17 Managing Groundwater Development in Karnataka

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Groundwater irrigates over 50 percent of India's net irrigated area (Directorate of Economics and Statistics 1992). As its name implies, this water is stored in underground aquifers and only can be used after it is lifted to the surface. Indian farmers traditionally tapped groundwater by hand, digging open wells and lifting the water with bullock-drawn buckets. Open wells are still common, but machine-drilled tubewells and borewells with motorized pumpsets are now widespread. Open wells usually are relatively shallow, rarely more than 10 meters deep; borewells and tubewells on the other hand, are usually over 60 meters deep (Radhakrishna and Jitendra Kumar 1992) and sometimes over 200 meters deep (Shah 1993), tapping water resources far below the surface.

In this chapter, we explain what physical determinants of groundwater affect supply and demand in Karnataka, and we demonstrate how property rights are a critical factor in determining how groundwater is managed. We also discuss various private and government actors in groundwater management and some economic principles relevant to their activities and objectives.

1. Determinants of Access to Groundwater

Several factors are important for determining who uses groundwater and how much they use. Most limiting is its availability—that is, its depth and flow rate. These physical characteristics make it difficult to manage groundwater in an efficient, equitable, and sustainable way. Second is the legal and social system governing access to it. Third is the financial requirements of drilling, running, and maintaining wells and of conveying the water. We shall look at all of these in turn.

1.a. Groundwater hydrology

The availability of groundwater depends on rainfall levels, subsurface geological features, and surface topography, soil type, and vegetative cover. Together, these factors determine the amount of water potentially available, the infiltration rate, the storage capacity, and the rate at which aquifers can be recharged after water is extracted.

In alluvial river valleys, the soil and subsoil layers can hold large quantities of water, creating large aquifers that are seasonally recharged by the monsoon. In dry, hard rock regions, on the other hand, seepage and water retention are low because, when the water hits the hard rock layer, it either flows down the slope and away in underground streams, or trickles into fissures in the rock. Average recharge in the hard rock areas of southern India ranges from 6.5 to 12.5 percent of rainfall. The alluvial areas of the Indo-Gangetic plains, in comparison, recharge at rates of 15.0 to 22.5 percent of rainfall (Moench 1992).

Tank-fed aquifers in the Deccan Plateau provide abundant water during the monsoon but gradually dry up as the summer wears on. Many deep aquifers function in the same way, although depletion and recharge may take place at much slower rates. In fact, some deep aquifers in hard rock areas are not recharged by seepage, or are recharged at such imperceptibly slow rates as to be essentially nonrenewable. All farmers with wells in these areas are currently advised by the Karnataka Electricity Board to use pumps of 3 horsepower or less to limit the rate at which water is withdrawn. This would allow shallow aquifers to recharge faster and reduce the chances that deep aquifers are *mined*, that is, permanently depleted. However, as shown in table 17.1, nearly 60 percent of farmers use bigger pumps. Most of these large pumps are in the hard rock areas, suggesting the likelihood of groundwater overdraft.

Seepage of water from unlined canals in canal command areas contributes to groundwater availability. Water tables in command areas often are so high as to cause the kinds of waterlogging and salinity problems

Table 17.1. Number of pumpsets in Karnataka by horsepower, 1986–87

Horsepower	Number of pumpsets	Percent of total recorded
0–3	145,378	42.2
4–5	175,265	50.8
6–8	16,051	4.7
9–10	6,333	1.8
Greater than 10	1,694	0.5
Not recorded	31,508	9.1
Total	376,229	109.1
Total recorded	344,721	100.0

Source: Department of Minor Irrigation 1991, 47 described in chapter 16. In these areas, pumping water from wells helps reduce ecological externalities associated with canal irrigation; well and canal irrigation are mutually beneficial activities. In such water-abundant areas, pumps larger than 3 horsepower do not pose a problem.

The physical characteristics of aquifers are notoriously complex and location specific, and we provide only a brief, simplistic overview here. Interested readers may refer to the reference list for further sources of detailed information about aquifers (Karanth 1987, 1989; Dhawan 1986).

1.b. Groundwater property rights

As discussed in box 6, chapter 6, groundwater is essentially an open access resource in India. Any owner of land has the right to sink a well and extract the water below his plot. Aquifer boundaries are unknown, however, so a given well owner shares access to groundwater with an unspecified group of other well owners. Because cooperation among users is thus difficult to organize, groundwater is not managed as common property. Some regulations of groundwater use exist on paper, but given the lack of information on aquifer boundaries, they are not enforceable.

Controlling its extraction is also difficult. As we learned in chapters 6 and 8, under circumstances of no ownership the private cost to the user is less than the actual cost to society, but only the user reaps the benefits. This tends to lead to overexploitation of the resource, which is neither efficient nor sustainable.

1.c. Equity in access to groundwater

Sinking a well to extract groundwater is a costly investment. Drilling a borewell costs roughly Rs 25,000 and is risky because there is no way to be certain the well will tap an aquifer. Even if a well is not dry, the amount of yield can vary widely. Efficient credit markets along with insurance can help poor farmers invest in wells. Even if they cannot afford to dig their own wells, farmers can still gain access to irrigation water through groundwater markets (Shah 1993). If none of these markets exist, groundwater development can widen gaps in income distribution.

The fugitive nature of the groundwater resource (box 6, chapter 6) also contributes to inequitable access. Wealthier farmers are in a better position than poorer farmers to deepen existing wells as the water table falls. This underscores the need for efficient credit and insurance markets to support investments.

1.d. Risk of well failure

The National Bank for Agriculture and Rural Development (NABARD) defines borewells yielding less than 2 liters per second (or 1,582 gallons per hour) at the time of installation as failed wells. By this criterion, NABARD calculates the probability of well failure to be 70 percent. Analyzing the data from 7,311 borewells in Karnataka, Radhakrishna and Jitendra Kumar

(1992) report that about 60 percent of the borewells yielded 1.26 liters per second or less and about 5 to 20 percent of the borewells (depending on the region) yielded no water at all.

