Article

Distressed Elephants: Policy Initiatives for Sustainable Groundwater Management in India

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Abstract

This article reviews the dominant arguments which shaped public policies in the agricultural groundwater sector in India. It also examines the initiatives to arrest groundwater depletion. It is a synthesis of the research carried out by the author over the last two decades and review of the work by others. Following were the arguments that shaped public policies in the agricultural groundwater sector in India, as per the review: high density of farm wells in remote areas increases the transaction cost of metering and charging for electricity on a pro-rata basis, as a tool to control groundwater draft; groundwater economy is controlled by small and marginal farmers, and attempts to regulate it are politically sensitive; and raising power tariff would adversely affect farmers who buy water. Furthermore, the regions with high density of wells do not experience intensive groundwater use; groundwater economy is mainly controlled by large farmers. In water-abundant regions, subsidized power does not reduce the monopoly of water sellers; in water-scarce regions, an increase in power tariff would have only marginal effect on it; and, in semi-arid regions, raising farm power tariff would result in improved efficiency, equity and sustainability in groundwater use and would be socio-economically viable. In water-scarce regions, the large public funds spent for watershed management, dug well recharging and community-based water harvesting produce no positive outcomes. Attempts to introduce electricity pricing or groundwater taxes or water rights are absent. Schemes promoting the use of micro irrigation do raise farm productivity, but leave no incentive among farmers to reduce water use.

Keywords

Well owners, water buyers, groundwater economy, micro irrigation, electricity pricing, water rights.

Introduction

In India, well irrigation currently accounts for nearly 65 per cent of the gross irrigated area. The key policies followed by the central and state governments in the country, which have driven the phenomenal growth in well irrigation, are: subsidized or free electricity for groundwater pumping in the farm sector; institutional financing for well development with subsidies for well drilling and pump installation, in areas which are categorized as 'safe' for exploitation; free or subsidized power connection for agricultural uses, especially to small and marginal farmers (Kumar, Sivamohan, & Narayanamoorthy, 2012a). Both free power and flat-rate system of pricing electricity in the farm sector have serious negative impacts on the efficiency and sustainability of groundwater use in agriculture (Kumar, 2005, 2007; Saleth, 1997; Shah, Scott, Kishore, & Sharma, 2004).

This article reviews the dominant arguments which shaped public policies in the agricultural groundwater sector in India for many decades and examines their viability. It compares and contrasts the past and current initiatives to arrest groundwater depletion in India, in terms of their ability to bring about sustainable groundwater use. It uses the extensive empirical research and analytical reviews done by the author on groundwater socio-ecology, and the management initiatives of non-governmental organizations (NGOs), civil society and the government agencies.

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Arguments that Shaped Public Policies in Groundwater and Agriculture in India

During the last two decades, several aggressive arguments have been made, which have dominated the published writings and academic discourse. These arguments have been instrumental, to a great extent, in shaping public policies in the agricultural groundwater sector in India. They are as follows: high density of farm wells in remote areas increases the transaction cost of metering and charging for electricity on a pro-rata basis, as a tool to control the groundwater draft (Shah et al., 2004); groundwater economy is controlled by millions of small and marginal farmers, and any attempts to regulate it would threaten their livelihoods and, therefore, are politically sensitive (Deb Roy & Shah, 2003); and raising power tariff, by raising the selling price of water, would adversely affect the poor water-buyer farmers (Mukherji, Shah, & Banerjee, 2012).

One dominant argument against the shift in power pricing is the higher marginal cost of supplying metered electricity owing to the high transaction cost of metering. This may reduce the net social welfare as a result of reduction in demand for electricity and groundwater in irrigated agriculture and net surpluses that individual farmers generate from farming (Shah, 1993). The second argument is that for the power tariff to be in the responsive (price-elastic) range of the power demand curve, prices have to be so high that they become socially unviable or politically untenable (Saleth, 1997). The third argument is that under pro-rata tariff, the increased cost of pumping groundwater would be transferred to water buyers (Mukherji et al., 2012). Mukherji et al. (2012) argued that under flat-rate tariff, the water buyers would gain from low irrigation-water charges due to competitive water markets, because well owners would have greater incentives to pump more water.

These arguments were very effectively used to question the effectiveness of the measures that were mooted from time to time to control and regulate groundwater use in India, such as agricultural metering and pro-rata pricing of electricity, state control of groundwater abstraction by farmers and subsidized electricity for agricultural groundwater pumping.

The transaction-cost argument is one of the most pervasive arguments in the electricity–groundwater management debate in India. This has mainly stemmed from the sheer number of groundwater abstraction structures in India, estimated to be around 25 million. However, in the advancement of this argument, little attention has been paid to the number of wells in regions that actually require the co-management of electricity and groundwater. The fact is that the overwhelming numbers of wells in India are in the Indo-Gangetic belt (Scott & Sharma, 2009). This region, especially the eastern Gangetic plain, does not experience serious long-term problems of groundwater overdraft (Sharma, 2009).

There is hardly any empirical work that substantiates these arguments. In fact, the studies conducted to examine the validity of the arguments and claims find serious flaws in them. They pertain to the following: equity in access to groundwater and the question of who controls groundwater economy; how electricity and diesel subsidies can be used to promote access equity; the impact of increase in power tariff on equity, efficiency and sustainability of groundwater use, including the functioning of water markets in semi-arid water scarce regionsThese arguments and claims are summarized in the subsequent sections.

Is Access to Groundwater Equitable in India?

