like universal metering and commercial power tariffs, though very effective and tried in a few states, are unlikely to be politically acceptable everywhere. In the meanwhile, second best solutions like feeder segregation and improving quality of power supply through technical interventions will have to suffice.

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HIGHLIGHT

Managing Energy-irrigation Nexus in India

A Typology of State Interventions

Aditi Mukherji, Tushaar Shah and Mark Giordano

Managing Energy-irrigation Nexus in India A Typology of State Interventions[1,2]

Research highlight based on IWMI (2012a)[3]

Genesis of energy-irrigation nexus in India

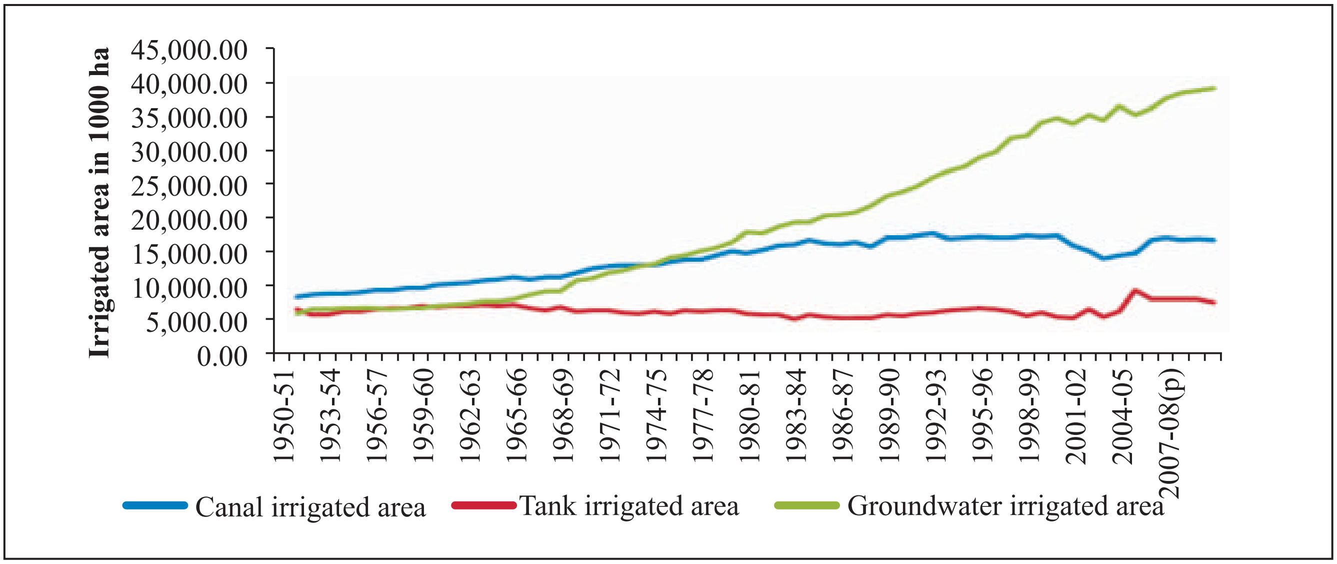
Many countries of the world, such as the United States, China, Mexico, Spain, Pakistan, Bangladesh, Iran and India have a long tradition of groundwater irrigation. Around 1960, India was lagging behind many of these countries in terms of groundwater irrigated areas. However, in the subsequent 50 years, India's groundwater use has grown at a much faster pace compared to these countries. Many factors explain this extraordinarily rapid growth - low cost of pumps and drilling equipment; institutional finance; high population pressure on farm lands; stimulus provided by public tube well programs; arrival of Green Revolution technologies; lack of canal irrigation in most places and massive investment in rural electrification. However, arguably by far the most powerful factor, which explains why groundwater irrigation grew faster in India than elsewhere is the regime of flat rate tariff and power subsidies that India has evolved to support groundwater irrigation. At present, India's agriculture is overwhelmingly dependent on groundwater (Figure 1).

The genesis of unique energy-irrigation nexus in India was the policy decision in many states to supply unmetered power to the agricultural sector. This coupled with the deep dependence that farmers now have on groundwater irrigation and the energy subsidies which helps perpetuate this dependence makes the case of India rather unique. Table 1 shows the evolution of this nexus in Northern and Southern states in India.

