Energy Regulations as a Demand Management Option: Potentials, Problems and Prospects

R.P.S. Malik
Agro-economic Research Centre, Delhi University, Delhi

Introduction

Irrigation is the predominant user (more than 80 %) of water resources in India. Of the total net irrigated area (NIA) of 58.54 million hectares (mha) in the country during 2004-05, almost 64 % was irrigated by groundwater. The NIA by tubewells and wells is almost double the net area irrigated by canals. During 2003-04 more than 50 % of NIA in Bihar, Gujarat, Punjab, Madhya Pradesh, Maharashtra and Rajasthan, around 50 % in Haryana and Tamil Nadu and close to 40 % in Orissa and West Bengal was irrigated by wells and tubewells. Increased reliance on groundwater for irrigation has led to an increase in the demand for energy, i.e., electricity and diesel for pumping groundwater. At the all-India level, of the total electricity consumption of 411,887 Gwh during 2005-06, consumption for agricultural purposes accounted for about 22 %. In a number of states electricity used for pumping groundwater constitutes more than 30 % of the total electricity consumption. The electricity consumption for irrigation pumping over the years has been increasing both as a result of an increase in the number of tubewells and an increase in electricity consumption per tubewell. The latter has partly been on account of the larger amount of electricity required to pump groundwater from greater water depths as a result of a decline in the water table.

Groundwater irrigation has been a preferred source of irrigation for the farmers. Irrigation with groundwater not only enables individual farmers irrigation 'on demand', which few surface systems can offer, it is also generally more productive compared to surface irrigation. In general, one cubic meter of groundwater applied to crops is more productive than one cubic meter of surface water. Some of the available evidence in India suggests that crop yield/cubic meter on groundwater irrigated farms tends to be 1.2-3 times higher than on surface water irrigated farms (Dhawan 1989). A study conducted by IWMI indicates that farmers with wells obtain 50 to100 % higher value of output per acre compared to canal irrigators (quoted in Shah et al. 2003). As a result, the rapid expansion and increasingly greater reliance on the use of groundwater for irrigation has contributed significantly to agricultural and overall economic development of India, thereby providing stability to agricultural production and contributing towards reducing the incidence of poverty. It is estimated that about two-fifths of India's agricultural output comes from areas irrigated with groundwater (World Bank 1998).

The increased dependence on groundwater has largely been necessitated by the poor performance of the existing surface irrigation water infrastructure. Furthermore, its limited coverage and lack of extension to newer areas over the years; huge financial requirements and long gestation period required for its construction; inadequate availability of water in the available canal network; and its inability to meet the time-specific irrigation water requirement of the water-intensive and water-sensitive crops have all been attributed as negative factors associated with surface irrigation, which have compelled farmers to opt for groundwater irrigation. Most of the groundwater development has taken place through the private initiative of millions of individual farmers, though the government has facilitated this development through provision of several incentives and concessions such as subsidized credit, subsidized diesel, and extensive coverage of rural electrification, and also by making electricity available at highly subsidized rates with liberal tariff charging policies.

The creation of an enabling environment for development of groundwater has succeeded in: a) the proliferation of tubewells; b) in extending irrigation to newer areas; c) in accelerating the pace of food grain production and contributing to its stability; and d) in providing significant economic benefits. However, in the absence of any strategy to monitor, regulate or restrict the growth of tubewells and the amount of water that can be extracted from these structures, the amount of water that is being currently extracted from these structures in several parts of the country far exceeds the amount of water that should be extracted for promoting sustainable use of groundwater. Table 1 gives an overview of the extent of over development of groundwater in some of the important groundwater using states of India, while Figure 1 gives a pictorial view of the regions of over development of groundwater. As a result of over development of groundwater, the groundwater tables are falling rapidly in several regions raising serious concerns and posing major challenges, which require to be addressed both to sustain the benefits of groundwater irrigation and to ensure the sustainability of gains in agricultural production. A quarter of India's harvest may well be at risk from groundwater depletion (Seckler quoted in Shah et al. 2001).

Based on a review of some of the available literature, the present paper attempts to synthesize the experiences gained from some of the attempts made at limiting groundwater overdraft through intervention of energy supply and/or pricing policies. Based on the experiences gained from these exercises the paper attempts to suggest some alternative interventions, which in isolation and/or in combination with energy policies can help achieve a more sustainable use of groundwater.

Approaches to Groundwater Management

Developing effective management systems for groundwater, unlike surface irrigation systems, is beset with problems. The lack of information and understanding regarding groundwater availability and its dynamics presents a major challenge. Without both the data and a shared understanding of the problems, those engaged in developing solutions and evolving social consensus needed to implement such decisions are finding it difficult to promote a more sustainable use of groundwater. Nevertheless, given the concerns over falling water tables, promoting more sustainable use of groundwater has attracted the attention of researchers and policymakers not only in India but in several other countries around the world, which are also confronted with problems of groundwater overdevelopment.

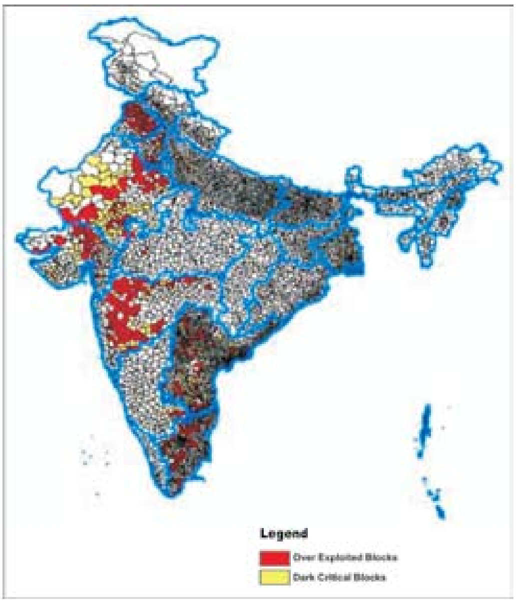
Table 1. Stage of groundwater development in some of the important states of India.

State	Rainfall (mm)	Districts	Mandals /Blocks/ Talukas	Net Annual GW Available (BCM)	Annual GW Draft (BCM)	Stage of GW Develop -ment	Over-exploited	Critical	Semi-critical
Andhra	561-1,113	23	1,104	32.95	14.90	45	219	77	175
Bihar	1,232	37	589	27.42	10.77	39	0	0	0
Gujarat	1,243	25	184	15.02	11.49	76	31	12	69
Haryana	615	20	108	8.63	9.45	109	55	11	5
Karnatka	1,779	27	175	15.30	10.71	70	65	3	14
Kerala	3,073	14	154	6.23	2.92	47	5	15	30
M.P.	917	48	459	35.33	17.12	48	24	5	19
Mahrashtra	1,433	35	231	31.21	15.09	48	7	1	23
Orissa	1,502	30	314	21.01	3.85	18	0	0	0
Punjab	780	17	138	21.44	31.66	145	103	5	4
Rajasthan	504	32	236	10.38	12.99	125	140	50	14
Tamil Nadu	995	30	384	20.76	17.65	85	142	33	57
Uttrakhand	1,523	13	78	2.10	1.39	66	2	0	3
U.P.	1,279	70	-	70.18	48.78	70	37	13	86
W.B	2,074	18	341	27.46	11.65	42	0	1	37

A number of direct and indirect demand-side management and supply-side augmentation approaches have been suggested in the literature and tried in various parts of the world at different points in time in order to address issues relating to groundwater overdraft and its more sustainable use. Some of the approaches that have been employed include regulatory, participatory community-based management, augmentation of groundwater supply through artificial recharge, and energy supply and energy pricing policies. While the impact of these approaches, in isolation and/or in combination, and in the short-term and the long-term, on groundwater management has varied in different locations, in the prevailing underlying conditions in general, none of these approaches have been uniformly effective in controlling excessive groundwater abstractions at different locations. We briefly review the salient features of three of the approaches that have often been attempted.