The definition of well failure is somewhat subjective, however: it depends on the method of irrigation and the crop grown. Efficient irrigation methods, such as sprinkler or drip irrigation, can be used successfully even with borewells yielding only 0.38 liters per second (Kumaraswamy 1992). Therefore analysts and policymakers should be cautious when discussing well failure.

2. Determinants of Demand for Groundwater Irrigation

The amount of utilizable groundwater and the percentage actually pumped in Karnataka vary greatly by district. In general, however, demand is high, while supply is relatively low. Demand for groundwater is derived from the costs of obtaining it and its benefits to crop production. Costs are both fixed and variable. Benefits depend on the extent to which water constrains yields, which varies by location and season, and on crop prices. The higher the crop price, the greater the benefits of increased yields from irrigation.

The costs of appropriating groundwater include drilling, pumping, and conveyance costs. Drilling costs in turn depend on the type of drilling technology, the cost of credit, and the risk of well failure. The lower the drilling cost, the higher the demand for groundwater.

Extraction costs and the cost of pumping depend on the type of power used, which in India is either diesel or electricity. The costs of these technologies depend on the initial investments required and their operating costs, which reflect the price of fuel and the reliability of access to it. Electricity is less expensive in most states but is not always reliable. In addition, not all farmers can acquire an electrical connection. The far higher cost of diesel in most states is sometimes offset by being more reliably available, but requires facilities to transport and store it. In some places, there is also a high risk that dealers adulterate diesel, further raising its effective cost.

Water conveyance systems also affect cost, and hence demand. Simple gravity systems through unlined field channels are most frequently used. In other cases, pipes direct water to the highest point in the field before gravity takes over or to sprinklers or drip irrigation systems to conserve water.

Digging wells and buying extraction and conveyance systems can be considered fixed costs, which should be broken down into long- and short-term fixed costs. The well itself is fixed in the long term—once the well is sunk, it cannot be removed—but conveyance costs are only fixed in the short term. Pipes, sprinklers, and drip systems can be moved or replaced if the farmer so desires. Pumping, on the other hand, is a variable cost. Once an irrigation system is in place, it is the variable costs that determine a farmer's choice of how much irrigation water to utilize on a given crop.

Groundwater utilization is thus highly dependent on the pricing structure used for electricity. This means that electricity price policy can be a powerful tool to affect farmers' use of groundwater. Several pricing systems are possible, each with its own advantages and disadvantages. We discuss two: flat rates, whereby farmers pay a single rate per year regardless of how much power they actually consume; and pro rata tariffs, whereby farmers pay for electricity on the basis of how much they consume.

2.a. Efficiency and sustainability under flat rate and pro rata pricing

Under flat rate pricing, electricity costs the user one price no matter how much or little he or she uses. The price can be tied to some other factor, like pump size that may or may not affect consumption. Flat rates can, of course, be high or low. If they are low, few potential or current users will be discouraged on the basis of cost from using as much electricity as they want. If the rate is high enough, many users may be kept out of the market, but for those who can afford the fee, there again is no incentive to conserve. Either way, flat rate pricing encourages inefficient water use because it reduces the marginal cost of electricity virtually to zero. Since the only marginal costs are labor and wear and tear on the pump, crops are irrigated to the point at which the effect on yield is zero.

The impact of a pro rata system is quite different from a flat rate system. If a pro rata system replaces a flat system, pump owners in the short run will tend to irrigate less because the marginal cost of electricity consumption will rise. They could conserve water by applying less to a given crop or by shifting to a less water-intensive crop. Figure 17.1 shows the optimal level of irrigation under flat rate and pro rata pricing. Two pro rata prices are shown: the first is the social price (P^*),[1] the second is the subsidized price (P^s).[2] In panel A, pump owners would move along the demand curve D^0 for electricity (and irrigation water), from the flat rate equilibrium quantity at Q^f to the lower equilibrium at Q^* at unsubsidized (social) pro rata prices, or to Q^s at subsidized pro rata prices (panel B).

Long-run elasticities are higher under pro rata pricing for at least two reasons. First, some farmers shift to more efficient water delivery systems, such as drip and sprinkler, to reduce their electricity costs. In figure 17.1, panel A, this is represented by a shift in the demand curve from D^0 to D^1 and a reduction in irrigation levels from Q^* to Q^{**}, or in Panel B, under subsidized pro rata pricing, from Q^s to Q^{ss}.

1. The social price of electricity can be defined as the cost of generating and transmitting electricity or as its value in alternative uses, which would equal the price in perfect competition. The latter definition is superior because it fully reflects the opportunity costs of allocating electricity to a given use.