Some researchers have argued that groundwater is a more democratic resource, with greater geographical spread of wells, unlike canal irrigation which is concentrated, and, therefore, promotes access equity (Deb Roy & Shah, 2003). However, the analysis of data on the ownership of wells, obtained from 11 major Indian states, shows that there is skewness in ownerships of all types of wells towards medium and large farmers. A little more than 20 per cent of large farmers own dug wells, 16.5 per cent of them own shallow tube wells and 0.4 per cent own deep tube wells. Hence, a total of 37 per cent of large farmers own wells. However, as regards marginal farmers, 2.5 per cent own dug wells and 3.5 per cent own shallow tube wells. The ownership of deep tube wells is close to nil in this category of farmers. Hence, only 6 per cent of marginal farmers own wells.

Mukherji (2005) used the nationwide data of pump ownership across landholding classes provided by the National Sample Survey Organization (NSSO) to re-emphasize the point about access equity in water through machine power. He used the data on change in the pattern of distribution of ownership of pumpsets (diesel, electric and others) to make a point that small and marginal farmers are getting increasing access to pumpsets. For this, he looked at the percentage of pumpsets owned by different landholding classes in 1976–77 and 1991–92, which showed that a greater percentage of pumpsets were owned by small and marginal farmers in 1991–92 (10.7%), as compared to 1976–77 (5.3%). A smaller percentage of pumpsets were owned by large farmers in 1991–92 (25%) as compared to 1976–77 (35%).

However, to analyze equity in access to groundwater, one has to understand 'what percentage of farmers under different landholding classes own pumpsets' rather than 'what percentage of the pumpsets are owned by farmers belonging to different landholding classes'. In 1991–92, only 2.46 per cent of the sub-marginal farmers (holding less than 0.50 ha) and 11.7 per cent of marginal farmers owned pumpsets as against 22 per cent of small farmers and 69.5 per cent of large farmers. Hence, it can be said that pump ownership is skewed towards large farmers.

Some researchers argue that water markets are far from shrinking and on the contrary, contribute to more than 60 per cent of India's well-irrigated area. For instance, Mukherji (2005) estimated the contribution of pump-rental markets to India's irrigated area to be nearly 20 million ha (mha). For this, he studied the data available from NSSO. This is the first attempt of its kind in assessing the size of groundwater markets in India, and therefore has merit. However, his assessment had some flaws.

Mukherji (2005) used the data on the percentage of holders who resort to water purchase. His estimation was based on the gross cultivated area within that particular category of holders. There could be two potential sources of error in using such a procedure: (a) a water buyer might irrigate only a fraction of the entire holding with purchase water, and figures of cropping intensity would not represent irrigation intensity; and (b) there could be major variations in the gross cropped area among farmers belonging to the same landholding category. Therefore, following the above methodology would lead to the over-estimation of the area covered by water markets.

Mukherji (2005) estimated the net area irrigated by the pump-rental market as 20.29 mha.[1] This was compared against the estimates of (net) area irrigated through lift by pump-rental markets for 1976–77 (which is 0.8 mha) to build the argument that water markets have expanded remarkably during the 20-year period. If these estimates are anywhere close to reality, then the actual area irrigated by pump-rental services would be one-third of the net irrigated area in the country.

As regards groundwater, if we treat the area irrigated through lifting from wells/tube wells as nearly 60 per cent of the total net irrigated area, then pump-rental markets should account for nearly 12 mha of the net well-irrigated area. But the fallacy of this claim can be understood from the following statistics. The total number of landholdings of marginal farmers as per 1991 census is 61.9 million, and the total size of the holdings is 24.53 mha. According to NSSO, of the 25 million households that reportedly hired pump-rental services in 1997–98, 75 per cent (18.75 million) are marginal farmers. Going by the estimates provided by Mukherji (2005), about 15.2 mha (75% of 20.3 million) of land in terms of the net irrigated area must have been irrigated by marginal farmers through pump renting if we assume that the area irrigated through rental services is more or less the same across landholding categories. The land owned by marginal farmers, who hire pumps, can be estimated as 7.33 mha. Even if we assume that the marginal farmers who purchase water do not own wells, the net irrigated area is more than the total land owned, which shows that irrigation through pump renting is over-estimated.

There are also issues with the manner pump-rental markets are viewed. It is always assumed that pump-rental markets operate between well owners and non-well owning, small and marginal farmers, who lack capital to invest in wells and pumpsets. For instance, Mukherji (2005) had argued that given the large number of water buyers—estimated to be 25 million households, against a total of 21 million households owning tube wells/wells or pumpsets—pump-rental markets help the resource-poor farmers (Mukherji, 2005, p. 6). Implicitly, all those who avail off pump-rental services were treated as those who do not have direct access to well irrigation.

Such a view leads to the interpretation that many small and marginal farmers who do not own well are served by pump-rental markets. But the evidence available from water-abundant eastern India and water-scarce Peninsular India contradict this view. For instance, in Bihar, given the smaller size of the parcel, many farmers find it economically unviable to install a well for each parcel of land. Instead, they prefer to install one borewell (shallow) for the largest sized parcel and decide to purchase water from well owners for the smaller sized ones. They also sell water from their borewells to the nearest well owners.

Underlying the question of 'who controls groundwater economy' is the issue of access equity. It is quite clear that direct access to groundwater is a privilege only for a small percentage of farmers in India. Water markets are the important socio-economic feature that determines the nature of groundwater economy to a great extent. The lesser the monopoly price of water, the higher would be the degree of access equity through groundwater markets. However, diametrically opposite views exist about the role of water markets in promoting access equity in groundwater (see, e.g., Palmer-Jones, 1994; Saleth, 1997). While Shah (1995) argues that groundwater markets are 'oligopolies', Palmer-Jones (1994) showed that the electricity pricing policies and lack of institutional regime governing the use of water increase the monopoly of well owners.