The regulatory approach to bring groundwater extraction down to sustainable levels envisage putting direct restrictions on the amount of groundwater that can be extracted - through metering of all wells, establishment of formal water rights, issuing of permits, administrative controls including regulatory and economic mechanisms etc. The direct approach to groundwater management thus requires putting in place a legal and regulatory framework to allocate, administer and enforce the requirements of the approach. Sometimes very innovative regulatory approaches have been used to curb groundwater extraction. For example, to conserve groundwater, the Government of Punjab would not start paddy procurement operations at a time when early sown paddy, which requires more water than paddy sown at normal time, arrive in the market after harvest. However, this did not work. The Punjab Government has recently introduced the Punjab Preservation of Sub-Soil Water Ordinance 2008, which prohibits the planting of paddy by the farmers in the state before June 10 to conserve groundwater. The ordinance provides for the government agencies to plough the area with the standing crop of such farmers who transplant paddy before the notified date. The effectiveness of this order in dissuading farmers to sow early paddy and thereby conserve groundwater is, however, yet to be seen.

Figure 1. Overexploited and dark critical blocks.



Source: Government of India, Ministry of Water Resources, Central Ground Water Board

To enable the states to enact groundwater legislation, a model bill to regulate and control development of groundwater has been circulated by the Ministry of Water Resources to all the States/Union Territories (UTs). So far 11 States/ UTs Andhra Pradesh, Goa, Tamil Nadu, Kerala, West Bengal, Bihar, Himachal Pradesh and Union Territories of Chandigarh, Lakshadweep, Pondicherry, Dadra and Nagar Haveli have enacted and implemented groundwater legislation. However, the effectiveness of their implementation and enforcement is not known.

While some success in reducing groundwater draft through some such and similar regulatory measures have reportedly been made in a few water-scarce countries such as Jordan and Israel, the situation is more complex in countries such as India where millions of individual private tubewell owners, dispersed through the length and breadth of the country with varying groundwater availability and demand conditions, are engaged in groundwater extraction. Putting into effect such an approach and overseeing its implementation in a country of the size of India is nearly impossible. The Chinese, with stronger state commitment to groundwater regulation, with a more elaborate reach and local authority structures have still found it impossible to regulate groundwater overdraft in North China Plains (Shah, Giordano and Wang 2004). Nor have the Americans been able to implement real groundwater demand management with their elaborate structure or water rights and groundwater districts, nor have Spaniards and Mexicans with their efforts to promote groundwater user associations.

As an alternative to state regulation of groundwater, some experts have suggested community management of groundwater, similar to community involvement in management of surface water irrigation projects. Though this approach in its various formats has been tried at a number of locations in several countries of the world, the global experience on the outcome of this approach is limited and is conditioned upon conditions prevailing at a very local level. In India such an approach is being tried in the seven drought-prone districts of Andhra Pradesh under the Andhra Pradesh Farmer Managed Groundwater System Project (APFMGS). However, the effectiveness of this approach in promoting sustainable use of groundwater is still not known. Attempts at managing groundwater have, therefore, relied more on indirect management approaches.

Several indirect approaches have been employed in the past with varying degree of effectiveness in different regions at different points of time. Some of these approaches include: restricting institutional credit for installation of tubewells and denying new electricity connections for tubewells. For example, the National Bank for Agriculture and Rural Development (NABARD) has been using 'control of institutional financing for development of wells' in overexploited areas. But this approach has by and large been ineffective in checking overdraft due to large-scale private financing in the development of wells. Similarly, the State Electricity Board's denial of new agricultural power connections in overexploited areas, and in critically developed areas when regulations in relation to spacing of wells are violated, has been ineffective due to the use of old power connections for newly drilled wells (Gass et al. 1996).

Since groundwater development depends directly on energy, management of energy supply and pricing have often been suggested as more effective indirect options for controlling groundwater extraction. In what follows, we elaborate further on these two approaches and examine the likely efficacy of energy management in reducing groundwater withdrawal and slowing down the rate of decline in the water table.

Energy Regulations as a Demand Management Option

The two primary sources of energy for groundwater pumping are electricity and diesel. The regulations governing the use of energy basically relate to pricing of energy and its supply. We briefly describe these below:

Energy Pricing Policy

To encourage development and use of groundwater for irrigation, the government has been providing to the farmers both electricity and diesel for irrigation pumping at prices which are far lower than their supply costs. However, the level of subsidy in the two cases differ, and as a result the energy cost for a given amount of groundwater extraction using electric tubewells is much lower than that of a diesel pumping set. Coupled with problems in availability of diesel; ease in operation, lower running, repair and maintenance cost of electric tubewells; the technological superiority of electric tubewells in drawing water from deeper aquifers; the general preference of the farmers in areas which have access to electricity is to use electricity operated tubewells. However, in areas with poor or no rural electrification or where electricity supply is severely restricted or uncertain, the farmers have no choice but to use diesel pumping equipment either as a stand alone device or as a standby arrangement with electric tubewells. Diesel pumping sets also offer a choice in areas with a shallow groundwater table. In fact, most of the eastern Indo-Gangetic Basin and parts of the western Indo-Gangetic Basin rely on diesel pump-sets for groundwater pumping.

The subsidy on electricity works not only through the lowering of the price of electricity per se but also through the way the electricity is charged from the farmers. The government has been charging farmers for electricity on very liberal tariff terms. Electricity for irrigation is charged either on the basis of a flat rate (FR) tariff structure or on a pro-rata basis on the actual metered consumption, though some states also provide free electricity. The system of charging for electricity on FR basis, wherein an electric tubewell owner is charged for electricity at a flat monthly/annual rate per horsepower of the electric motor installed regardless of the number of hours for which the electric motor is actually used or could be used (due either to availability of electricity or crop water requirement), is the most widely practiced power tariff system.

While some states charge uniform per HP tariffs irrespective of the size of the motor, some may charge on the basis of a 'stepped-up-flat-rate-system' where higher horse power motor owners pay a higher per horse power charge. In this method, since the marginal cost of pumping additional water is almost zero, the farmer has incentive to pump more for his own use or for sale to other farmers. At the same time farmers do not have any incentive to use either the available electricity or groundwater more efficiently. Abbie et al. (1982) argue that the fixed cost of electricity (FR) "… provides no incentive for efficient use of energy, and hence water." The Rajadhyaksha Committee (1985) report on efficient generation and use of power has indicated that FR policy of electricity invariably encourages wasteful use of electricity since its marginal cost becomes zero for the owners of water lifting tubewells. . According to the working group of minor irrigation for the 'Eighth Five Year Plan' the introduction of a FR tariff of electricity would make farmers waste water and take to crops that require more water.