2. The flat rate price is shown as P^0 because the marginal cost under flat rate pricing is zero.

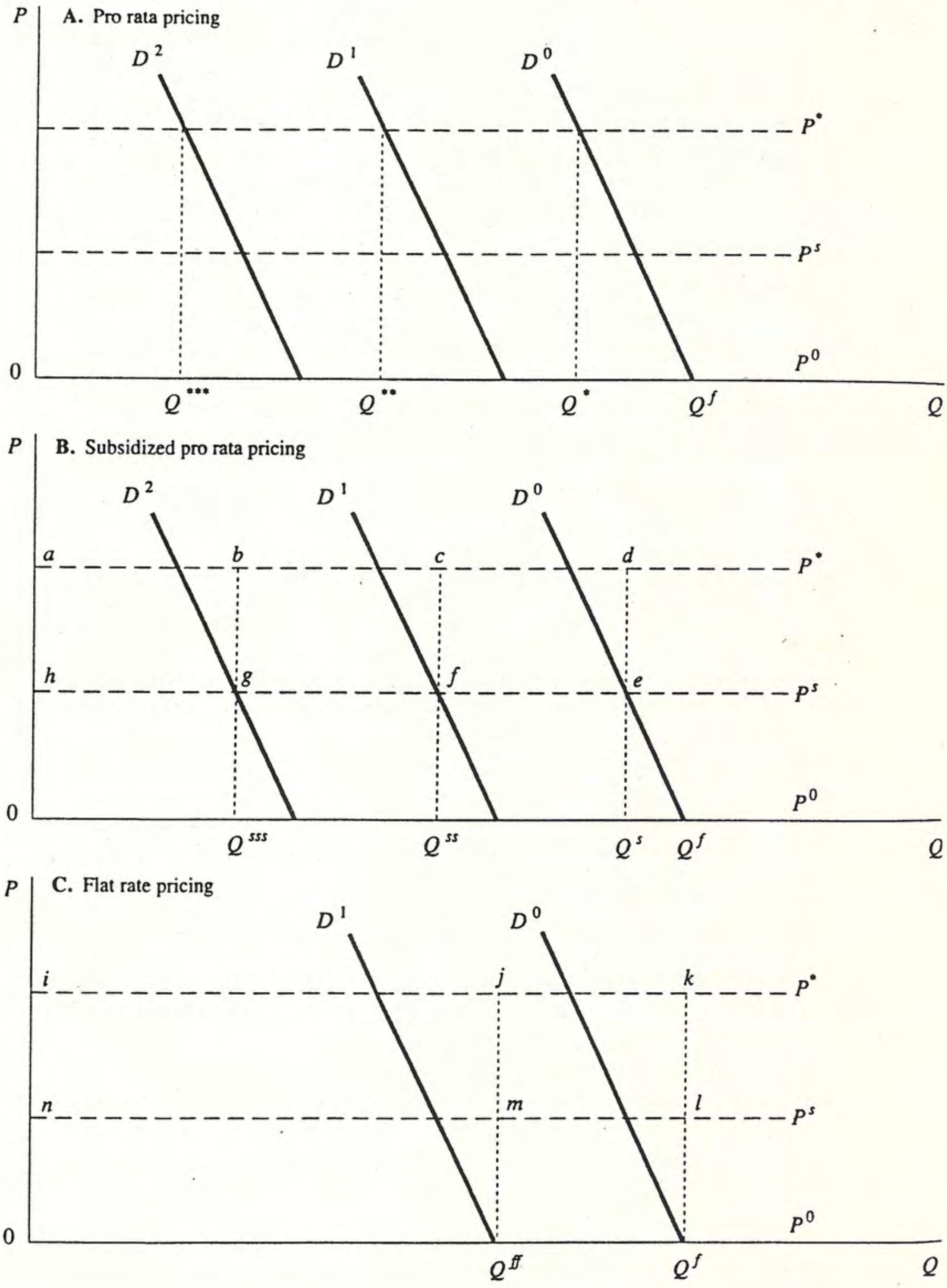

Fig. 17.1. Effect of price increases on electricity demand under pro rata and fixed rate tariffs

Second, investment in irrigation wells will be lower than under flat rate systems due to the lower expected returns. As some borewells go dry over time, there might even be a net decrease in the number of wells in areas with especially scarce groundwater. This adjustment would take a relatively long time. It is represented in figure 17.1, panel A, by a further shift in demand to D^2, with the irrigation level at Q^{***}. A shift to subsidized pro rata pricing would produce the same effect but to a lesser extent. In panel B, if the price rises from P^0 to P^s, the long-run irrigation level will be Q^{sss}.

It is important to understand that a simple increase in the flat fee would not accomplish the same goals. In the short run, each individual well owner would still irrigate at the socially excessive level of Q^f in figure 17.1, panel C, because the marginal cost would remain zero. There would be no incentive to either reduce the quantity pumped or adopt water-conserving systems. In the long run, well investment would decrease because higher total costs would reduce the benefit-cost ratio. Demand would shift from D^0 to D^1, but irrigation levels would remain at Q^{ff} (where D^1 intersects the X axis) because marginal cost would remain at zero.

2.a.1. *Administrative problems of pro rata pricing*

The effects of pro rata pricing are mixed, however. As mentioned above, meters must be installed and monitored on all electrified pumps. The administrative cost would be extremely high as there are over 900,000 electrified pumpsets in the state. Any revenue gains associated with pro rata pricing would be countered by the increased administrative costs. If the flat rate is high enough, on the other hand, state electricity boards can collect the same revenue with a flat rate as with pro rata pricing (Shah 1993, 116). Moreover, when power has a positive incremental cost (as under pro rata pricing), the incentive to pilfer power increases (Shah 1993, 117–18), further reducing financial benefits to the state. Flat fees also are easier to collect than variable pro rata fees, partly because the amount due under flat fees is known to everyone. Pro rata pricing introduces opportunities for farmers to make side payments to those who monitor meters to reduce their bill.

2.a.2. *Equity effects of flat rate pricing*

The effects of flat rate pricing are also mixed. This pricing system encourages development of water markets, which enable farmers who cannot afford wells to benefit from groundwater irrigation. Flat rate pricing is conducive to the development of water markets because well owners can supply water to their neighbors at a much lower cost. Since the cash cost of pumping is nearly zero, the variable cost to the water supplier is only the opportunity cost of not supplying water to his own crop. This opportunity cost depends on the capacity of his well, the amount of land he operates, and the types of crops he grows. The benefits of flat rate pricing are therefore more likely to be transferred to farmers without wells in water-abundant areas, such as canal and tank command areas.. In dry areas, where well capacity is low, well owners will sell less water and thus retain a greater proportion of the benefit. This suggests that equity effects of flat rate pricing are important in water-abundant areas, but not where water is scarce.

Water markets flourished in many states after the introduction of flat rates (Shah 1993). More farmers without wells received irrigation water, and the price they paid for it fell. Well owners obviously benefited from increased water sales as well. The negative side of this situation is that, since flat rate pricing encourages well owners to pump more water so they can sell to their neighbors, there is a real risk of exceeding sustainable limits of extraction. Barah (1992) and Nadkarni (1992) discuss the relationship between groundwater markets and sustainability.

Not surprisingly, sustainability of groundwater usage also affects equity. Groundwater overdraft causes the water table to fall, so that farmers must continually deepen their wells to have access to water. This poses difficulties for poor farmers, who might not be able to keep up with their neighbors in the race to tap the steadily falling water table. To the extent that flat rate pricing encourages overdraft and causes the water table to fall, it discriminates against poor people by raising the cost of well investment. This obviously has negative effects on equity.