Impact of India's energy-irrigation nexus on agriculture, groundwater and power sectors

The nexus produced far reaching impacts - direct and indirect, positive and negative - in three important sectors of the Indian economy: agriculture, groundwater and power.

Figure 1 Area irrigated by different sources in India, 1950-51 to 2009-10



Source: Agricultural Census, GoI n.d.

[1] This IWMI-Tata Highlight is based on research carried out with support from the International Water Management Institute (IWMI), Colombo. It is not externally peer-reviewed and the views expressed are of the authors alone and not of IWMI or its funding partners.

[2] The authors gratefully acknowledge support received from ESMAP – a multi donor trust fund managed by the World Bank. We also thank Dr. Mohinder Gulati for his constructive comments to an earlier draft of this report.

[3] This paper is available on request from p.reghu@cgiar.org

Table1 Phases in development of energy-irrigation nexus in Northern and Southern States in India

Phases in energy-irrigation nexus	Policy imperative	Outcome and challenges
Phase I: Drive for rural electrification (1950s to mid-1970s)	To promote electricity use in agriculture and incentivizing farmers to maximize power use per connection	Slow progress in rates of tube well electrification because costs of tube well were still prohibitively high compared to crop income. This was the pre-Green revolution period.
Phase II: Introduction of flat electricity tariff and free power (late 1970s onwards)	As number of electricity connections increased, transaction costs of meter reading and billing increased and most utilities introduced flat tariff whereby amount paid, if any, got delinked with quantity supplied. This brought in lack of accountability on the part of both farmers and utilities. This also coincided with Green Revolution	The current invidious energy-irrigation nexus problems owe its origin to supplying unmetered power to agriculture. This gave perverse incentive to farmers to over-exploit groundwater and even to utilities to hide their inefficiencies in the garb of agricultural power
Phase III-Attempts at containing Power Subsidies and Groundwater Depletion (since early 2000s)	In 9 critical states (including our study states) power subsidies and groundwater abstraction got caught in a vicious downward spiral necessitating renewed efforts at managing this nexus.	Free or subsidized power led to rapid increase in groundwater demand and unmetered supply led to lack of accountability on the part of the farmers and utilities. Farmers' dependence on electricity for pumping groundwater increased, partially as water table lowered due to over exploitation. They organized themselves into powerful lobbies for maintaining power subsidies and electricity for pumping groundwater emerged as an important political issue.

Source: Shah et al. 2012

Agriculture

The Green Revolution technology worked in tandem with groundwater irrigation to create some 40 million hectares of irrigated area by 2001 (GoI 2005) and much of India's increased food production is due to this subsidized electricity. Initially, vibrant water markets, encouraged by flat tariff, extended the benefits of the boom to poor water buyers (Shah 1993). As per 54th NSSO round of 1997-98, 46.3 percent of rural households in India reported hiring irrigation services from their neighbors. There figures were 33.8, 16.6 and 19.3 percent in Andhra Pradesh, Karnataka and Punjab respectively (Mukherji 2008). However, as groundwater got depleted and power supply reduced, these markets became less pro-poor and more exploitive (Sarkar 2011) and disappeared altogether in some states like Karnataka. Management of canal and tank commands deteriorated because tube wells reduced farmers' need to co-operate in managing them better (Shah 2009). Rainfed areas, such as Telangana benefited greatly from supplemental well irrigation (Vakulabharanam 2004) and access to irrigation. Droughts still plague Indian agriculture; but food production has become more resilient, thanks to widespread subsidized groundwater irrigation. For example, during the drought year of 2009 when rainfall deficit was 33 percent and 66 percent in Punjab and Haryana, reduction in area under irrigated paddy was only 0.7 percent and 10 percent respectively, thanks to intensive groundwater use supported by current power policies (GoI 2009).