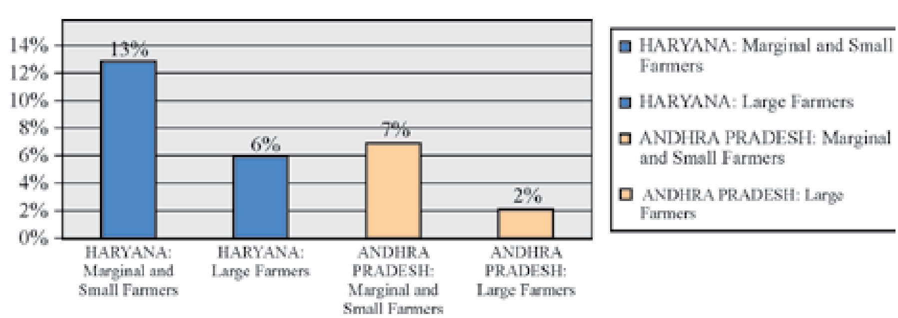
While charging for electricity on a flat rate basis has often been criticized for promoting inefficient use of groundwater and electricity, and for the mounting losses of the SEBs, these tariffs have also been credited with resulting in a significant growth in the market for pumped water. Empirical studies record some form of exchange of groundwater in Gujarat, Punjab, Uttar Pradesh, Andhra Pradesh, Tamil Nadu and West Bengal. (Dubash et al. 2000). According to Shah (1993) although flat rate system of pricing electricity would produce a low level of efficiency in the use of energy, it would produce higher levels of social welfare as compared to a pro rata system of pricing due to the incentive it offers farmers to resort to pump more water and the incentive to sell water at any positive price given the zero marginal cost of pumping water. This has enabled even those farmers who could not buy a pump to benefit from subsidized power supply and has made it possible for the power subsidy to reach even small and marginal farmers who do not own pump-sets.

It has also been suggested that the flat tariff regime is wrongly maligned; in fact, the flat tariff that South Asia has used in its energy–irrigation nexus so far is a completely degenerate version of what might otherwise be a highly rational, sophisticated and scientific pricing regime. A zero tariff is certainly not a rational flat tariff; nor is a flat tariff without proactive rationing and supply management. To most people, the worst thing about a flat tariff is that it violates the marginal cost principle that advocates parity between the price charged and marginal cost of supply. Yet, businesses commonly price their products or services in ways that violate the marginal cost principle, but make overall business sense. Flat rates are often charged to stimulate use to justify the incremental cost of providing a service.

However, in regions with limited groundwater availability, the flat tariff system has widely been argued to be regressive and inequitable towards small landowners and irrigators. According to Bhatia (2007), although small and marginal farmers, generally, operate pumps with lower hp in absolute terms, there appears to be an inverse relationship between the farm size and the horsepower per hectare of gross cropped area, i.e., small farmers tend to invest in higher hp per unit of cultivated area relative to large farmers. For farmers who use electric pumps only, under the flat rate system of electricity pricing in Haryana, electricity tariffs for small and marginal farmers,[1] accounted for more than 13 % of the gross farm income compared with only 6 % of the gross farm income for large farmers (see Figure 2). According to the World Bank (2001) study, "to gain more insight into the regressive nature of the flat rate tariff, it is useful to compare the share of electricity tariffs for electric pump-set owners with the share of diesel costs for non-electric diesel pump owners." For non-electric diesel pump owners, the share of diesel costs account for an average of 7 % of the gross farm income compared with electricity charges that constitute 13 % of the gross farm income for small and marginal farmers using electric pump-sets only. The highly regressive nature of the electricity tariff cost share, as opposed to diesel cost share, arises due to the flat rate tariff structure of electricity pricing, wherein farmers pay on the basis of installed hp rather than on the basis of per unit consumption (as in the case of diesel pumps).

Under a metered or pro-rata tariff system, an electric pump-set owner is charged for actual (kWh) power consumed on the basis of metered consumption of electricity. Some of the states, which charge for electricity on a flat rate basis, too offer farmers a choice for paying for electricity on an actual metered consumption basis rather than on a flat rate basis. While a majority of the farmers prefer the flat rate basis for payment, some farmers (between 10 to 15 %) in some states use the metered tariff. For example, in Haryana, electricity supply to almost 90 % of agricultural consumers is unmetered. In Maharashtra, metered connections used 865 million kWh or 11 % of the total agricultural consumption of 7,757 mn kWh in 2002-03. In no state in India is electricity consumption to the agricultural sector charged wholly on the basis of metered consumption. The tariffs even in the case of metered consumption are also highly subsidized and are nowhere near the true cost of generation and distribution of electricity.

Figure 2. Electricity costs as a % of gross farm income in Haryana and Andhra Pradesh: 2000.



[1] In Haryana, marginal and small farmers operating less than 2 ha of land accounted for 52 % of total farmers while large farmers operating more than 5 ha accounted for 17 % of total farmers.

Many researchers argue that pro rata electricity tariff, with built in positive marginal cost of pumping could bring about an efficient use of the resource (Shah 1993; Moench 1995; Saleth 1997; Kumar and Singh 2001). Nevertheless, some argue that the levels of tariff at which demand becomes elastic to pricing are too high to be viable from political and socioeconomic points of view (de Fraiture and Perry 2002). Shah (1993) opines that while the pro rata system of pricing might induce higher efficiency in the use of energy and water, it will produce lower level of social welfare including farmers' economic surplus as compared to a flat rate system of pricing due to the reduction in demand for groundwater, and the increasing marginal cost of supplying energy. Electricity for the agricultural sector, like any other electricity consuming sector, was charged from farmers, up to around mid-1970s, on the basis of actual metered consumption. During the mid 1970s and 1980s, most of the State Electricity Boards (SEBs) shifted away from metering of electricity sales to agriculture consumers and introduced flat-rate tariffs based on the capacity of the pump-set (Shah 1993; World Bank 2001). This was mainly on account of the difficulty in monitoring the large number of pump-sets and the very low collection rates. This shift was apparently a matter of administrative convenience, meant to minimize transaction costs involved in metering, billing and the collection of bills from agriculture consumers scattered in remote areas. This practice was put in place due in part to the numerous complaints about the harassment of farmers by the SEB field staff.

Of late, however, in spite of most Indian states offering major inducements to tubewell owners to opt for metered connections, only a few have taken to them. . In Andhra Pradesh, Gujarat and Kerala all moves towards metered power consumption have met with farmer opposition on an unprecedented scale. In other states of India, however, farmers' opposition to metered tariff has been partly due to the subsidy contained in the flat tariff and also because they find the flat tariff more transparent and simple to understand. It also spares them the tyranny of the meter readers. Moreover, there are fears that under a metered tariff system, SEBs will start imposing all manner of new charges under different names. In addition, groundwater irrigators raise the issue of equity with canal irrigators, arguing that if the latter can be provided irrigation at subsidized flat rates by public irrigation systems, they too deserve the same terms for groundwater irrigation.

Energy Supply Regulations

Due to the existence of an overall demand-supply gap in the electricity sector, electricity supply to the agriculture sector is generally restricted and falls far short of the sector's requirement. Already the SEBs in almost all the states are supplying electricity to agriculture only for a limited number of hours – generally on an average between 2 to 8 hours per day. Even this limited supply is often provided during night hours. The quality of supply, e.g., certainty, reliability and voltage stability leaves much to be desired. The reason for the supply of electricity to the agriculture sector generally during night hours is because of the low demand of electricity from other sectors of the economy at that time and, as such, the opportunity cost of power is lower at that time than its supply cost. It is, however, very unlikely, that some SEBs are deliberately restricting the supply of electricity to agriculture to conserve groundwater.

To partially circumvent the constraints created by the shortages/uncertainties in the availability of electricity, a number of farmers have installed electric motors of higher horse power than is required in order to draw the requisite quantity of water during the restricted hours of supply of electricity. In addition they have installed an automatic switching mechanism to turn on the tubewell as and when electricity is made available. A number of farmers have also invested in diesel operated pumping equipment as a backup arrangement or use even their tractors in place of a diesel engine to draw groundwater. Those who cannot invest in any backup arrangement try to apply more than the required water during the period when the power supply is available, reduce the area under water-intensive crops, apply the available water thinly over larger areas and accept lower crop yields, attempt to buy water from neighbors, or simply take the risk of letting the crop ruin for want of water. Such an electricity-water supply scenario has led to: a) overcapitalization of agriculture; b) constrained the growth of agriculture; c) resulted in inefficient use of water, energy and equipment; d) led to a reduction in farm profitability; and e) has increased pollution through increases in CO2 emissions into the environment from the burning of diesel. Such a supply scenario has also disproportionately affected the marginal and small farmers and other farmers who do not have a tubewell of their own and therefore, depend on buying water from their tubewell-owning neighborhood farmers.