2.b. Alternatives to price mechanisms

There are other, more limited, methods for improving efficiency that do not rely on pricing of electricity. Technical requirements can be imposed on pumpsets—their quality, technical specifications, and capacity—and on conveyance systems, including delivery pipes and water distribution systems. Small pumpsets reduce farmers' ability to irrigate intensively, counteracting the incentive created by free power. High-quality delivery pipes reduce leakage losses, thus increasing pumping efficiency. Sprinkler or drip irrigation also reduces water requirements; drip systems reduce water requirements for water-intensive row crops by 50 percent (Kumaraswamy 1992).

Quantitative rationing is potentially a powerful nonprice policy tool. Strict limits on power availability, combined with restrictions on pump sizes, prevent farmers from heavily irrigating water-intensive crops. Some quantitative rationing has been imposed to date, but never to the extent that it constrains farmers' irrigation decisions.

Different nonprice regulations must sometimes be used in conjunction with each other to be effective. If quantitative rationing is desired, for example, it should be combined with restrictions on pump size. Otherwise farmers will expand their current practice of overcoming scheduled power cuts by pumping water into storage tanks or ponds, and irrigating later by gravity. Small pumps would limit the opportunity to store. If drip irrigation is being promoted, on the other hand, quantitative rationing would be a deterrent because this method of irrigation requires a consistent flow of water. Farmers using drip irrigation would have to buy water storage structures and irrigate by gravity when the power goes off.

There are other problems with nonprice regulation. For example, many farmers may not be able to afford sprinkler systems. They are most likely only feasible for high-valued crops, most of which are relatively water intensive. More importantly, nonprice regulations are very difficult to implement. Enforcing the use of high-quality pipes, for example, is nearly an impossible task.

Finally, nonprice policies tend to regulate groundwater use in an arbitrary and illogical manner. For example, strict, across-the-board power rationing would make it difficult to irrigate water-intensive crops. Therefore special exceptions would have to be made to provide water to those regions that are suitable for water-intensive crops. But because such regions frequently do not follow neatly defined boundaries, it would be administratively difficult, if not impossible, to target them. Under pro rata pricing, however, water allocation would be self-targeting.

3. Actors in Groundwater Management: Their Objectives, Constraints, and Opportunities

Wells do not yield much water in the hard rock geological conditions prevailing in most of the state, and overdraft is common in some regions. The key issue is how to meet farmers' demands for groundwater while discouraging overdraft in a way that is economically efficient, equitable, and administratively and politically feasible.

It is clear that these policy issues affect many diverse client groups involved in managing groundwater. These groups include direct users, state and central government institutions, quasi governmental agencies, and nongovernment organizations, particularly

- Farmers (private agents)
- Legislators and policymakers (all levels)
- Department of Mines and Geology (state government)
- Central Groundwater Board (central government)
- Karnataka Electricity Board (state government)
- National Bank for Agriculture and Rural Development (NABARD) (quasi central government)
- General Insurance Corporation (quasi central government)
- Minor Irrigation Department and *Zilla Parishads* (state government)
- State Watershed Development Program
- Nongovernment organizations (voluntary sector)
- Borewell drillers and water diviners (private agents)

Each group differs widely in objectives and interests, but together they shape the groundwater situation. The remainder of this chapter presents each client group's activities, objectives, and constraints, and discusses the economic issues relevant to them. Several creative approaches to these complex issues also are presented.

3.a. Farmers

Farmers who irrigate with groundwater are the largest client group concerned with groundwater management. In dryland areas, irrigation makes possible high, stable crop yields; in the tailend areas of canal and tank commands, it reduces the risk of insufficient surface water. While farmers would like irrigation water to be under their individual control, inexpensive, and reliable, these objectives cannot all be realized. And as already explained, groundwater by nature cannot be privately controlled with complete property rights. We will demonstrate that the cost and reliability of groundwater delivery are highly positively correlated: groundwater cannot be both inexpensive and reliable. How farmers use and manage groundwater thus depends on the actions of the groups listed above, which we will discuss before concluding with the implications for farmers.

3.b. Policymakers and legislators

Policymakers have great leverage over all other groups interested in groundwater. The laws they set dictate the activities pursued by government agencies and determine the rules that private actors must follow in pursuing their own objectives. In the discussions of all client groups in this chapter, we refer explicitly and implicitly to policymakers.

Policy is made at the central, state, and sometimes local levels of government, each having different responsibilities. Groundwater management is technically the domain of the state government, but other policies are determined at other levels of government, which we will identify as we proceed.

The most fundamental policy determining groundwater management concerns the determination of property rights to groundwater. This is handled at the state level of government. Groundwater law as specified by the Indian Easements Act effectively states that all farmers have the right to pump as much water as they please from the aquifer below their land. Because many well owners share the same aquifer, and because groundwater is a fugitive open access resource, current use is inefficient and unsustainable. But attempts to promote cooperative groundwater management are unlikely to make progress until laws are changed.

The correlative rights doctrine, which forms the basis of California's groundwater law, is attractive because all farmers above an aquifer retain rights to a reasonable share of the water beneath them, even when the supply is insufficient to meet everyone's needs. Groundwater does become their common property. But is this approach feasible in India? Shah (1993) points out that in California a few hundred farmers at most share an aquifer, but in India there could be thousands or even tens of thousands. Furthermore, reliable groundwater maps do not exist, so even the boundaries of the resource to be held in common are not known. This is not a good basis for successful common property resource management (chapter 6).

What if the California approach could be modified to Indian conditions, however? Since groundwater rights cannot now be distributed at the level of the aquifer, a second-best alternative might be to assign them at the village or hamlet level, with all inhabitants of a village sharing equal use rights. Arbitrary levels of access to groundwater would have to be established since the property rights would not correspond to the physical boundaries of aquifers. Also, a major debate would concern whether groundwater belonged only to well owners or to everyone, with well owners paying a fee to a village association for the right to use groundwater.