Groundwater

All the nine critical states (Punjab, Andhra Pradesh, Karnataka, Haryana, Gujarat, Rajasthan, Madhya Pradesh, Maharashtra and Tamil Nadu) developed a precarious groundwater situation which is getting worse every year. Figure 2 shows percentage of electric pumps to total pumps in different districts of India and Figure 3 shows stage of groundwater exploitation in different blocks. Comparing figures 2 and 3 shows that groundwater stress has peaked in areas where electric tube wells dominated. The nine critical states have 1363 - 85 percent - of India's 1610 critical and semi-critical blocks[4] (Planning Commission 2007). Groundwater abstraction here exceeds

[4]Where, respectively, more than 100 and 85 percent of the groundwater resource has been developed.

long term recharge; as a result, farmers are chasing declining water levels. Except for Madhya Pradesh, in all other states, number of electric pumps far exceeds the total potential of such pumps (Figure 4). In hard rock peninsular India, failure of wells and tube well-related indebtedness have emerged as an important driver of farmer suicides. Besides severe environmental impacts and public health hazards arising from geogenic groundwater contaminants, especially fluoride, the future sustainability of groundwater-based agriculture itself is in question in these states. Free and unmetered power also weakened incentives for water harvesting and groundwater management, as well as sustaining traditional and new surface water bodies (Shah 2009).

In 2001, the World Bank estimated farm power subsidies to be around "US$6 billion a year - equivalent to about 25 percent of India's fiscal deficit, twice the annual public spending on health or rural development, and two and a half times the yearly expenditure on irrigation." (Monari 2002:1). In 2008-09, state electricity utilities had booked a total subsidy of Rs. 29665 crores[5,6] against which they received a subsidy of Rs. 18388 crore ~ (PFC, 2010). Removal of meters on tube wells has undermined energy accounting in power utilities and impaired their internal accountability systems. While total electricity generation has been increasing steadily, so have the transmission losses (Figure 6). The average aggregate technical and commercial (AT&C) loss in the country is about 40 percent, with wide inter-state and inter-utility variations. According to the Economic Survey 2006-07, the major portion of losses of the utilities to the tune of Rs. 20000 crores is due to theft and pilferage. More than 75 percent–80 percent of the total technical loss and almost the entire commercial loss occur at the distribution stage. It is now common knowledge that utilities hide their technical losses and pilferages under the garb of agricultural power supply since it is unmetered.[7]