While the prevailing electricity supply scenario might have succeeded either marginally or not at all in restricting the groundwater withdrawal in water-scarce areas, it has hurt badly the area where groundwater availability scenario is not stressed. Some of the available estimates suggest that the shortages in and poor quality of the supply of electricity for irrigation pumping causes huge private and social losses every year in terms of foregone agricultural production and frequent burn-out of transformers and electric motors. While no economy wide estimates of the impact of shortages/ unreliability of electricity on the agricultural sector are available, some of the available estimates of power restrictions suggest a cost to the agriculture sector in the range of Rs. 9 to Rs. 14 /kWh (at 1995-96 prices) against the true resource cost of generating and distributing electricity in rural areas, which is estimated at between Rs. 3.50 to Rs. 4.00 /kWh and actual cost to the farmer of about Rs. 0.20 /kWh (Dhawan 1999). Other available evidence suggests that voltage fluctuations cause tubewell electric motors to burn-out at least twice in a year resulting in an annual repair cost of more than Rs. 2,000 per tubewell. Depending upon the type of strategy adopted, the capital cost of back-up systems to cope with the prevailing power situation could vary over a wide range – from a minimum of Rs. 10,000 to more than Rs. 100,000 per farm.

Can Power Price per se Reduce Groundwater Extraction?

While energy pricing policies have contributed positively in promoting the development of groundwater and in extending irrigation to hitherto unirrigated areas, it is now increasingly being suggested that these same energy pricing policies, especially that of electricity, have also been responsible for the overdevelopment and unsustainable use of groundwater, leading to a decline in the water tables in many parts of the country. It has, therefore, been advocated that increasing the price of electricity for irrigation pumping, with or without a change in the system of charging for electricity, can curtail the demand for electricity and thereby lower groundwater withdrawals and promote more efficient use of electricity and groundwater. The question that needs to be addressed is: can raising the price of electricity, with or without a change in tariff charging regime, curtail groundwater withdrawal? If so, at what level of price increase this can happen? Does increased electricity price also imply improved equity and improved efficiency in the use of electricity and groundwater?

In India, pricing of power to farmers has always remained an important issue - for power sector reforms, for agricultural policy and also as a politically tempting ploy. The issue of using power pricing policy as an instrument for electricity and groundwater conservation in the farm sector in India has been extensively debated, and continues to be the focal point of the many discussions that take place in the country. However, there is an absolute paucity of sufficient empirical data to compare and analyze the differential impacts of different levels of pricing of electricity on water and energy demand and productivity. Due to lack of data and the complexity of the issues involved, divergent views have emerged on the efficacy of raising electricity prices in influencing the withdrawal and use of groundwater and/or in promoting its equitable, efficient and sustainable use (Shah 1993; Palmer-Jones 1995; Saleth 1997; Kumar and Singh 2001; IRMA/ UNICEF 2001; de Fraiture and Perry 2002).

In most of the discussions on the impact of increasing electricity price on groundwater extraction, it is assumed that the demand curve for power is continuous and presumably its shape convex throughout its entire range, and that all increases in price of electricity lead to a reduction in the electricity demand and, therefore, a fall in groundwater extraction. This assumption has often been made without reference to the groundwater availability scenario, electricity availability scenario, the depth to water table, the prevailing price of electricity or the level of price increase envisaged, the relationship between electricity prices and diesel prices and the relationship between price of surface water and groundwater. Most of these one to one relationships between increase in electricity prices and a reduction in groundwater withdrawal implicitly assume that all other factors remain unchanged and do not influence the water use decision of the farmer. This line of discussion also does not take in to consideration the purpose (crop) for which the groundwater is being used and the prevailing agricultural production scenario aside from availability of and price of groundwater. Any discussion on the likely impact of increased electricity price cannot be constructive if this discussion is divorced of the purpose (crop) for which the water is being extracted from the use of that electricity, or the marginal value of production that is being derived from the use of this electricity/ groundwater.

Electricity for irrigation is one of the many inputs that go into the agricultural production process. From the government's perspective, electricity price is one of the many policy interventions that it makes, in isolation or in combination with other inputs, in promoting the growth of the agricultural sector, in general, or any region or crop, in particular. Similarly, from the farmers' perspective, electricity price is one of the many factors that goes in to the decision-making process in regard to deciding on optimal factor and product combinations, in particular, which crops to grow, how much area to allocate to different crops, and what production inputs to use and in what quantity. Additionally, for many groundwater irrigated crops, cost of electricity for irrigation pumping may constitute a small component of the total cost of production (Naraynamoorthy 1997). If one were to take these broad decision-making factors into consideration, probably one may find that increases in electricity price per se over a substantial range may not necessarily make any impact on a farmer's decision relating to groundwater draft. In all probability so long as the marginal value product of groundwater is positive, any increase in the price of electricity will not lead to a reduction in use of electricity or of groundwater.

Perhaps, in one of the most comprehensive and systematic analysis of the issues involved, Saleth (1997) opines that the nature and magnitude of efficiency, equity, and sustainability impacts of power tariff policy depends on the nature and shape of the power demand curve, both at the individual and aggregate level that links power tariff and power consumption on the one hand and power consumption and groundwater use on the other. Saleth (1997) suggests that the power demand curve is not continuous throughout its range, but actually has a ‘kink’ or discontinuity, the position of which is determined by a combination of economic, agronomic and hydrological and even technological factors. The presence of kink in the power demand function implies that within a certain range of power tariff, power consumption (and hence groundwater withdrawal) becomes insensitive to variations in power tariffs. First, the larger the size of the kink, the lesser will be the scope for making groundwater withdrawal sensitive to changes in the power tariff. Second, if at all the farmers are responsive to tariff changes there is a point in which they will switch to diesel pump-sets provided the groundwater table and diesel availability make such energy switching technically and economically feasible. Thus, to the extent power tariff changes trigger energy switching, electricity tariff changes become still less effective in controlling groundwater withdrawal.

Saleth (1997) concludes that there is no way we can avoid either the kink in the power demand both at the individual and aggregate contexts or its multifarious implications for water withdrawal and use. The persistence of the kink under the current power tariff structure and power supply conditions clearly suggests how ineffective a power tariff could be as an instrument of groundwater regulation. It is, however, important to empirically estimate the level at which the kink appears under standardized conditions, and according to Saleth (1997), policy-wise this is the most relevant issue for further empirical research.

To What Extent Can Electricity Tariffs be Raised?

There are essentially three criterion which can rationally be employed to fix upper limits of electricity tariffs - (1) on the basis of the cost of generation and distribution of power; (2) on the basis of parity with diesel prices - in terms of what it would cost to draw an equivalent amount of water using a diesel pumping set; and (3) in terms of opportunity cost of electricity used for pumping groundwater. However, if the government wants to cross-subsidize other power consuming sectors at the cost of the agricultural sector, which may perhaps never be politically or otherwise feasible, or forcefully discourage withdrawal of groundwater by farmers, it can raise electricity price to a level even beyond the three stipulated criterion.