This idea is not presented as a serious proposal, but as a point to stimulate the imagination. Without innovative ideas, it will not be possible to make groundwater function as a true common property resource. This is an important area where researchers and other activists can put alternatives onto the policy table.

3.c. Department of Mines and Geology

The Department of Mines and Geology (DMG) is a nodal authority of the Karnataka government formed to manage geological resources, and under it is the State Groundwater Board. The DMG's objective is to promote and monitor systematic groundwater development, including checking indiscriminate drilling of borewells. From the network of 1,500 observation wells throughout the state, the DMG documents data on water levels every month to prepare hydrographs. It determines the stage of groundwater exploitation in each *taluk* (block) according to the ratio of groundwater extraction to recharge in each block. If the extraction rate exceeds 85 percent, the block is designated as a "dark" area, meaning groundwater is overexploited; if it falls between 65 and 85 percent, the block is considered "gray"; if it is below 65 percent, it is considered "white." Groundwater development is encouraged in white and gray areas but discouraged in dark areas.

When providing institutional financing for well drilling became an important program in the early 1970s, it was mandatory for loan applicants to seek permission from the DMG. The DMG would dispatch a geologist to visit the farm to provide detailed technical information to determine whether groundwater would be available, at what approximate depth, and at what location. It also specified the type of pump, its horsepower, and the type of irrigation conveyance structures to be used. This helped establish technical control over the resource, and it provided statistics regarding types of wells and aquifers, as well as the depth of and spacing between wells. Open wells were required to be at least 183 meters (600 feet) apart and borewells at least 242 meters (800 feet) apart.

Since the mid-1980s, the number of loan applicants has been so great that the DMG can no longer monitor them. There is thus no documentation of the extent of groundwater extracted, pump capacity needed to lift groundwater, well depth, year of construction, or other details relating to groundwater development. The DMG has proposed establishing a groundwater authority to regulate borewell drilling and groundwater extraction. This authority would examine (a) the purpose for which water is to be used, (b) the extent to which the well is likely to compete with other uses, (c) the availability of water versus the need to conserve it, and (d) any other relevant factors. Although this has been presented to the state legislature several times, it is not likely to be established. The main problem is that while the authority would have vast powers in principle, it is not likely that it would be able to enforce them.

3.d. Central Groundwater Board

The Central Groundwater Board studies groundwater hydrology in every state. It employs zonal officers who maintain a series of observation wells to monitor groundwater levels and recharge rates. The board has no policymaking power in the states, since groundwater legislation is handled at the state level. It can, however, report to the central government on the groundwater situation and urge it to use its influence on state policymakers. For example, the central government could threaten to withhold electricity supplies to the states should it wish to convince them to adjust prices charged to groundwater users.

3.e. Karnataka Electricity Board

The Karnataka Electricity Board (KEB) is entrusted with transmission and distribution of electrical power to different consumers. It purchases electrical power generated by the Karnataka Power Corporation at prices specified by the government and sells it to consumers. It also purchases electrical power from other institutions for meeting additional power demands in the state. Electrical pumpsets have spread rapidly since the early 1980s (table 17.2), and supplying power to them has become a major challenge to the KEB.

3.e.1. *The KEB's power pricing policy*

In the early 1980s, the KEB and several other state electricity boards initiated an annual flat tariff based on the horsepower of the pump used, replacing the previous pro rata fee system based on actual power consumed. The new policy was intended to promote groundwater development and avoid the high administrative costs of installing electrical meters for irrigation pumpsets and recording meter readings over wide areas.

After the shift to flat rate pricing, the annual tariff in Karnataka was Rs 50 per horsepower (hp) for pumps up to 5 hp, and Rs 60 per hp for all larger pumps. In April 1992, even this flat tariff was removed to gain the political support of the farm lobby. Farmers no longer have to pay any power tariff for irrigation pumpsets up to 10 hp at the time of installation, as long as they have cleared all arrears to the KEB. For pumpsets beyond 10 hp, the KEB installs an electric meter and charges at the rate

Table 17.2. Cumulative number of electrical pumpsets in Karnataka

Year	Energized pumpsets
1957	11,058
1967	71,189
1970	130,820
1977	259,272
1980	308,719
1987	588,491
1990	744,045
1993	905,687

Source: KEB 1993

Note: These figures overestimate the actual number of energized pumpsets because the KEB does not substract electrical connections no longer in use.

of 50 paise per kilowatt-hour subject to a minimum of Rs 130 per hp per year beyond 10 hp. Since 99.5 percent of Karnataka's pumpsets are 10 hp or less (table 17.1), virtually no farmers pay the power tariff.

Since the KEB cannot distribute power for which it cannot pay, this constraint is transferred to farmers and other users through scheduled and unscheduled power cuts and voltage fluctuations. Irregular power supply reduces the volume of groundwater lifted and imposes costs on farmers for monitoring power availability with hired labor or automatic switches. Farmers also build water storage structures so they can irrigate by gravity when enough is collected. Ultimately, it means that resources are being devoted to socially wasteful activities, both from the farmers' and society's perspectives.

Two recent proposals have been made. One required the state to pay the KEB a flat rate of Rs 0.50 per kilowatt-hour (kWh) of electricity consumed by farmers for irrigation pumps up to 10 hp, leaving the KEB to collect the rest through higher charges to industrial users or record a loss. The second, made by the Central Board of Irrigation and Power in July 1992, recommended to all state governments that electricity for irrigation pumpsets once again be charged on a pro rata basis at the rate of Rs 0.50 per kWh. The KEB's actual price is Rs 1.00 per kWh, so a significant subsidy would remain. Karnataka has not yet changed its policy.