Figure 2 Energy divide in groundwater economy

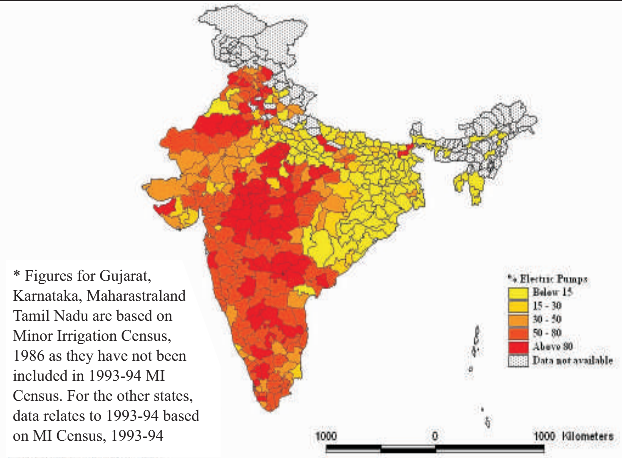


Figure 3 Groundwater stressed blocks of India

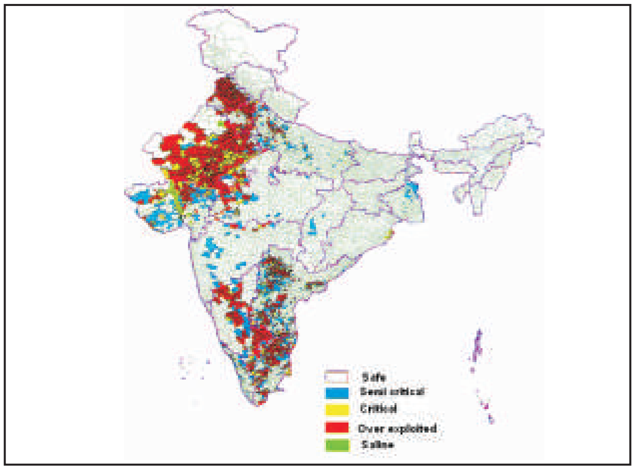
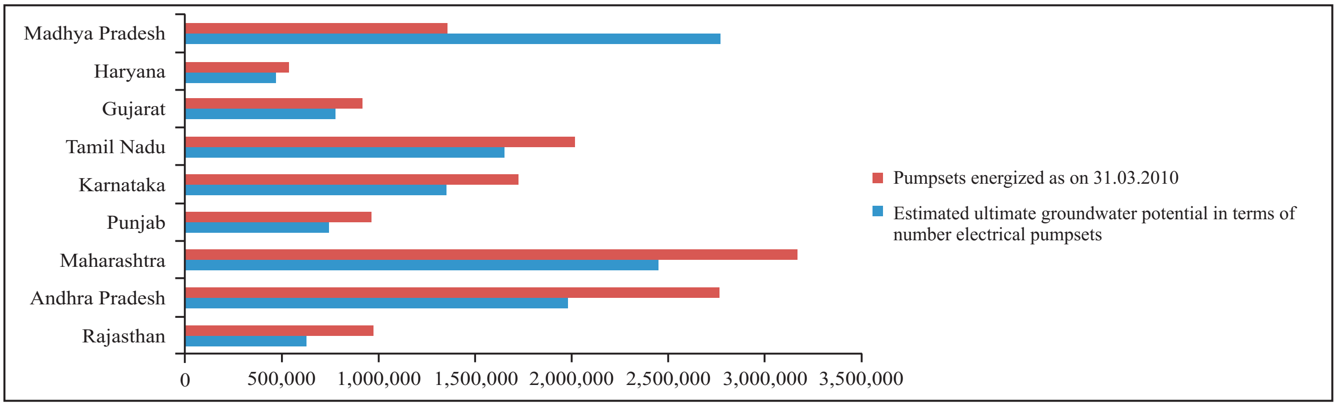


Figure 4 Number of electric pumps (potential vs. actual)



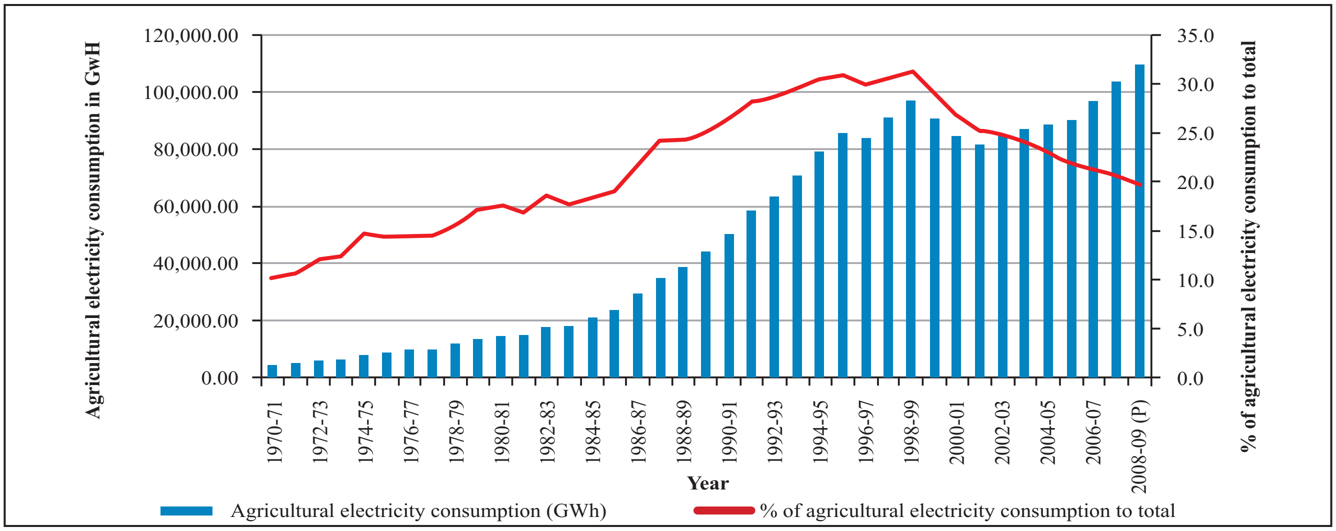
Source: Central Electricity Authority, 2010