Fixing electricity prices on the basis of its opportunity cost has problems. The opportunity cost of electricity can vary substantially depending upon several factors such as the extent of shortages in availability of electricity, the alternative uses to which the power diverted from irrigation pumping can be put, place, time of the year and time of day etc. No estimates of opportunity cost of electricity are generally available, and this criterion has never been used for fixing power tariffs in agriculture. The maximum tariffs thus can be fixed in terms of the remaining two criteria. According to Saleth (1997), so long as the marginal productivity of power in the reckoning of farmers remains higher than the full cost price of power, full cost tariff would not be effective in controlling power consumption, and hence groundwater withdrawal. Under the second option, he argues that, farmers could as well shift to diesel pumps, which could have positive efficiency effects but tariff fixation based on the price of diesel would certainly have some adverse impacts on small and marginal farmers, vis-à-vis income from irrigated crops, and access and equity in groundwater.

To illustrate, with any increase in the price of electricity, even up to the level equivalent to its cost of generation and distribution or to the level of price comparable to the corresponding cost of diesel, as long as the marginal value product of water is positive the farmer will continue to extract groundwater. And so long as cultivation of a given water-intensive crop (say Paddy in Punjab) is more profitable than the cultivation of the next most profitable crop, irrespective of the water requirement, say Maize, a rational farmer will continue growing water-intensive paddy. Increases in price of electricity will, of course, narrow down the profitability gap between the two crops as also the absolute profitability of the farmer from cultivation of paddy. As a result there may occur some saving in groundwater extraction and electricity consumption owing to an improved efficiency in the use of electricity and groundwater. But this minor efficiency-induced water conservation is unlikely to make any significant change in groundwater withdrawals, not least the kind envisaged through an increase in electricity tariffs.

It is also frequently argued that as a result of an increase in electricity prices and the increased cost of water, farmers may switch their cropping pattern in favor of high-value crops by which they could keep the 'marginal value productivity' of power and water, high (Saleth 1997). However, in practice such switching of crops may not happen. Even if the cultivation of high-value crops such as horticultural, sericulture, or floriculture is more profitable than cultivation of say, paddy, at higher prices of electricity, such a switching may not take place if the supporting infrastructure for disposal of such specialized high-value crops (such as marketing, processing, cold storages etc) is not available. If these crops are more profitable than say, paddy at a higher price of electricity, then they are more profitable at lower prices of electricity also. So if a farmer were to switch his cropping pattern in favor of high-value crops in response to an increase in electricity prices he could have done so even at the subsidized price of electricity. If that were so, diversification in cropping patterns and savings in water would have occurred even at lower prices of electricity.

Under such circumstances, to make a dent on the withdrawal of groundwater, electricity tariffs may need to be raised to a level so as to completely appropriate the difference between the marginal productivity and marginal cost of power. While such a rate would be in the responsive region of the power demand curve that can alter power demand and groundwater use, there are high chances of poor social viability and political acceptability. Poor social viability is owing to reduced net returns. Whereas political risk is owing to the fact, that the tariff regimes which run into the responsive region of power demand curve would be different for the various geohydrological environments. Apart from political difficulty in raising the power tariff for agricultural users, it is also unfair to do so as long as canal water continues to be given at a low rate (Saleth 1997).

Realizing both the political problems of raising the power tariff for agricultural users and also the unfairness of doing so when canal water continues to be given at a low rate, the Planning Commission in a recent study, without elaboration, suggested that in order to make farmers account for the marginal cost of pumping water, the farmers may be given an entitlement upfront of say, Rs.6,000 corresponding to 3,000 kwhr at Rs.2/kwhr. The charges for their consumption will be deducted from this amount and the surplus, if any, will be handed over to the farmers at the end of the year. This approach may be tested on a pilot basis to examine if the transactions costs of implementation can be kept manageable (Planning Commission 2007).

Can Power Supply Affect Groundwater Extraction?

Given the likely limited effectiveness and political sensitivity of raising the electricity tariffs, it is often suggested that tariffs remaining the same, restricting the quantum of electricity supplied to farmers would constrain the farmers from operating the tubewells and, thereby help in lowering the withdrawal of groundwater. This would also help the SEBs in containing their losses on account of supply of electricity to the agricultural sector. In fact, the current electricity supply scenario to the agricultural sector in most of the states in India is already one of restricted supply. The restrictions on supply of electricity are, however, partly due to the overall demand-supply gap in the availability of electricity and partly due to the desire of the SEBs to contain the level of subsidy. In practice, however, the restrictions on availability of electricity operate not only in terms of fixed hours of supply during the day or night following an announced supply schedule (the hours and period of supply), but is often random and decided at the last minute by the SEBs. Furthermore, it is not only the hours of electricity supply that matter, but also the quality of the electricity supply (voltage of supply and fluctuations in voltage) during those hours that is equally important in determining the quantum of the groundwater withdrawal that can be made during this period. It is not known if these restrictions on electricity supply in any state have been made with the deliberate aim of reducing groundwater draft.

Power rationing is an important instrument that could definitely help reduce water withdrawal. To partially circumvent the constraints imposed by the restrictions/uncertainties in the availability of electricity, a number of farmers have, however, installed: a) more than the required number of tubewells; b) installed electric motors of higher than required horse power to draw the requisite quantity of water during the restricted hours of supply of electricity; c) installed automatic switching mechanism to turn on the tubewell as and when electricity is made available; and d) have invested in diesel operated pumping equipment as a backup arrangement or use their tractors in place of a diesel engine to draw groundwater (see among others, Saleth and Thangaraj 1993). Those who cannot invest in a supplementary/backup arrangement try to: apply more than the required water during the period when the power supply is available; reduce the area under water-intensive crops; apply the available water thinly over larger areas and accept lower crop yields; attempt to buy water from neighbors; or simply take the risk of letting the crop get ruined for want of water.

The decision on the appropriate response action by the farmer is, of course, governed by the relative economics of investing in / adopting alternative strategies and the likely marginal returns from adopting such a strategy. Such an electricity-water supply scenario has, nevertheless, led to an overcapitalization of agriculture; constrained the growth of agriculture; resulted in inefficient use of water, energy and equipment; and, has led to a reduction in farm profitability. Such a supply scenario has also disproportionately affected the marginal and small farmers and such other farmers who do not have a tubewell of their own and depend on buying water from their neighbors who own tubewells. It is, however, not known if these restrictions on the supply of electricity have been able to make any reduction in groundwater draft. In a recent study, Planning Commission opined that restricted power supply can help in some situations but not across-the-board, However, with time, farmers, like others, will demand supply for longer hours and eventually on a 24X7 basis (Planning Commission 2007). The benefits of restricting groundwater use through restricting electricity supply, if any, will then disappear.

Need for Combining Power Price and Supply

Given the likely limited or possibly no impact per se of either altering the price of electricity for irrigation pumping or of restricting the supply of electricity on groundwater pumping, some researchers have suggested intelligently combining electricity supply restrictions with suitable adjustments in electricity pricing as a possible solution to restricting groundwater withdrawal and in lowering the rate of fall in the water table. In a comprehensive analysis of the issues involved, Shah[2] et al. (2003) have suggested that the flat-tariff option, combined with intelligent power supply rationing, is a logical, viable alternative that could cut wasteful groundwater extraction and reduce power use in groundwater extraction. The approach involves: (1) gradually raising flat tariffs to cut power utility losses; (2) supplying farms with fewer hours of power per year, but ensuring a quality power supply during periods of moisture stress; and (3) metering at the feeder level to measure and monitor farm power use, to allow better management of agriculture power supply and use. Pitching for a flat rate tariff setting the authors argue that "the metered and flat-tariff regimes are not simply alternative pricing policies—they are completely different business philosophies." Using a metered tariff, a power utility can, of course, recoup its costs and supply the customers with as much power as they want, when they want it. The flat tariff, by contrast, allows power utilities to use sophisticated management to provide a high-quality, but carefully rationed, power supply and yet remain viable. According to the authors, "the key to making a flat tariff work is supply rationing."