3.e.2. *Cost to the KEB of alternative price policies*

We see that under the current flat rate pricing or either of these two proposals electricity would be subsidized. If we return to our analysis of figure 17.2, we can compare the KEB's likely subsidy outlay under the two systems. The current subsidy is equal to the total quantity of electricity consumed for irrigation multiplied by the KEB's cost per unit. This is equal to the rectangle *ikln* in panel C. If flat rate pricing is retained but the annual fee is raised, electricity consumption in the short term will not change, and the subsidy will equal the rectangle *ikln* minus the sum of

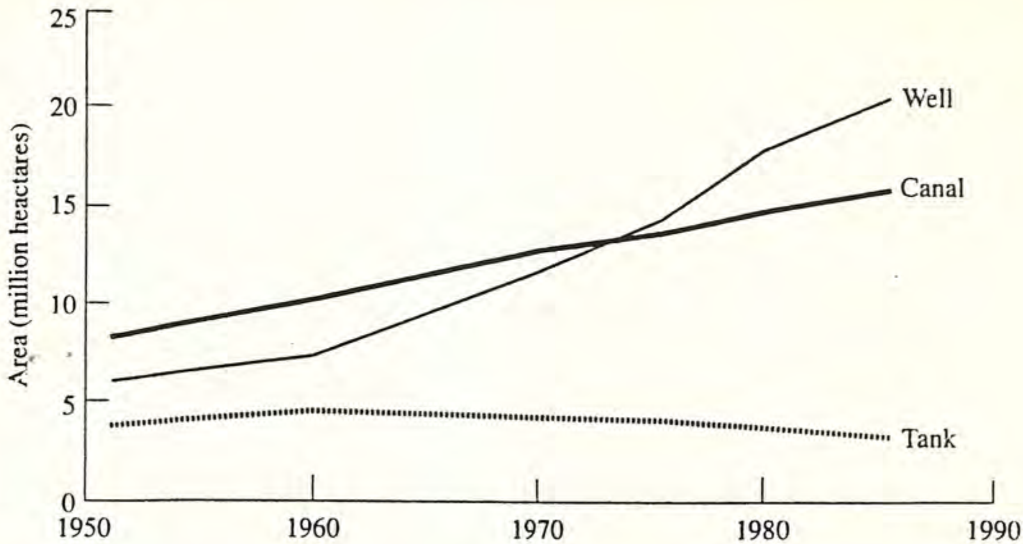

Fig. 17.2. Area irrigated by source, all India

the flat fees paid by all the farmers. In the long term, the increased flat rate will reduce the rate of investment in new wells, so the subsidy will equal *ijmn*, minus the sum of flat fees paid by all farmers.[3] Since the flat fee paid by farmers is not related to the quantity of electricity provided, it is not represented in the graph.

If subsidized pro rata pricing is introduced, on the other hand, the total amount paid by the government will be much smaller than under the flat rate. There will be an immediate reduction in electricity consumption, leaving the subsidy equal to the rectangle adeh (panel B), or the difference in the KEB's actual cost and the subsidized rate, multiplied by the (lower) quantity of electricity consumed. In the long term, as demand shifts further, the subsidy will equal *abgh* in panel B.

Clearly, pro rata pricing can reduce the KEB's burden significantly because of the mechanism of price elasticity of demand. The difference in demand response to a change in the flat fee compared to the introduction of pro rata pricing is critical. If policymakers and administrators understand this benefit of pro rata pricing, they will be far more receptive to it.

Of course, how demand will actually change due to changes in price is an empirical question that depends on the elasticities observed. Research is needed to identify farmers' price elasticity of demand for electricity. Given the political and administrative problems of pro rata pricing, however, opportunities for the KEB to improve efficiency are limited. Without price

3. In a dynamic setting, well investment would increase over time, and a change in price policies would slow the rate of growth, but not necessarily reduce its absolute level. This static graph shows that the number of wells actually falls, which is not necessarily what would happen.

reform, technical regulations and quantitative rationing of power are the only policy instruments available, and they are not problem free.

3.e.3. *Practical arguments for price reform*

Budget pressures on the KEB are mounting. The KEB must pay high debt service charges for loans from the central government's Rural Electrification Corporation, which finances electrification. In addition, irrigation claims 36.5 percent of the electricity supplied by the KEB but provides only 7 percent of its total revenue (KEB 1992, 42–45). According to the National Council of Power Utilities, this is principally because the KEB, like other state electricity boards, imposes low (or no) power tariffs on irrigation pumpsets (Chandrakanth and Romm 1990).

Part of the budget deficit is recovered by charging industrial users high rates. The fact that industry thus subsidizes irrigated agriculture is seriously objected to by the industrial sector. In Andhra Pradesh, which has a similar power tariff structure, lawsuits have been raised by industrial firms against the Andhra Pradesh State Electricity Board (personal communication with APSEB officials). Moreover, some industries have left the state due to the declining electricity supply and pricing policy (Raman Rao 1993).

Price reform eventually will be inescapable. Supplying power virtually free of cost is too expensive for the Karnataka economy. Under the existing system, "free power" has become "scarce power," and unpredictable power cuts and fluctuating current are becoming more and more serious problems (text box 17.1). Nonprice mechanisms are too difficult to implement, and ultimately they probably are no more beneficial to farmers than the current low flat rate pricing. In addition, the industrial sector will not tolerate continually rising costs and poor service. Ultimately, political acceptance of price reform in some form will develop. Either a pro rata pricing system or a higher flat rate would be an improvement. If it is administratively feasible, pro rata pricing is preferable to flat rate pricing because it encourages more efficient water use and does not require rationing.

3.e.4. *An approach to making pro rata pricing administratively feasible*

Despite its drawbacks, pro rata pricing is the most attractive pricing system because it is the most efficient and has the least incentives for wasteful consumption of power and groundwater. But development of an effective electricity pricing system based on pro rata pricing will require a creative approach. The biggest challenge will be to overcome the need for the KEB to monitor meters on all irrigation pumps.