Rights to groundwater in India are attached to land-ownership rights, and they are governed by the English Common Law or 'Law of Dominant Heritage'. Hence, every land owner has the right to access groundwater (Saleth, 1996). But there is no limit to the volume of groundwater that a land owner can abstract. This peculiar situation gives a strategic advantage to resource-rich farmers to maximize the outputs and profits in two regions: (a) where the physical availability of groundwater resources is limited and (b) where the risk involved in investing for well development is high.

The comparative advantage enjoyed by the resource-rich farmers is leading to natural monopolies, where they would be in a position to dictate the terms of the trade. The prevailing power-pricing policies in all groundwater-scarce states give better opportunities to resource-rich farmers as they would not have to pay for electricity in proportion to the (water) production volume. Hence, the analysis of equity impacts of water markets and the informal groundwater economy from a pure market perspective is distorted.

The returns that water buyers and well owners get are equally important. For instance, in northern Karnataka, while water sellers earn a net income of INR 16,173 per acre, water buyers earn only INR 7,208 per acre of the irrigated crop. Also, the average gross irrigated area and irrigation intensities (3.65 acre and 15.21 inch) are much smaller for water buyers when compared to water-selling well owners (6.2 acre and 25.91 inch) (Deepak, Chandrakanth, & Nagaraj, 2005). To sum up, as resources become more and more scarce, water markets would give greater opportunities to resource-rich farmers to earn extra income and would put the resource-poor farmers to a highly disadvantageous position. The current institutional regime and power-pricing policies increase the monopoly power of resource-rich well owners.

Can Energy Subsidies Reduce Price of Groundwater in the Market?

The last two decades have seen remarkable degree of debates on the impact of public policies relating to irrigation on the access equity in groundwater, particularly the economic impact of well irrigation on different classes of farmers (see Mukherji et al., 2012; Saleth, 1997; Shah, 1993). Eastern India provided the best climate for the debate. The economy of rural eastern India is highly agrarian in nature. The region has the highest rate of poverty and largest concentration of poor people in the country, mainly attributed to stagnation in agriculture (Shah, 2001). The total factor productivity (TFP) growth in agriculture has been the lowest in the eastern region (Evenson et al., 1999). A few researchers have argued that groundwater development and cheap well irrigation could trigger agricultural growth and economic prosperity (see Mukherji et al., 2012; Pant, 2004; Shah, 2001). Appropriate public policies for promoting well irrigation in this groundwater-abundant region among the poor, small and marginal farmers have been the main topic of this debate. While public tube well programmes have failed in states like Uttar Pradesh (UP), the focus of researchers has shifted to policy instruments for promoting efficient groundwater markets (Kumar, 2007).

Many researchers have argued that in eastern parts of India, large-scale rural de-electrification had a significant impact on well irrigation. They argued that with deteriorating quality of power supply in rural areas, the farmers, who were using electric motors to pump groundwater, are now shifting to diesel engines (Kishore, 2004; Mukherji, 2005; Mukherji & Shah, 2003). According to them, this has not only affected the cost of abstraction of groundwater, but has also influenced the functioning of groundwater/pump-rental markets with rising charges for irrigation services.

This is quite understandable that change in the water-abstraction mechanism from electric to diesel would automatically affect the irrigation charges (Kumar & Singh, 2001; Saleth, 1997). Hence, some researchers have advocated policy interventions, such as energy subsidies, pump subsidies and low flat rates, for promoting equity in groundwater in eastern India (see, e.g., Kishore, 2004; Shah, 2001).

The theoretical proposition is that the fuel charges must be kept low, or good quality electricity be supplied. The same should be charged on a flat-rate basis so as to keep the marginal cost of pumping very low in the first case, or farmers' incentives for pumping more and more groundwater should be high, which would reduce the implicit cost in the second case. Such arguments have been made by many researchers (Shah, 2001). However, the issue of 'monopoly power' of well owners that influences the terms of trade, including water rates, has not been touched upon by the scholars working on public policies for promoting equitable access to groundwater (Kumar, 2007).

If a good number of well owners in an area own diesel engines, then the electric pump owners would also raise their hourly charges to make it closer to the water production cost incurred by diesel-pump owners. Since well owners have to bear high 'transaction cost' to obtain power-supply connections, only a few enjoy the privilege of having electric motors. The same applies in the case of obtaining government subsidies for diesel pumps. It prevents the poor farmers from going for wells and pumpsets. Hence, the pump owners charge monopoly rates for water in the rental market As a result, there is very little one can do to change the way well irrigators behave or water markets operate through changes in power-pricing policies in eastern India (Kumar, 2007).

The real challenge lies in improving the process of securing electricity connections in the farm sector and providing resource-poor small and marginal farmers easier access to pump subsidies.[2]

Extending the findings of such studies from eastern India for water-scarce regions, such as western India, central India and the Southern Peninsula, would be untenable. The reason is that in water-scarce regions, the price at which water is traded does reflect the scarcity value of the resource. The higher value of water is a result of the large gap in the demand and supply of water and the high capital cost required to secure groundwater through drilling. Similarly, poor chances of hitting groundwater again in situations of well failure also lead to the higher value of water (Kumar, 2007).