For example, Gujarat does not need to supply 3,000 hours of farm power per year. It can make its farmers happy (and cut its losses) by supplying only 1,200 hours, provided those 1,200 hours are made available when most needed. It is thus suggested that the rational tariff with intelligent power supply rationing to the farm sector holds out the promise of minimizing the wasteful use of both resources (water and power) and of encouraging a technical change towards water and power saving. It has been suggested that "with intelligent management of power supply, it is possible to satisfy irrigation power demand, e.g., by ensuring 18-20 hours of power a day for 40-50 key moisture-stress days in the kharif and rabi seasons (around 2 and 5 weeks, respectively)." Providing an order of magnitude figures on the likely savings in groundwater extraction and power consumption following such an approach, the authors assert: "our surmise is that such a strategy can reduce annual groundwater extraction in western and peninsular India by 12-18 km3 per year, and also reduce power use in groundwater extraction by around 2-3 billion kWh of power, valued at Rs. 40-60 billion per year" (Shah et al. 2003). It is, however, not known how practical and effective this approach is to groundwater management and, whether this approach has been tried anywhere. In a subsequent paper, Shah asserts that the 'Jyotigram Yojana', wherein the Government of Gujarat has separated the feeder line for agriculture consumers from the domestic line in some parts of Gujarat, is premised on the suggested approach to co-manage groundwater and electricity.

Other researchers (e.g., Kumar 2008, personal communication), however, do not share the perceptions of Shah on both the practicality of the suggested approach to groundwater management in Gujarat as well as the suggestion that this groundwater management approach formed the basis of 'Jyotigram Yojana'. The viability and feasibility of separating the agriculture supply network from other rural supply networks has been questioned. On the approach to groundwater, it has been argued that practically, with supply of full power for 30-40 days of

[2] See Shah (2003). Also see, Shah (2000; 1993) and Shah and Raju (1987).

the year, no crop except some very short duration ones can survive in the semi-arid and arid regions, where groundwater use is intensive. Even in winter for crops like wheat, irrigation is required for more than 90 days as the crop water demand is more or less evenly distributed over the season. This is because there is a significant time lag (nearly 30-45 days) between the farmer who does sowing first and the one who does sowing last. Also, at a given point of time, macro-level power rationing cannot simulate the micro-level demand, which varies from farmer to farmer depending on the area irrigated, crop type, date of sowing, climate etc. Kumar also argues that the main idea behind 'Jyotigram Yojana' was to boost and vitalize rural small industries with 24-hour supply of good quality 3-phase power for the domestic sector. Fearing that it would encourage farmers to run their agro-pumps round the clock, the GEB separated the feeder line for agriculture from the domestic one. It continues to ration the power supply to agriculture to about 8 hours per day throughout the year as it has been doing for more than 2 decades now. And, there has been no change in the power supply hours.

This Yojana seems to help only the farmers in some places (in alluvial areas with plenty of groundwater), who used to indulge in power theft using converters, use power beyond the official supply hours, and stopped power theft with feeder line separation. But, they are now using higher capacity pumps to abstract more water, and are often under-reporting the 'connected load'.[3] In any case, in the hard-rock areas, the power rationing is unlikely to have any impact either way. In these areas, the open wells and bore wells yield 3-4 hours, and farmers do not need power for several hours. Hence, it does not matter even if GEB 'reduces' the supply to 8 hours per day. In fact, contrary to the findings of Shah, after Jyotigram, the groundwater draft in Gujarat has gone up substantially, if GEB data on electricity use in the farm sector is any indication. Again, the reason is more groundwater is available for pumping owing to good monsoons. Kumar also opines that the suggested approach, though not helping to solve the problem of over-draft, would, at the same time, make access to groundwater more inequitable. The reason is that the rich farmers would find ways to overcome the constraints of reduced power supply hours and would eventually increase their monopoly power, but it is the resource-poor farmers who would bear the brunt.

Need for Metered and Progressive Power Pricing

While it is important to combine power pricing with supply regulations, it is necessary for power pricing to be based on progressive rates rather than fixed and flat rates. This is in view of the serious limitations of flat rates in managing groundwater draft. In a critical examination of the groundwater management approach based on flat rates suggested by Shah et al. (2003), Bhatia (2007) argues that flat rate tariff combined with rationing of power may not be the ideal way to make optimum use of scarce resources. Bhatia's articulates his reservations on the following counts.

[3] In a subsequent communication Dinesh Kumar (personal communication dated June19, 2008) suggests that on the basis of field work undertaken in North Gujarat, heavy theft of electricity in the region through under reporting of the connected load and the use of Thetta continues. In fact, UGVCL has been running into heavy losses during the past 2-3 years. The estimated loss in the first quarter of this year is Rs. 62 crores.

Opportunity Costs of Peak Power

It is important to recognize that the 'allocation' of power to the agricultural sector has to be seen in a 'power systems' perspective and also take in to recognition the opportunity cost of allocating power to agriculture during the peak periods (during the day or season). Allocating 18-20 hours of power a day for 40-50 days in a year will deprive other users of this critical power for their priority uses during these periods. While it is difficult to estimate the 'opportunity cost' of this type of management of power, the 'benefits foregone' in alternative uses may be so high that from a societal perspective the allocation of power to agriculture may not be an optimum use of the scarce peak power. Alternatively, the costs of coping strategies for users other than agriculture may be so high that this will raise the total system costs to a high level.

Revenue Loss

In the ongoing power sector reform process, it would not be possible to ensure that farmers will get the power that they need, at the time when they need it because that will be against the philosophy of revenue maximization that is being suggested for power supply companies. Accepting the system of flat rates for electricity use will provide incentives to managers in the power sector to 'minimize' supply of power to the agricultural sector as the revenue from an additional unit of electricity will not only be negative but will reduce the total revenue for the power company. Under a flat rate tariff system, the power supply to agriculture during the peak period is likely to be reduced by about 50 % of the power availability from the current level.[4] This will result in the type of 'de-electrification' that occurred in the East UP during the 1980s and 1990s (Shah 1993; 2000), since power distribution companies will avoid supplying power to the farm sector.

Centrality of Metered Tariffs in Power Reform

In a large number of states, state electricity regulatory commissions (SERCs) have been set up as a part of the reforms process to rationalize tariffs and improve the power supply. Some of these SERCs have mandated/suggested the installation of meters for all consumers. Flat rate tariffs will go against the mandated requirements imposed by the SERCs. Reducing subsides through raising flat rates will be politically unacceptable, since this will involve raising fixed rates to very high levels. For example, to comply with the demands from the Gujarat Electricity Regulatory Commission., Gujarat's board intends a 350 % price-hike on the supply of power to the farmers, raising the annual charge from Rs. 500/hp (unchanged since 1989) to Rs. 1,700/hp and, eventually to Rs. 2,100/hp (Shah et al. 2003).

Equity Implications

Although small and marginal farmers generally operate pumps with lower hp in absolute terms, there appears to be an inverse relationship between farm size and the horsepower per hectare of gross cropped area, which small farmers tend to invest in higher hp per unit of cultivated area relative to large farmers. As a result the flat rate tariff structure of electricity pricing, where farmers pay on the basis of installed hp rather than on the basis of per unit

[4] It is difficult to get data on how much of the power used in agriculture takes place during the peak period. This figure of 50 % is from the IWMI-Tata studies.

consumed, becomes regressive in nature. As against this regressive tariff structure under the flat rate system, electricity regulatory commissions may devise 'life-line rates' under metered tariffs for some categories of users (up to a given level of electricity consumption).