One possible approach would be for the KEB to monitor electricity consumption at the village level and let the villagers sort out for themselves who owes what share. The KEB would hold the entire village accountable for payment defaults, drastically reducing the KEB's administrative burden. The villagers, of course, would have to manage electricity

Box 17.1. Farmers' response to unreliable power

In many villages of rural Bangalore and Kolar districts, full voltage is made available only after 9 PM. Borewell farmers get single phase supply (implying low voltage) between 9 AM and 3 PM and between 6 PM and 9 PM. Supply is most irregular in summer, when power production is lowest. To mitigate the effects of this situation, farmers in several villages have devised their own strategies, including (a) installing automatic starters costing between Rs 500 and Rs 1,000, which save time restarting pumps after every occurrence of low or no power, and (b) building earthen water storage structures or small ponds costing Rs 2,000 to Rs 3,000 or lined structures for Rs 25,000 to Rs 30,000. Farmers also are increasingly bearing other burdens imposed by erratic power supply: heavy repairs to their irrigation pumps are frequent, yields are uncertain, and debt service payments are mounting. Considering the predicament of farmers caused by erratic power supply, dependable power has become more economically important than achieving 100 percent rural electrification.

Box by N. Nagaraj, Dept. of Agricultural Economics, UAS, Bangalore

as a common property resource, but it would be relatively easy for them to monitor each farmer's power consumption. Whether or not they could cooperate to allocate payment responsibilities effectively and fairly is not known.

There may be superior alternatives, but this idea is the kind of creative approach that is needed. Economists can play a useful role in considering the likely strengths and weaknesses of alternative pricing systems. They can interact with knowledgeable people such as NGO officials to develop ideas that are both economically and administratively viable.

3.f. National Bank for Agriculture and Rural Development

The National Bank for Agriculture and Rural Development (NABARD) is a development bank—an apex body promoting agricultural and rural development in India. It provides refinancing facilities to scheduled commercial banks as well as primary cooperative agricultural and rural development banks located in all *taluks*. These banks, which finance well irrigation in the white and gray *taluks*, give small and large farmers long-term loans with subsidized interest rates (7 to 12 percent) and long repayment periods (10 to 15 years).

NABARD's financing of wells only in white and gray areas is a policy tool used to restrict overexploitation of groundwater. This policy can have only a limited effect, however, because NABARD's groundwater classifications follow *taluk* boundaries, which do not correspond to aquifer boundaries. Groundwater maps are not sufficiently detailed to allow accurate delineation of groundwater use. There may well exist within dark *taluks* pockets with productive aquifers. However, farmers in such areas cannot now obtain institutional credit. Moreover, because withholding credit does not affect wealthy farmers who do not need it, this policy tool is neither highly effective for restricting groundwater overexploitation nor is it equitable.

Institutional financing of well irrigation rose from Rs 18.3 million to Rs 317 million between 1968–69 and 1987–88, a sixteen-fold increase. It played a major role in stimulating groundwater development: during this period, the proportion of wells sunk with institutional financing increased from 26 to 50 percent. However, as can be expected when scarce goods are subsidized, demand for institutional credit exceeds supply. Given the high demand for well investment and its perceived high profitability, economic justification for credit subsidies is not clear.

The lack of detailed groundwater maps and the government's requirement that it subsidize well investment loans limits NABARD's opportunities to regulate groundwater development. Nevertheless, as part of the loan provisions NABARD can insist that (a) sound technical groundwater surveys be conducted before drilling, (b) the driller use the right-sized bits, and (c) farmers use good pumps of the right capacity and good delivery pipes. It can encourage farmers to use efficient methods of irrigation such as sprinkler or drip systems by providing lower interest rates or longer periods of repayment. And it can develop incentive mechanisms for farmers who grow lightly irrigated crops.

As with changing the electricity pricing system, however, many of these measures would be very difficult to implement in practice. For example, good groundwater surveys cannot guarantee that wells will yield water; monitoring drilling and pumping equipment is administratively difficult; and subsidies for drip and sprinkler systems will be helpful only if electricity management problems also are sorted out.

3.g. Borewell drillers and water diviners

The number of borewell drillers has increased geometrically since borewell technology became widely available, but their exact number is not known. They do not have permanent offices but tend to be nomadic, searching for farmers who wish to sink borewells.

Neither are their success and failure rates known. Individual borewell drillers are supposed to record data on borewell logs, but the Department of Mines and Geology does not collect it. Since the drillers work in areas covering different types of rock formations and aquifers, they could record data on the depth of groundwater at each location, the size of casing used, yield, and pump capacity. This information would be of great use in determining the probabilities of borewell success and in designing groundwater regulations.

Water divining has become a big consultancy business for both local water diviners, who use a Y-shaped branch and dowsing techniques, and others who use geophysical survey methods. Many of the latter have a masters degree in geology and are formally employed elsewhere. The charges for the local divining method range from Rs 50 to Rs 150 per visit, plus expenses. The charges for geophysical survey diviners ranges from Rs 200 to Rs 500 per visit. Some farmers use both methods to confirm the availability of water.

There is some debate about the extent to which water diviners and borewell drillers should be regulated. Proponents of regulation argue that it is needed to ensure high-quality service and to prevent digging of wells where well density is already too high. Opponents argue that in a market system nonperformers will go out of business, so the quality of service is self-regulated. It does seem likely that only competent diviners can stay in business because contracts are made by the farmer on the basis of some prior knowledge of the diviner. But neither borewell drillers nor diviners have reason to refrain from drilling in overexploited areas.

Borewell drillers in particular roam the countryside in search of business and may be hired without personal knowledge of their skill. Moreover, many farmers may lack the technical understanding of borewell technology to judge its quality. Old, dull drill bits can cause flaws in the well that reduce pumping efficiency, wasting electricity. Faulty equipment sometimes causes wells to deteriorate quickly, although no flaws are at first visible. It is thus important to ensure that drillers use proper equipment. Drillers should be subject to checks by the DMG to ensure that their equipment meets minimum standards.

Farmers seeking water where well density is too high can drill deeper than all the neighboring wells. Such individualistic behavior, however, leads to ever deeper wells, and increasingly low returns to each investment. Ultimately, farmers can only tolerate the low returns with highly subsidized electricity pricing; public funds therefore pay for these wasteful investments. This situation also favors wealthy farmers with access to capital because they can deepen their wells more rapidly than others. Regulating borewell drillers can help avoid such a situation.

The DMG's proposed groundwater authority would require that drilling be done only after it has issued a permit specifying the site of drilling, depth, and other details. In practice, however, this would be very difficult to manage because drilling takes place over such a wide area. The endless delays of such control would be too stifling.