[5] 1 USD = Indian Rupees 50

[6] One crore = 10 million

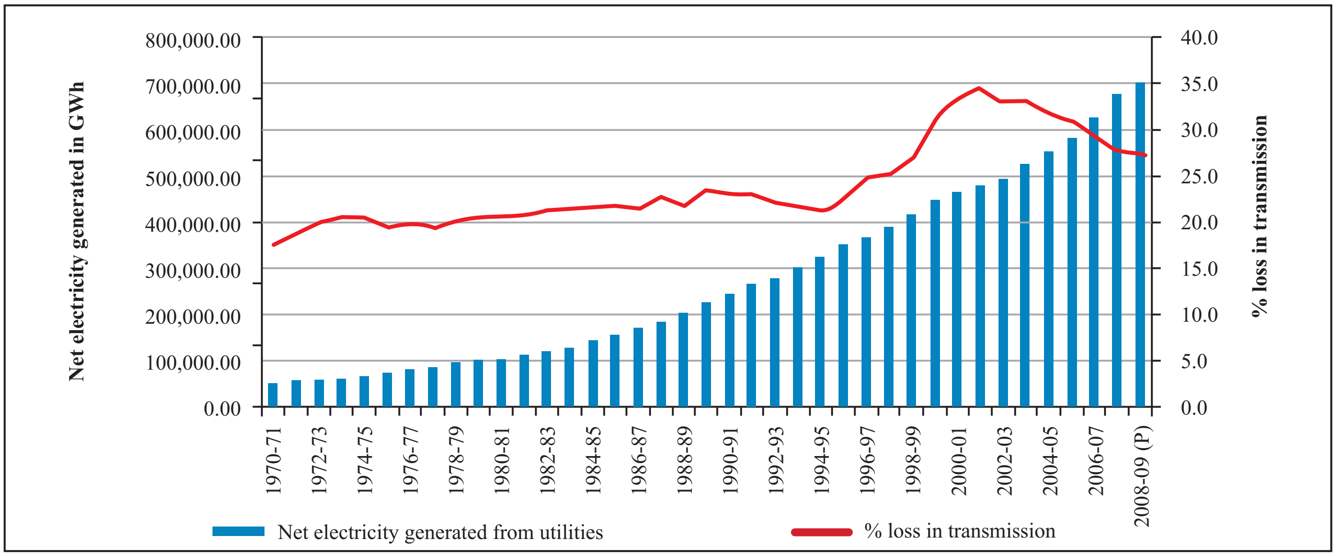
[7] A World Bank (2001) study in Haryana and Andhra Pradesh in 2000 estimated that farmers consumed 27 percent less power than utilities attributed to them and the actual transmission and distribution (T &D) losses of utilities were 47 percent instead of the 33 percent they claimed.

Figure 5 Growth in agricultural electricity consumption, 1970-71 To 2008-09



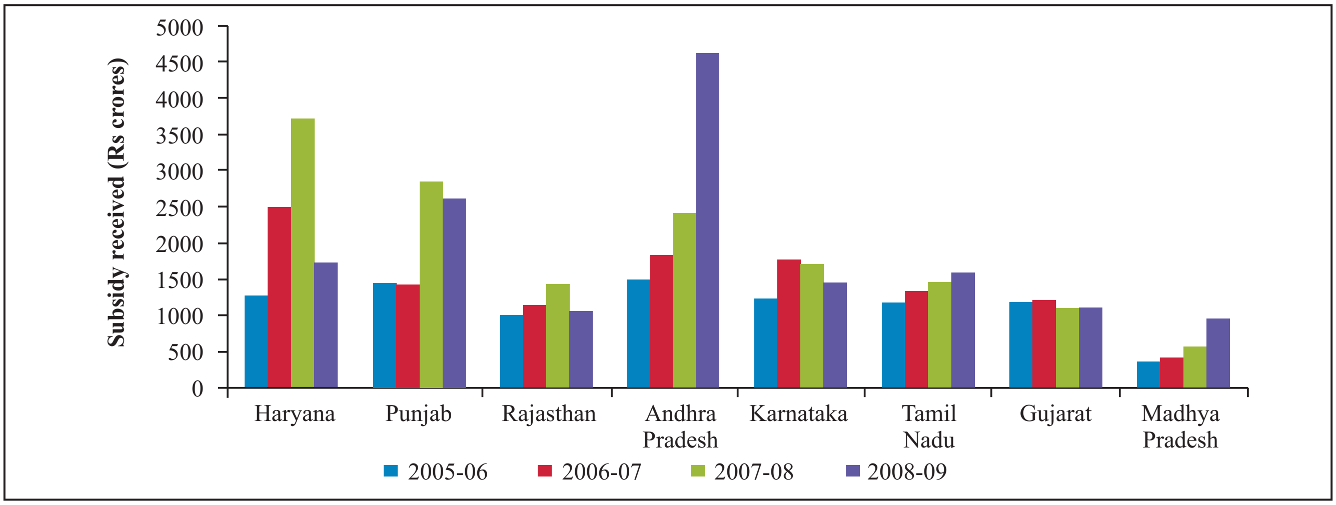
Source: Data from Central Electricity Authority, published in GoI 2007 and 2010