Administrative Problems

Like metered tariff systems, flat rate tariff systems too are not free from administrative problems. For example, in a recent study (World Bank 2001) of the flat rate system in Haryana, a number of problems have been noted including the detection of illegal connections and the presence of discrepancy between the hp record of the utility and the actual pump size hp. The readings of 78 electronic meters installed on agricultural pump-sets showed that, on average, the actual connected load is about 74 % higher than the official utility record. The implementation of unmetered tariffs is seen to result in a significant loss of revenue for the utilities due to under-reporting of the actual capacity of pumps by farmers. This tends to allow the utility staff discretion in how they monitor and verify the capacity of pump-sets in the field at regular intervals, which may in turn result in increased collusion between consumers and utility staff and ultimately lead to corruption.[5]

Conservation Incentives

In the flat rate system of electricity pricing, once the user pays the charges as per pump capacity, the marginal cost of electricity for operating the pump-set is zero, and the farmer can pump more water subject to availability of power and water. In areas of relative water abundance (e.g., east U.P., Bihar, Orissa and West Bengal), this may be a good thing since additional water supplies can be used for irrigating crops on the farm or water may be sold to farmers who do not own electric motors. However, in areas of relative water scarcity (western India and peninsular India), this will create problems since there is no incentive for energy (and groundwater) conservation.

Based on the points noted above, Bhatia (2007) argues that for energy regulations to be an effective indirect means for groundwater management, power supply regulations should be combined with metered rather than the flat rate electricity tariff. When electricity is metered, farmers would learn the real cost of power and water and be forced to economize on their use. Plus, the power utilities would gain valuable information on actual power usages (essential for efficient management and cutting commercial losses). Furthermore, in addition to charging for electricity based on metered consumption, innovations in metering (including 'Smart Cards') and charging for power consumption should be scaled-up so that charging separate tariffs for peak and off-peak power is possible. Efforts should be made to have a politically acceptable solution where off-peak power is charged at very low rates (to cover marginal cost of supply) and peak power is charged at its opportunity cost, which may be higher than its cost of supply. This will provide the right price signals to consumers to use power when it is most valuable for them. Also, it will maximize the revenues of producers since they will allocate power where it brings best value.

---

[5] In the Haryana study (World Bank 2001), under the farmers' attitude survey, it was found that about 69 % of farmers surveyed favored metered supply. According to HVPN these statements by farmers are not confirmed by their actual practices in reality, because the metered connections have decreased from 107,000 in 1996 to 74,000 in 2000, compared to unmetered connections that have increased over the same period from 267,000 to 285,000.

Coupled with these efforts, Bhatia (2007) suggests that innovations in institutional mechanisms for power distribution in agriculture (e.g., making village Panchayats responsible for power distribution) should be tried. Bulk power could be supplied to persons (as in China) or community organizations and they, in turn, can be responsible for its distribution and collection of revenues. As a part of the Orissa power sector reforms, village committees were setup in a number of villages to facilitate interaction between utility and consumers, redressing grievances, bill distribution, and metering and cash collection. Such village committees are expected to perform like a cooperative where they will be billed based on the transformer readings, and the entire responsibility for collection will be transferred to them. In Gujarat, a MOU has been signed among GEB, GERC and IRMA for the pilot project, which has been given to IRMA for a feasibility study and for identification of co-operatives in each of the five zones of GEB, so as to facilitate the handing over of the distribution system to local bodies/ consumer co-operatives. According to Shah et al. (2003) there are also institutional solutions to this that are not receiving sufficient attention. In the early decades of this century, USA resolved this problem by promoting Rural Electricity Co-operatives (RECs); India also tried these in the 1960s but only half-heartedly. RECs are interesting because they target precisely the problem that makes power supply to South Asian agriculture costly and unprofitable. If the village buys power in bulk and retails it to its members, the transaction costs of power supply can be reduced dramatically.

Way Forward

Sustainable management of groundwater is a key challenge in a large number of countries facing overexploitation of groundwater. Given the strong linkages between groundwater and energy, energy management obviously holds an important, though definitely not the sole, key to face this challenge. Although the debate on the efficacy of energy management in controlling groundwater overdraft continues, recommended policy alternatives, as discussed above, have tended to be ineffective. Several additional complementary policy measures suggested for regulating groundwater overdraft, such as enacting and enforcing groundwater laws, establishing clear tradable property rights of water, pricing of groundwater, installing licensing and permit systems, have also not proved to be effective in checking groundwater overdraft. Saleth (1997) opines that even an imperfect system of water rights will have much more sustainable benefit than the most perfectly designed but ineffective instruments. While nobody disagrees with the need for some measures, nothing has yet worked on the ground, and as a result the groundwater situation continues to degenerate from bad to worse.

It is important to underline that mere availability of groundwater coupled with sufficient or insufficient availability of energy on the one hand, and availability or non availability of subsidies on energy for groundwater pumping on the other hand, does not constitute a sufficient condition for either extraction or overextraction of groundwater. It is the return from the use of the groundwater that primarily drives its extraction, though prevailing energy prices themselves may, in part, determine the profitability from the use of groundwater. If the cost of groundwater extraction at unsubsidized energy prices is uneconomical, provision of subsidies may help in bridging this gap and encourage groundwater extraction. If, however, the extraction of the groundwater at unsubsidized, prices is economical, the subsidy on energy prices may increase the returns from the use of groundwater not necessarily only by the amount of the subsidy on electricity, but by a much larger amount, if the subsidy encourages shifts in cropping patterns.

The current situation of overextraction of groundwater in many regions obviously has occurred, because the yield derived from the use of groundwater is more than the cost of its extraction. The yield derived from the use of groundwater cannot, however, be attributed as the yield of groundwater as groundwater is one among many other factors acting either independently or jointly in conjunction with several other factors, which culminate in determining this return yield. There is, however, no denying the fact that water productivity in groundwater irrigation is higher than that in surface irrigated and rain-fed areas. Given the multiplicity of factors determining the yield of groundwater irrigated areas and returns from the use of groundwater, it is not surprising that energy management policies per se either via manipulation in energy prices or supply controls, as discussed above, may have made limited or possibly no impact in farmers' decision regarding limiting the extraction and use of groundwater to sustainable levels. As such, they are unlikely to contribute towards a meaningful solution to overextraction and excessive groundwater irrigation. When groundwater use is influenced by a multiplicity of factors, it is clear that no single factor can alter the nature of groundwater use. Saleth (1997) also concludes that power tariff policy alone cannot be an effective tool for achieving efficiency, equity and sustainability in groundwater use.

Efforts aimed at controlling groundwater extraction, to bring it closer to sustainable levels of development, have to be made simultaneously on a number of fronts, including through development and more intelligent execution of policies – supply, pricing, regulatory, participatory - affecting groundwater-energy nexus. Perhaps a change in demand behavior of agricultural users, brought about through encouragement of shifts in cropping patterns in favor of less water using crops, can play a more important role in bringing down the level of groundwater extraction. This would, however, require action on a number of fronts. The first, and most important, is demystifying the science of groundwater hydrology and empowering groundwater users at the micro-level to understand the dynamics of groundwater availability, the process and sources of groundwater recharge, and the sustainable level of groundwater yield available for use in a year. This would create a much better appreciation of the problem at the ground level and create awareness and a need for conserving groundwater, and prepare the basis for introduction/adoption of new crop varieties, which are less water intensive and/or for better ways of water application, without any shifts in the crops cultivated or sacrificing the crop yields. It could, additionally, lay the basis for bringing in shifts in cropping pattern towards less water intensive crops. Encouraging such shifts in the cropping pattern, however, would require engineering shifts in relative crop profitability in favor of crops intended to be introduced. Apart from other factors, this would require interventions on two important issues: 1) realignment in output pricing policies; and 2) ensuring market support for the new crop.