Nevertheless, in such a situation, one can only reduce the cost of pumping water and not the scarcity value of the resource or the price buyers are willing to pay. Such a reduction in cost can only be done through adjustments in the price of electricity used for pumping. But this reduction would be just marginal as the cost of energy is a small fraction of the total pumping costs. The only leverage is to manipulate the electricity prices. However, all the State Electricity Boards in western India, central India and the Southern Peninsula are following subsidized flat rates (Kumar, Scott, & Singh, 2013). Hence, the benefits due to reduction in the variable (implicit) cost of pumping through the introduction of subsidized flat-rate charges for electricity are least likely to be transferred to water buyers.

A study of water buyers and well owners in both electric- and diesel-well commands in eastern UP and south Bihar validated this point. In eastern UP, the monopoly price ratio (MPR) was higher in the case of electric-well commands than that in the case of diesel-well commands. The price charged by electric-pump owners, who paid for electricity on the basis of connected load, was 3.6 times higher than their cost of pumping, whereas the price charged by diesel-pump owners was only 1.8 times higher than their cost of pumping (Kumar et al., 2013).

In southern Bihar, the trend, however, is the opposite. The average price charged by electric-well owners is lower than the implicit cost of pumping water (INR 0.70/m^3 against INR 0.77/m^3), whereas the average price charged by diesel-well owners (INR 2.15/m^3) is higher than the cost they incur for pumping groundwater (INR 1.87/m^3). However, these are based on average figures of cost and price. A look at the cost and price figures for individual wells brings out a different picture. A few electric-well owners incur very high implicit pumping costs, making it higher than the average selling price. The MPR of many electric-well owners is higher than even the average MPR of diesel-well owners (1.15) and much higher than that of many individual diesel-well owners who incur very high production costs. More importantly, the MPR for some diesel-well owners is less than 1.0 (Kumar et al., 2013).

Another interesting phenomenon found in both electric- and diesel-well commands is that the selling price of water is more or less the same across the farmers, though the unit cost of pumping water varies. The selling price is decided by market conditions irrespective of the cost farmers incur for pumping water (Kumar et al., 2013). Fewer numbers of potential sellers against a large number of potential buyers would increase the monopoly power of well owners. Perhaps this is what is happening in the village with electric pumps in eastern UP. On the other hand, the presence of a large number of sellers against a few buyers would reduce the monopoly power of well owners. They would be forced to sell water at prices conditioned by the market (Kumar, 2007). Perhaps this is what is happening in the village with electric pumps in southern Bihar.

To summarize, the mode of pricing of electricity does not influence the monopoly power of well owners in the market. On the other hand, the flat-rate pricing puts large well owners in a very advantageous position as they could bring down their implicit unit cost of pumping groundwater. Therefore, pro-rata pricing of electricity would promote equity in access to groundwater, if many farmers from within the same area have access to electricity connections (Kumar et al., 2013).

To elaborate our argument, it would be right to argue that hike in power tariff under pro-rata pricing or under the flat-rate system would lead to an upward trend in irrigation cost across farmers. However, adjusting the flat-rate tariff to lower levels may not result in the overall reduction in the price of water in the market. On the other hand, pro-rata pricing has its own benefits. Introduction of unit pricing of electricity would put the small landholding well owners in a more comfortable position as they do not worry about paying any fixed cost for electricity. They would be in a better position to adjust the prices to respond to the market as the implicit cost of pumping would be much lower than that in the earlier case. Thus, they would be able to expand the customer base. In other words, the amount of opportunity available for both large and small well owners for increasing the sale volume would be more or less the same. Therefore, as prices get regulated, groundwater economy would become more or more formal with the introduction of metering and pricing based on unit consumption (Kumar, Singh, & Singh, 2001).

Impact of Electricity Pricing on Energy and Groundwater Demand in Agriculture

Highly subsidized and flat-rate mode of electricity pricing creates disincentives for the efficient use of groundwater in agriculture (Kumar, 2005; Saleth, 1997). One of the responses for higher energy tariff would be for farmers to improve the efficiency of water abstraction devices, including pumpsets and the suction pipes, if possibility exists. Nevertheless, beyond a point, this cannot help reduce the cost of irrigation, and, therefore, the subsequent response will be to make water use more efficient with two aims. One is by reducing the cost of irrigation input and the other by increasing the gross return. This can be done through three major steps: (1) by improving the technical efficiency of water use by optimizing irrigation water application, (2) by improving agronomic efficiency in water use (kg/m^3 of water) by optimizing agronomic inputs to crops and (3) by shifting to crops with higher water productivity in economic terms (INR/m^3) (Kumar, 2005, 2007).

We present the findings of a recent empirical study to illustrate the impact of energy pricing on groundwater demand for crop production, the socio-economic viability of farming as well as sustainability and equity in groundwater use. The study compared the farming enterprises of electric-well owners who pay for electricity on the basis of connected load (flat-rate tariff), diesel-well owners who pay for energy on the basis of consumption and buyers of water from electric- and diesel-well owners in eastern UP and southern Bihar, along with farmers who pay for electricity on a pro-rata basis in northern Gujarat. Here, the buyers of water from diesel-well owners incur higher water charges as compared to the buyers of water from electric-well owners. However, three categories of farmers—diesel-well owners who irrigate their own farms, buyers of water from electric-well owners and buyers of water from diesel-well owners—are proxy for pro-rata electricity pricing, along with the farmers in northern Gujarat whose power consumption is metered.[3]

The physical productivity of water in crop production (kg/m^3) for different irrigated crops was estimated by taking the ratio of the yield of the crop per unit area (kg/ha) and the volume of irrigated water applied per unit area (m^3/ha). The economic productivity of water in crop production for different crops (INR/m^3) was estimated by taking the ratio of the net income return from crop production for the respective crops per unit area of land (INR/ha) and the volume of water applied per unit area (m^3/ha). The net return for each crop was estimated by subtracting the input costs of seeds, farm labour, machinery, fertilizer, water and electricity (INR/ha), from the gross income (INR/ha), which was obtained by multiplying the yield of the crop (kg/ha) by its farm gate price (INR/kg) (Kijne, Barker, & Molden, 2003). The volume of water applied to each crop was estimated by multiplying the discharge of the well (m^3/h) from which irrigation was provided to the crop, measured in the field, and data on the total duration of irrigation applied to the respective crop over the entire crop season, obtained from the farmers during the survey.