Figure 6 Net electricity generated and percentage of transmission losses, 1970-71 to 2008-09



Source: Data from Central Electricity Authority, published in GoI 2007, 2010

Figure 7 Actual Subsidy received by State utilities in Rs. crores (2005-06 to 2008-09)



Source: Power Finance Corporation (2009; 2010) (1 USD = INR 50)

Growing power subsidies became financial burden to the state governments and are on the rise in these critical states (Figure 7). The removal of metering and introduction of highly subsidized tariff of electricity led to high levels of power (and groundwater) use per hectare. Rao (2008 cited in Shah 2009) estimated average annual power use per hectare of groundwater irrigated area as high as 6997 kWh for Karnataka, 5630 kWh for TamilNadu, 5863 kWh for Andhra Pradesh and 5297 kWh for Gujarat. Of India's total farm power consumption of some 87000 GWh, almost 78000 GWh, or 90 percent, is concentrated in these nine critical states. Farmers do not have enough incentives for responding to groundwater scarcity by shifting to suitable cropping pattern that reflects scarcity value of groundwater. Food procurement policies and Minimum Support Prices (MSP) that favor rice and wheat also blunt farmers' response to this scarcity lower their incentives for crop diversification, and moving away from water intensive paddy crop to oilseeds and other crops. This is true in the case of Punjab, where it is now well recognized that "Agricultural diversification will work only if the current system of procurement based on minimum support price (MSP) is changed in favour of new crops because it provides a powerful economic incentive to prolong the wheat paddy rotation" (Singh 2004:5589).

Managing energy-irrigation nexus through groundwater and agricultural interventions

The problems facing the electricity sector due to unmetered supply to agriculture and consequent lack of incentives among farmers to make efficient use of electricity and among the utilities to do robust energy accounting is now widely acknowledged. Since this nexus involves three sectors of the economy, efforts are being made on all these three fronts. On the groundwater front, many states, including Andhra Pradesh have promulgated groundwater laws. Punjab introduced a law banning paddy transplantation before 14th of June and this reportedly had the effect of reducing groundwater withdrawals by up to 9 percent (Singh 2009), but at the same time exacerbated energy problem by increasing peak demand during that limited window of transplanting. Other initiatives include community management of groundwater in Andhra Pradesh (van Steenbergen 2006), introduction of efficient irrigation technologies and government or community led initiatives of managed aquifer recharge (Sakthivadivel 2007). On the agricultural front, initiatives including attempts to lure farmers away from water intensive paddy crops through diversification, better on-farm water management practices, such as mulching, zero tillage, laser leveling etc. (Humphreys et al. 2010) are being tried. However, in absence of suitable energy policies that gives incentives to farmers to use groundwater efficiently, none of these above measures are likely to be entirely successful.