To substantiate the relevance of the two factors listed above, it is important to cite an example. Concerned by declining groundwater tables, several half-hearted interventions have been made in different states in India to bring about shifts in cropping pattern towards less water using crops. For example, a few years ago, in Haryana, cultivation of sunflower as a substitute for paddy was encouraged to conserve groundwater. Due to the relatively higher profitability of sunflower, a small number of farmers responded to this initiative and shifted partly from cultivation of paddy to sunflower. The next year, through the demonstration effect, some more farmers followed suit. In the following year too, some more farmers made these shifts in their cropping pattern. As a result of increased production, and lack of market support, the output prices crashed and relative crop profitability again tilted in favor of paddy. The farmers again switched back to cultivation of paddy and, thus the efforts aimed at conservation of groundwater through shifts in cropping pattern ended.

Hence, given the importance of a large number of factors in influencing extraction and use of groundwater, efforts aimed at promoting more sustainable use of groundwater must take a system's view of the situation and not try to limit solutions to only those arrived at through improved management of groundwater-energy interactions, though improved management of groundwater-energy nexus will continue to be central to any other complementary strategy adopted. Given the differentials in ownership and access to different factors of production by different categories of households, any interventions aimed at promoting more sustainable use of groundwater must evaluate the differential implications such an intervention makes on different sections of the society, and the trade-offs involved in conserving groundwater vs. food security, environmental sustainability and other social impacts.

References

Abbie, L.; Harrison, J.Q.; Wall, J.W. 1982. Economic returns to investment in irrigation in India. World Bank Staff Working Paper No. 536. Washington, D.C. The World Bank.

Bhatia, R. 2007. Water and Energy Interactions in India. In 'Handbook of Water Resources in India,'eds. John Briscoe and R.P.S.Malik. The World Bank and Oxford University Press, New Delhi.

de Fraiture, C. ; Perry, C. 2002. Why is Irrigation Water Demand Inelastic at Low Price Ranges? Paper presented at Irrigation Water Policies: Micro and Macro Considerations. Jointly organized by World Bank and Government of Morocco, June 15-17, 2002, Adigar, Morocco.

Dhawan, B.D. 1989. Studies in Irrigation and Water Management. New Delhi, India: Commonwealth Publishers.

Dhawan, B.D. 1999. Studies in Indian Irrigation, New Delhi, India: Commonwealth Publishers.

Dubash, N. K.; Rajan, S.C. 2000. Power Politics: Process of India's Power Sector Reforms. Economic and Political Weekly XXXVI (35).

Gass, G.; Kumar, D.; Mc Donald, D. 1996. Groundwater Degradation and Its Socioeconomic and Health Impacts: Practical and Policy Options for Mitigation. Draft Report of VIKSAT-Natural Resources Institute Collaborative Research Project.

IRMA/UNICEF. 2001. White paper on water in Gujarat. Report submitted to the Government of Gujarat, Gandhinagar.

Kumar, D. 2005. Impact of Electricity Prices and Volumetric Water Allocation on Energy and Groundwater Demand Management: Analysis from Western India. Energy Policy 33.

Kumar, D. 2008. Meeting notes about the impact of JGY, June 18, 2008 (Personal communication).

Kumar, M.D.; O.P. Singh. 2001. Market Instruments for Demand Management in the Face of Growing Scarcity and Overuse of Water in India. Water Policy 5 (3): 86-102, 2001.

Malik, R.P.S. 2002. Water–Energy Nexus in Resource-poor Economies: The Indian Experience. Water Resources Development Vol. 18, No. 1, 47–58, 2002.

Shah, T. 2003. Governing the Groundwater Economy: Comparative Analysis of National Institutions and Policies in South Asia, China and Mexico. Water Perspectives, Vol. 1, No. 1, March 2003.

Shah, T.; Giordano, M.; Wang, J. 2004. Water Institutions in a Dynamic Economy: What is China Doing Differently from India? Economic and Political Weekly, Vol. xxxix, No. 31, July 31- August 6. pp 3452-3461.

Saleth, R.M.; Thangaraj, M. 1993. Distribution Pattern of Lift Irrigation in India: An Analysis by Hydro-geological Regions. Economic and Political Weekly, 28 (39): A102-A110.

Malik, R.P.S.; Goldar, B.N. 1998. Electricity Prices and Sustainable Use of Groundwater: Farmer's Willingness to Pay for Electricity in Haryana. Presented at The Applied Development Economics Conference, Delhi School of Economics, January 1998.

Malik, R.P.S. 1995. Electricity Prices and Sustainable Use of Groundwater: Evaluation of Some Alternatives for North-West Indian Agriculture. In Moench, Marcus (1995) op cit.

Moench, M. (ed). 1995. Electricity Pricing: A Tool for Groundwater Management in India. VIKSAT-Natural Heritage Institute, Ahemdabad.

Mukherji, A. 2007. The Energy-irrigation Nexus and Its Impact on Groundwater Markets in Eastern Indo-Gangetic Basin: Evidence from West Bengal, India. Energy Policy 35 (2007).

Narayanmoorthy, A. 1997. Impact of Electricity Tariff Policies on the Use of Electricity and Groundwater: Arguments and Facts. Artha Vijnana 46 (3).

Palmer-Jones, R. 1995. Groundwater Markets in South Asia: A Discussion of Theory and Evidences in Moench, M. (ed) 1995. Electricity Pricing: A Tool for Groundwater Management in India. VIKSAT-Natural Heritage Institute, Ahemdabad.

Planning Commission. 2007. Report of the Expert Group on Groundwater Management and Ownership. Government of India, New Delhi.

Rajyadhykaksha Committee. 1985. Report of Committee on Efficient Generation of Power. Planning Commission, Government of India, New Delhi.

Saleth, R. Maria. 1997. Power Tariff Policy for Groundwater Regulation: Efficiency, Equity and Sustainability. Artha Vijnana 39 (3): 312-322.

Shah, T.; Scott, C.; Kumar, A.; Sharma, A. 2004. Energy-Irrigation nexus in south Asia: Improving groundwater conservation and power sector viability. Research Report 70: Colombo, Sri Lanka: International Water Management Institute (IWMI).

Shah, T.; Scott, C.; Kishore, A.; Sharma, A. 2003. Energy–Irrigation nexus in south Asia: Approaches to agrarian prosperity with viable power industry, Research Report No. 70. Colombo, Sri Lanka: International Water Management Institute.

Shah, T.; Deb Roy, A.; Qureshi, A.S.; Wang, J. 2003. Sustaining Asia's Groundwater Boom: An Overview of Issues and Evidence. Natural Resources Forum, 27

Shah, T.; Molden, D.; Sakthivadivel, R.; Seckler, D. 2001. Global Groundwater Situation: Opportunities and Challenges. Economic and Political Weekly, October 27, 2001.

Shah, T.; Raju, K.V. 1987. Working of Groundwater Markets in Andhra Pradesh and Gujarat, Results of Two Village Studies. Economic and Political Weekly, March 23.

Shah, T. 2000. Wells and welfare in Ganga basin: Public policy and private initiative in eastern Uttar Pradesh, India. Research Report 54. Colombo, Sri Lanka: International Water Management Institute.

Shah, T. 1993. Groundwater Markets and Irrigation Development: Political Economy and Practical Policy. Bombay, India: Oxford University Press.

World Bank. 2001. India Power Supply to Agriculture, Vol 2, Haryana Case Study. New Delhi. The World Bank.

World Bank. 2001a. India Power Supply to Agriculture, Vol 3, Andhra Pradesh Case Study. New Delhi. The World Bank.

World Bank. 1998. India Water Resources Management Sector Review: Groundwater Regulations and Management Report. World Bank and Government of India, New Delhi. The World Bank.