Impacts on Irrigation Application and Water Productivity in Crop Production

The farmers who have metered power connection not only incur the marginal cost of using well water, but also pay a higher price for every unit of irrigation water (INR/m^3) as compared to their counterparts having flat-rate connections. Similarly, farmers who are buyers of water from electric- and diesel-well owners in eastern UP and southern Bihar also incur the positive marginal cost of using irrigation water, thereby paying higher unit costs of irrigation water compared to water-selling counterparts. Higher physical productivity of water use for a given crop indicates more efficient use of irrigation water through farm-water management or better farm management. Higher water productivity in economic terms means a better economic viability of irrigated production, if land is available in plenty (Kumar, Scott, & Singh, 2011).

The analysis of crop–water application and water productivity of various crops in the three seasons (Kharif, winter and summer) for well owners and water buyers in electric-well commands in eastern UP showed that the total amount of irrigation water applied for crop production is higher for pump owners as compared to water buyers, and the differences are statistically significant. Furthermore, for most of the crops, both physical and economic productivities of water are higher for water buyers than their water-selling counterparts. Equally important was the fact that water buyers did not grow crops during the summers when crop–water requirement is generally high, whereas well owners grow vegetable crops with high water demand (Kumar et al., 2013).

As regards diesel-well commands, the water buyers incurred higher cost for irrigation water. To economize on irrigation water, water buyers used to cultivate water-efficient crops, such as *arhar*, black gram and green gram, during the kharif season. During the summer season, only pump owners grew vegetables. The estimates of irrigation water application and water productivity in physical and economic terms for different crops showed that water buyers in diesel-well commands apply less amount of water to their crops when compared to their water-selling counterparts. Furthermore, the physical productivity of water (kg/m^3) and water productivity in economic terms (INR/m^3) was higher for water buyers when compared to diesel-pump owners for all the crops. This could be owing to the higher marginal cost of irrigation water in the case of diesel-well commands (Kumar et al., 2013).

In northern Gujarat, electric-pump owners, who paid marginal cost for electricity, maintained higher water productivity in both physical and economic terms for all the crops as compared to those who were paying for electricity on the basis of pump horsepower. Furthermore, they did not keep high water demand for alfalfa, which is a fodder, in their fields during the summers (Kumar et al., 2013).

The analysis of the irrigation water application and the water productivity of crops raised by two categories of farmers in diesel-well commands of southern Bihar plains showed that the average depth of irrigation was much higher for diesel-well owners as compared to their water-buying counterparts. As regards crop–water productivity, for all crops, except onion and summer green fodder, water buyers in diesel-well commands secured higher physical water productivity as compared to pump owners. Again, for all crops, except onion, water buyers secured higher water productivity in economic terms as compared to pump owners (Kumar et al., 2013).

Similarly, the comparison of estimated mean values of irrigation water application and water productivity in physical and economic terms for both pump owners and water buyers in the electric-pump command area in the southern Bihar plain for all crops showed that water buyers applied less water to their crops and maintained higher physical water productivity for many crops in comparison to electric-well owners. However, they secured lower water productivity in economic terms for most of the crops, except radish and onion. This could be due to the higher cost of irrigation water which many water buyers are paying, which eventually reduces net return from crop production (Kumar et al., 2011).

Overall, the following trends are observed: the net water productivity of water buyers from electric pumps is greater than that from diesel pumps both in eastern UP and southern Bihar; the net water productivity of electric-pump owners under flat-rate provision is comparatively less than that under pro-rata tariff; the water productivity of electric-pump owners in economic terms is less than that of diesel-pump owners; and the economic water productivity of water buyers from electric pumps is less than those from diesel-well owners. The analysis showed that water buyers in diesel- and electric-well commands and the farmers who have metered connections secure higher water productivity in physical terms (kg/m^3) for most crops as compared to water-selling well owners. This means that when confronted with the positive marginal cost of irrigation water, farmers are encouraged to use water more efficiently (Kumar et al., 2011, 2013).

Farm-level Water-productivity Impacts

The analysis for diesel-well commands in eastern UP and southern Bihar clearly shows that water productivity in overall farm operation is much higher for water buyers than their water-selling counterparts. In electric-well commands also, the differences exist in favour of water buyers in spite of a very low marginal cost of using water. A similar trend was found in northern Gujarat. The water productivity improvement is highest in eastern UP in diesel-well commands where the water buyers incur the highest marginal cost of irrigation (Kumar et al., 2011, 2013).

Furthermore, the comparison between electric- and diesel-well owners in both the locations substantiates the earlier point that the positive marginal cost promotes the efficient use of water at the farm level. Therefore, when confronted with the positive marginal cost of irrigation water, farmers are encouraged to use water more efficiently over the entire farm from an economic point of view. Higher net water productivity in economic terms (INR/m^3), which farmers obtain even at a higher cost of irrigation water, is suggestive of the fact that it is possible to keep irrigation costs high enough to induce improved efficiency in water use in both physical and economic terms without compromising on farming prospects (Kumar et al., 2011, 2013).