Managing energy-irrigation nexus from through electricity sector interventions

Given the severity of the energy irrigation nexus problems, several states have tried different ways of managing it through energy side interventions. Experience across states is mixed. For example, *Jyotirgram* scheme of feeder segregation to improve quality and quantum of supply to village habitat has been very successful in Gujarat, but it has shown mixed results in Andhra Pradesh while it has not yielded the expected results in Haryana, Rajasthan, and Karnataka. It has been found that resource constraint (both energy and groundwater) has led to more efficient use and adoption of efficient irrigation technology such as laser levelling, drip irrigation etc. in Punjab and Karnataka (IWMI 2011 and 2012b), while strict laws such as postponement of paddy transplanting dates seems to have worked in Punjab. Similarly, improved quality of electricity supply and flexibility offered through Time of the Day meters in West Bengal seems to be working and benefitting both the utility and the farmers (Meenakshi et al. 2011). Therefore, based on existing power policy regimes, we attempt to construct a typology of power sector and groundwater management regimes in India.

States with free unmetered farm power of variable quality and ineffective rationing

Most of Indian states provide unmetered farm power to farmers. Often that power is of low quality and farm power rationing is ineffective because farmers are able to convert single-phase power to three-phase and run their pumps far longer than planned by the electricity utility. This is symptomatic of states like Madhya Pradesh, parts of Andhra Pradesh, Karnataka and Tamil Nadu. Here, farmers and society's gain from additional agricultural production is far less than the electricity utility's cost of providing that free power. This represents the worst case of perverse incentives in the use of power and groundwater in India. In survey of 499 farmers in Andhra Pradesh, Dossani and Ranganathan (2004) found that the average farm income from tubewell irrigation was less than the society's cost to serve power to them. Vijay Modi (2010, pers.comm.) arrived at the same conclusion with respect to summer irrigation of fodder crops in north Gujarat. In theory, the society as a whole would be better off if the electricity utility would pay off the farmer to surrender his power connection and stop irrigating, but this will have implications on food security and farmers livelihoods.

State with text book solution of metered power supply and near full cost recovery from farmers

A distinctly different power regime is found in West Bengal which has metered all its tube wells and now charges farmers at near-commercial rates, and offers them good quality power round the clock (Mukherji et al.2009). There is no subsidy on agricultural power in West Bengal (PFC 2010). The West Bengal strategy is a textbook economics solution which it was able to apply due to three reasons unique to socio-ecology and polity of the state. First, it has a small number of electric tube wells (only one lakh[8] or so), and so electric tubewell owners are unable to organize into a powerful 'vote-bank' (Mukherji 2006) as they have in Punjab, Haryana, Gujarat, Andhra Pradesh and Karnataka. Second, tube well owners, earlier subject to unusually high flat tariffs (US $50/HP/year against Haryana's US $10 and Gujarat's US $19), were more open to metering which make it easier for them to recover their electricity costs without being dependent on water-buyers (Mukherji et al. 2009). Third, rich alluvial aquifers of much of West Bengal allow tapping of groundwater from shallow depths, for which diesel pumps can become a viable alternative to electric pumps if electricity became prohibitively expensive. Applying the West Bengal strategy to all states of India would reduce farm power subsidies, and halt groundwater depletion. However, in the short run the solution would impose serious collateral damage and it is unlikely to be politically accepted in most of India (Planning Commission 2010).

States with 'second-best' politically acceptable solutions: feeder segregation, rationing and improving quality of power supply

Unlike Eastern India, where diesel pumps offer a viable alternative to electric pumps, this is not the case in western and southern India where groundwater tables are too low to be tapped by diesel centrifugal pumps. Here farmers' lobbies are strong and they oppose any attempt to curtail their power subsidy entitlements and text book solutions like that of West Bengal will not work. It is in this context that Gujarat's *Jyotirgram Yojana* of feeder segregation offers some useful lessons. Under the program, farmers are charged a flat rate tariff, allowing some cost recovery. However, rather than theoretically unlimited power supply, they are now constrained by explicit rationing of high quality power. Earlier, rationing was achieved through random power cuts and by shutting off 3-phase power supply to rural areas for 12-18 hours daily. Further, poor quality electricity - frequent tripping and voltage fluctuations - increased operating costs such as repair of burnt out motors. By addressing both of these issues, farmers' perceived value for flat rate they paid increased substantially. Agricultural power rationing was made possible without harming non-farm users through a US $250 million investment to rewire the country-side and separate feeders supplying power to tube wells from all rural feeders. Farmers in Gujarat now get 8 hours/day of uninterrupted, high quality power 3-phase power, and the Utilities can follow a roster of farm power supply that enables them to achieve a flatter load-curve than would otherwise be possible[9]. In Punjab, feeder segregation, along with High Voltage Distribution System (HVDS) has yielded similar results as we will see later in the report.