Sustainability Impacts on Groundwater

The results of analyses carried out in eastern UP and southern Bihar showed that the pumpage of groundwater per unit area of the cultivated land is lower for water buyers, though their holdings are of smaller size. The data for northern Gujarat showed that the pump owners having metered connections, in spite of having smaller sized land holdings (2.95 ha against 3.45 ha for those paying on the basis of connected load), use much less water per hectare of land (304 h per year) as compared to their flat-rate counterparts (444 h per year). The difference in aggregate pumping is much greater between farmers with and without metres. Such a high reduction in water usage per unit of cultivated land, which is disproportionately higher than the reduction in net return per unit of land, is made possible through high improvement in water productivity in economic terms. In spite of a slight reduction in pumping, the net return from the unit area of land was found to be higher for water buyers in eastern UP and southern Bihar plains. This was achieved through high improvement in water productivity through the selection of less water consuming and high valued crops[3] (Kumar et al., 2011, 2013).

Overall Impacts of Pro-rata Pricing of Electricity in Farm Sector

Pro-rata pricing for electricity does promote efficiency and sustainability in the use of groundwater. But, more importantly, the price level at which the irrigation demand starts responding to tariff hikes is socio-economically viable (Kumar et al., 2011). Pro-rata pricing is unlikely to create negative impacts on access equity in groundwater as selling prices for irrigation water are determined by the monopoly power of the well owners, and the mode of pricing did not have any influence on this monopoly power (Kumar et al., 2013). The positive efficiency impact of pro-rata pricing is evident from the lower application of irrigation that farmers apply for crops and the higher physical productivity of water in crop production. The sustainability impact is evident from the lower volume of groundwater used per unit of cropped area. The socio-economic viability is evident from the higher economic productivity of water at the farm level and the higher net return per unit area of the irrigated land. The empirical evidence raises further questions about the validity of arguments against pricing (Kumar et al., 2011, 2013).

Feasibility of Metering Agricultural Pumps

Power utilities and policy-makers in India recognize the importance of metering electricity from the point of view of both cost recovery and improving energy efficiency. For almost two decades, they have been toiling with this idea in a way that makes it fool proof as well as cost-effective. Earlier, there were problems of rampant tampering of meters and malfunctioning meters in rural areas (Kumar et al., 2011). However, now technologies exist not only for metering, but also for controlling energy consumption by farmers (Zekri, 2008). The use of energy and groundwater in remote areas can be monitored from a centralized location with the help of the prepaid electronic meters that are operated on satellite and Internet technology and can be recharged through scratch cards (Zekri, 2008). The fact that over the last 10–12 years there has been a remarkable improvement in the quality of services provided by Internet and mobile (satellite) phone services, especially in the rural areas, with a phenomenal increase in connections, also needs to be reckoned with.

Prepaid metres prevent electricity theft. They can be operated through tokens, scratch cards, magnetic cards or recharged digitally through Internet and SMS. It helps electricity companies to restrict the use of electricity. The utility can be decided on the 'energy quota' for each farmer on the basis of the reported connected load and the total hours of power supply, or sustainable abstraction levels per unit of the irrigated land. Farmers can pay and obtain the activation code through mobile SMS (Zekri, 2008). Hence, the transaction cost of metering can be substantially reduced.

Restricting farmers' energy use is equivalent to rationing water allocation for irrigation volumetrically (Kumar et al., 2011). When water allocation is rationed in volumetric terms, farmers would allocate the available water to economically more efficient uses (Kumar, 2005). Hence, restricting energy use will have a positive impact on the efficient use of groundwater by all categories of farmers. Here again, the energy quota will have to be decided on the basis of the geo-hydrological environment prevailing in the area and the optimum irrigation requirements (Kumar et al., 2011).

With metering-and-consumption-based pricing, there would be no need for restricting power supply to the farm sector, as is done currently. Unlimited power supply with stable voltage will ensure better quality of irrigation water than restricted power supply with voltage fluctuations. As some studies had indicated, the returns from irrigation are highly elastic to its quality (Kumar & Singh, 2001; World Bank, 2001). Therefore, the issue is not of feasibility, but the absence of political will, on the one hand, and the lack of innovative application of technologies to address the pressing social problems, on the other.

Small-scale Water Harvesting and Groundwater Recharge: Panacea for Water Problems?

Several governments, for fear of becoming unpopular, have shied away from introducing direct tax for groundwater or inducing marginal cost price for electricity used for groundwater pumping, in spite of growing problems of groundwater over-development in many semi-arid and arid areas. In spite of this, there has been over-enthusiasm among some provincial governments on taking up water-supply augmentation projects. Here, the policy has been to promote small-scale water harvesting and artificial recharge in over-exploited regions. The programme involved harnessing of local runoff during monsoon for recharging aquifers in the local area, with the participation of local communities through NGOs, community organizations and Panchayati Raj institutions. Small structures such as check dams, percolation ponds, dug-well recharge and sub-surface dykes are used for water harvesting and recharging. This was driven by the experiments of a few NGOs in states like Gujarat, Rajasthan, Madhya Pradesh and

Maharashtra, the success of which was decided purely on the basis of limited evidence available locally for limited time duration.

Large schemes were planned and executed in states like Gujarat and Rajasthan, which are naturally water-scarce regions with low-to-medium rainfall and high aridity. Such schemes never involved any hydrological planning and economic analysis at either the local catchment or the basin levels. In fact, the river basins where these schemes were implemented are characterized by poor runoff rates, low dependability of the runoff, high evaporation and excessively high irrigation water demands owing to high evapotranspiration rates, low effective rainfall and high arable land per capita (Kumar, Patel, Ravindranath, & Singh, 2008).

In naturally water-scarce regions of India, water harvesting or groundwater recharge faces several critical issues for basin planning. Such issues are: (a) poor dependability of the runoff harvested from local catchments; (b) heavy loss of water through evaporation from the systems during monsoon; (c) the limited groundwater storage potential of aquifers underlying most of the semi-arid and arid regions acting as a constraint for storing additional runoff; (d) negative downstream effects of intensive water-harvesting activities, when carried out in 'closed river basins', which reduce the overall economic viability of the system; and (e) the trade-off between increasing the hydrological benefits of water harvesting and improving cost-effectiveness (Kumar, Ghosh, Patel, Singh, & Ravindranath, 2006; Kumar et al., 2008).

Kumar et al. (2008) analyzed that several water-harvesting systems are economically unviable when the cost of capturing water and recharging were compared against the net income returns from the unit volume of water used in agriculture. While no scientific evidence exists so far to support the big claims about rainwater harvesting and recharge being made by some researchers (see, e.g., Shah, Gulati, Sridhar, Hemant, & Jain, 2009) and government agencies, water agencies continue to invest large amounts in such schemes. Among the official agencies that deal with groundwater at the national and state levels, there is too little appreciation of the fact that the basins in water-scarce regions, which face problems of groundwater depletion, do not have surplus runoff which can be harvested for recharge, and reservoirs and diversion systems already exist to tap the yield of these basins. Often the national-level aggregate data on hydrology are used to make the sweeping argument that a lot of monsoon runoff is draining into the oceans from the rivers of water-scarce basins and that it needs to be conserved.

As a matter of fact, in India, the government policies with regard to the water resources management sector were heavily influenced by what NGOs and civil society organizations in the country and abroad felt about the conventional approach to water management and the alternatives they brought to the debating table. It will not be inappropriate to say that the experience of dealing with the civil society groups while implementing schemes like the Sardar Sarovar Narmada project in western India had prevented the central government from even conceptualizing large infrastructure projects for water, which had social and environmental consequences in terms of forest submergence, displacement of communities in the upper catchment and requirements of large-scale land acquisition for the construction of infrastructure. Pandit (2014) rightly calls it 'environmental over enthusiasm' on the part of the government. The previous governments had found it quite convenient to invest more in small water-harvesting schemes and watershed management programmes (Kumar et al., 2008) and popular schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme (Bassi & Kumar, 2011), which were projected as the panacea for water-scarcity problems in dry land areas.

Can Micro-irrigation Help Reduce Groundwater Over-exploitation?

In recent years, both the central and state governments in India have tried to promote large-scale adoption of micro-irrigation (MI) systems, such as drip irrigation and sprinkler irrigation systems, through heavy subsidies. The minimum subsidy offered is 50 per cent and in certain cases it goes up to 90 per cent of the capital cost of the system. The underlying assumption is that in the conventional irrigation method, water-use efficiency is very low and a significant amount of water is wasted. However, with an increase in area under MI systems, the water-use efficiency in crop production could be increased, thereby leading to water saving and reduction in the use of groundwater wherever such systems find large-scale adoption.

However, the distinction between 'water applied' and 'water consumed' is hardly ever made by water-resource managers in practical applications and in deciding policies for improving water-use efficiency in irrigation systems and river basins. Hence, no attempt is made to study the impact of the MI system on basin-wide water-use efficiency and aggregate water use. It is assumed that groundwater use is reducing in semi-arid and arid regions which have seen the large-scale adoption of MI systems. The fact is that in many instances, the water consumed in crop production can be much less than the total water applied to the crop land and that a significant portion of the water applied in the field under the conventional method of irrigation is available for reuse through return flows. Also, the reduction in water use obtained through the use of efficient irrigation methods is nothing but a notional water saving and not real water saving at the level of irrigation systems or river basins (Allen, Willardson, & Frederiksen, 1998; Perry, 2007).

After Kumar and van Dam (2013), the extent of real water saving per unit of irrigated land through micro-irrigation technologies is determined by five major factors, namely crop type, climate, soils, type of micro-irrigation technology and geohydrology. They noted that under semi-arid to arid climatic conditions, the adoption of drip systems is likely to result in real water saving for distantly spaced crops, when the groundwater table is very deep and soils are light, whereas under humid and sub-humid conditions, the adoption of MI systems may not result in real water saving, with shallow water table conditions (Kumar & van Dam, 2013).

At the next level, the issue is to understand what farmers do with the saved water. Even if there is real water saving obtained through the use of efficient irrigation technologies, the question is whether the farmers would use the water to expand the area under irrigation or make voluntary cuts in water use. In case there is no real water saving with the use of the MI system, and the farmers expand the area under irrigation using the water saved (notionally) through the reduction in water applied in the area, this would lead to an increase in the consumptive use of water. Conversely, if there is real water saving as well as applied water saving, and if the farmers expand the area with the saved water, there may not be any reduction in consumptive water use at all.