The Jyotigram Yojana has thus reduced farm power subsidies, and there is also strong evidence that it has capped aggregate groundwater withdrawals without massive negative impacts on production. Moreover, it has reduced the wastage of power and groundwater and generated some incentive for efficiency in their use. The Gujarat experiment is thus a 'second best' solution to a complex problem. It is a techno-managerial fix to impose a certain discipline on tube well owners that reduces, rather than solves, the energy-groundwater problem but which was politically feasible. However, new challenges may undermine the continued efficacy of this second best. In far flung villages, farmers are alleged to steal power illegally hooking on village feeders which now have 3-phase power all day long. Many are known to use larger submersible motors than registered; and detecting such cases is not easy. However, Gujarat has a working model of implementing a conjoint solution that has improved the financial viability of the electricity utilities and begun to restore the state's precarious groundwater regime (Shah et al. 2008; Shah and Verma 2008). Punjab has also embarked on a similar path of feeder segregation, which they call Urban Pattern Supply. So far, they have segregated 95 percent of all feeders. Another tool in the kitty of second best solutions is that of high HVDS, which serves to improve quality of electricity supply to farmers and also prevents illegal tapping of electricity. Most states like Andhra Pradesh, Gujarat and Punjab have experimented with HVDS with success.

To conclude, our brief review shows that, second best solutions are appealing because in states where free power is the norm, it will be politically infeasible to withdraw free power and levy a tariff. Hence, there is a need to find solutions consistent with the public policy choice of free and subsidized power for agriculture and feeder segregation along with technical interventions to improve quality of power supply such as HVDS, offers just such second best solution.

[8]One lakh = 0.1 million

[9]However, recently, there have been several criticisms of this initiative where it is claimed that losses from segregated feeders continue to be high and that farmers now get even lesser number of electricity supply than they got in 2001 (Gujarat Samachar, 8th March, 2012)

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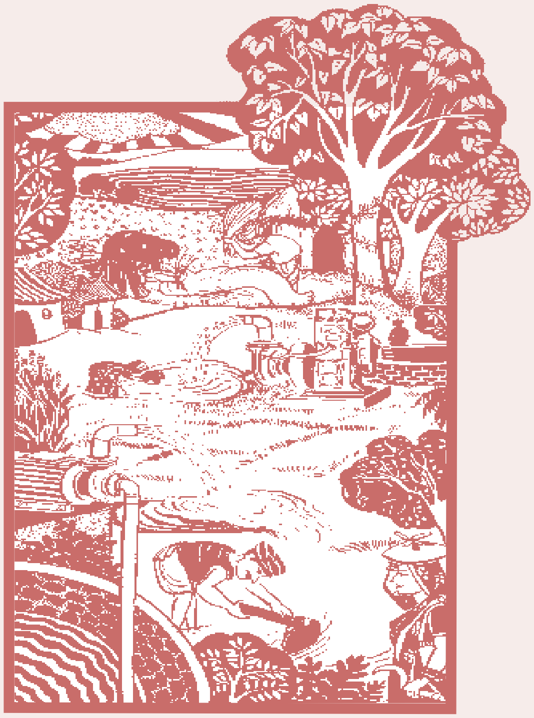

About the IWMI-Tata Program and Water Policy Highlights

The IWMI-Tata Water Policy Program (ITP) was launched in 2000 as a co-equal partnership between the International Water Management Institute (IWMI), Colombo and Sir Ratan Tata Trust (SRTT), Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Through this program, IWMI collaborates with a range of partners across India to identify, analyze and document relevant water-management approaches and current practices. These practices are assessed and synthesized for maximum policy impact in the series on Water Policy Highlights and IWMI-Tata Comments.

Water Policy Highlights are pre-publication discussion papers developed primarily as the basis for discussion during ITP's Annual Partners' Meet. The research underlying these Highlights was funded with support from IWMI, Colombo and SRTT, Mumbai. However, the Highlights are not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or either of its funding partners.

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