The most desirable situation is when the farmers do not expand the area under irrigation after MI adoption, in spite of the reduction in consumptive water use. However, they are rare. In many semi-arid and arid regions of India, only a small percentage of the crop land is under irrigation, and the tendency of the farmers after adopting the MI system is to go for area expansion.[4]

More importantly, there are serious questions about the incentive farmers have to improve water use efficiency in crop production. The reason is that water saving does not lead to any cost reduction for the farmer, in situations where they do not pay for electricity and water, which is mostly the case at present (Kumar & van Dam, 2013). In a recent study carried out in Aurangabad District of Maharashtra, which compared the water-use efficiency of irrigated sugarcane for three categories of farmers, namely straight furrow irrigators, serpentine furrow irrigators and drip irrigators, the average water-use efficiency was almost the same for drip and straight furrow irrigators (Kumar, Niranjan, Puri, & Bassi, 2012b).

There are situations where farmers have limited access to water owing to physical constraints induced by the geology and geohydrology, and where the opportunity cost of wasting water is real (Kumar & van Dam, 2013). However, in such situations, farmers might use the saved water to expand the irrigated area, as area expansion, which results in income increase, is one of the major incentives for them to use the drip. Hence, more than technology, the need is for creating appropriate institutional and policy framework for the use of water, which can create either the positive marginal cost or the opportunity cost of using water.

The provision of large government subsidies for the promotion of micro-irrigation technologies in India from the central and state governments is under the pretext that the use of these technologies would lead to positive externalities on the society, in terms of water and energy saving. However, there was no analysis from the policy-making bodies[5] to identify the situations under which real water and energy saving can happen through the use of this technology. Also there is no attempt to assess the impact of their adoption on the stress on the resource.

Initiatives for Sustainable Groundwater Management in India: Are We Heading in the Right Direction?

India faces the problem of the excessive use of groundwater for agriculture in the semi-arid and arid regions, with many millions of small holders pumping groundwater through wells and pumpsets (Kemper, 2007; Kumar, 2007). Groundwater overdraft problems are experienced in hard rock as well as alluvial areas (Kumar, 2007).

But political economic considerations guided policies in the water and energy sector that had implications for the sustainability of groundwater use for agriculture in rural areas. The politicians' views are largely myopic. For them, farmers constitute a major share of the rural vote bank. As a result, they consider measures such as raising power tariff and regulating energy supply in the farm sector as highly unpopular and suicidal, in spite of the growing evidence to the effect that farmers prefer good quality power which is priced more than free power, which is available for short duration (World Bank, 2001). Instead, they prefer popular schemes such as 'small-scale rainwater harvesting' for villages and also wish that the government should frame policies and legislations to favour investment in such schemes.

Large amounts of public funds are being pumped in every year for integrated watershed management, dug well recharging and community-based water harvesting in naturally water-scarce regions, without any hydrological considerations, and with no visible positive outcomes. However, there are no attempts to introduce market instruments such as electricity pricing or groundwater taxes or water rights. The politicians and policy-makers are also encouraged by some very pervasive arguments from researchers, such as (a) free power and subsidized diesel benefit poor small and marginal farmers who do not own wells, by lowering irrigation water charges in the market; (b) the transaction cost of metering and introducing metered tariff would be so high that it, if passed on to the consumers in the form of electricity tariff, would reduce the overall welfare benefits of groundwater irrigation, while substantially reducing farm incomes (Shah et al., 2004); and (c) small water-harvesting systems are cost-effective and improve water security in villages if built in large numbers and they have no negative social environmental effects (see, e.g., Shah et al., 2009). However, as evident from the previous discussions, these arguments are either flawed or no longer valid.

On the contrary, there is little appreciation among Indian policy-makers of the distinction between 'efficiency' and 'sustainability' in the context of agricultural water use. Hence, huge subsidies are offered for the purchase of micro-irrigation technologies by the government, under the pretext that there would be saving of water resources, resulting in societal gains. The adoption of water-saving technologies in irrigation in the water-scarce provinces is largely driven by these subsidies, as otherwise there is too little economic incentive for farmers to go for these systems under the current water and energy pricing regimes (Kumar & van Dam, 2013).

Notes

1. On the basis of the NSSO data, Mukherji (2005) had worked out the gross area irrigated by pump-rental markets, on the percentage of households using pump-rental services under different landholding classes and the gross area irrigated under these landholding classes using simple multiplication. The net irrigated area by pump-rental services for 1997–98 was subsequently worked out by dividing these figures by the cropping intensity.
2. The figures available from the Muzzafarpur district of Bihar on the price of water sold in the market to the diesel price show that although diesel prices have gone up tremendously from 1975 to 2003, the price of water has not gone up proportionately. As a result, the monopoly ratio dropped from 5.33 to 2.5. This is because of the increase in the number of wells and pumpsets in the area, which reduced the monopoly of the early owners of wells and pumpsets.
3. The primary data for the study included 60 farmers for each category of irrigators, such as well owners and water buyers for electric- and diesel-well commands in eastern UP and southern Bihar, and farmers with metered pump connection and those with flat-rate connections from north Gujarat, with a total sample size of 600. Comparison of irrigation applications and physical productivity of water in crop production for the same crop was used to analyze the impact of tariff change on groundwater-use efficiency. Comparison of net water productivity in crop production, dairy production and that for the entire farming system in economic terms, and also the net return per unit of land for the entire farm were used to examine the impact of tariff change on the socio-economic viability of farming. The average pumping rates per unit area of the irrigated land were used to analyze the impact of change in the tariff regime on groundwater use sustainability.
4. Exceptions are the alluvial areas of north Gujarat, Punjab and Haryana, where well owners irrigate their entire land.
5. Policy-making bodies such as the Planning Commission of the Government of India and the planning boards of the provincial governments.

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