3.h. General Insurance Corporation of India

The General Insurance Corporation (GIC), is a quasi central government organization that offers nonlife insurance coverage. Concerned by the high probability of borewell failure, the central government in the mid-1980s asked the GIC to offer an insurance package against borewell failure. The GIC collected a premium of 17.5 percent of the cost of each borewell, of which the state and central government each contributed 7.5 percent. The remaining 2.5 percent was paid by large farmers. Small farmers were exempted, their share being paid by the state government. An insurance payment equal to the cost of drilling was made to the farmer if the borewell yield fell below 1.01 liters per second at the time of drilling. The program was stopped after 1989, however, because it was too difficult to manage and because the premiums covered only 58 percent of the total claims. Management problems included determining who should bear the extra cost, calculating the premium, defining well failure, and avoiding incentives to cheat (also called *moral hazard*).

Calculating the correct premium requires sufficient data to know the probability of well failure and thus the expected cost of a successful well. According to Radhakrishna's and Jitendra Kumar's 1992 data, 5 to 20 percent of wells fail. The expected cost of a successful well thus is the cost of drilling (about Rs 25,000) plus 5 to 20 percent. But the exact probability of well failure varies so much with small changes in location that an insurer would want to estimate it separately for each case.

The correct premium and insurance payment also depend on the definition of well failure. By defining a failed well as one that yields less than 2 liters per second, the insurance scheme experienced a 36 percent rate of well failure. But as already explained, an arbitrary cutoff value to distinguish between success and failure makes no sense—success is a matter of degree. Research by Kumaraswamy (1992) found that by using efficient conveyance systems, such as drip irrigation, borewells yielding well below 1 liter per second can profitably irrigate various horticultural crops.

All these operational difficulties of the GIC well insurance scheme contribute to problems of moral hazard. In particular, given the arbitrary definition of well failure, failures are overestimated.

What should be done about well insurance? There is no clear reason why the government should bear the cost of insurance for farmers, not even small farmers. The expected cost of a successful borewell is the average cost of all attempts divided by the number of successful ones. This represents both the private and social cost of the average successful borewell. Thus from the point of view of efficiency, subsidies are not justified—the social cost does not exceed the private cost. Moreover, there are no clear nonefficiency reasons to subsidize the cost of insurance.

One possibility might be to operate insurance through private well drillers. They have the best information about the probability of well failure due to their widespread experience, and they can easily negotiate the terms (premium and insurance payment) with the farmer just before drilling. In this way, the terms can vary depending on the conditions. In fact, such informal insurance is already provided by many private borewell drillers. They charge approximately Rs 70,000 for drilling a borewell (under what is popularly called the "No Water, No Money" scheme) to bear the risk of well failure as against Rs 50,000 where the farmers themselves bear the risk.

In a perfect insurance market, insurance payments would vary with the degree of failure. The farmer's expenditure on the well would be such that he would pay for precisely what he gets, with a sliding fee scale depending on the water quantity and quality. Theoretically, insurance schemes managed by borewell drillers could operate on this basis. Measurement problems would be substantial, however, in part due to seasonal variations in well yield. In addition, much data would be needed to calculate the appropriate fees for different well yields.

3.i. Minor Irrigation Department and Zilla Parishads

Karnataka's Minor Irrigation Department is vested with managing irrigation works (chiefly tanks) with command areas of 40 ha or more. These include irrigation and percolation tanks, assorted small ponds, canals and other structures, and small lift irrigation schemes. *Zilla Parishads* are responsible for managing minor irrigation systems with command areas of less than 40 ha.

In the Deccan Plateau, the level of water in irrigation tanks and the rate of groundwater recharge are positively correlated (see chapter 18). The water in tanks is tapped by wells through lateral seepage and percolation from the submerged area, distribution channels, and command area. Irrigation tanks and open wells thus symbiotically serve agricultural production. Due to poor recharge capacities of hard rock areas, managing tanks for irrigation and recharge purposes is crucial for sustaining groundwater development.

Tank irrigation is decreasing throughout the country, however, while well irrigation is increasing (figure 17.2). It is estimated that the capacity of irrigation tanks has decreased by an average of 23 percent because of siltation (Environmental Management Services 1993). This clearly limits the role of tanks in groundwater recharge. Restoring irrigation tanks is the challenge facing the Minor Irrigation Department and the *Zilla Parishads*.

To do so, these organizations require three types of resources: technical capability, financial resources, and skills in understanding village social organization. Of these three, technical knowledge is not a constraint for either the Minor Irrigation Department or *Zilla Parishads*, both of which are staffed by capable engineers. Their continuing challenge in this field is to develop less expensive methods.

After tanks are rehabilitated, they must be managed properly or the investment will be wasted. Given the challenge of managing common property resources such as irrigation tanks, this cannot be taken for granted. The Minor Irrigation Department and *Zilla Parishads* would benefit from adding capability in this area, or by collaborating with NGOs and other organizations that already have it.

3.j. State Watershed Development Program

The State Watershed Development Program (SWDP) promotes improved dryland management techniques through technological focus on soil and water conservation on a watershed basis. Directly or indirectly, the SWDP is concerned with groundwater recharge in the watersheds because water conservation measures increase infiltration into the soil and into aquifers.

Measures that recharge groundwater do not necessarily benefit the farmer on whose land they are built. While water conserved in upper catchments provide moisture locally, most of it percolates into the ground and benefits aquifers in the lower catchment. There is thus insufficient incentive for the farmer in the upper catchment to invest in such measures:

the private benefit is less than the social benefit. Developing mechanisms for sharing benefits and costs in these cases is the SWDP's challenge. Social science researchers and NGOs can play a major role in this regard.

3.k. Nongovernment organizations

As tank and groundwater management cannot be operated under a private property regime, creating social organizations for successful common property management is a high priority. Because many NGOs have the capability of encouraging such development, the Minor Irrigation Department and *Zilla Parishads* can solicit their assistance in organizing tank irrigation users' groups. The KEB also can use NGOs in its efforts to devise an efficient, workable electricity pricing system.

Researchers working on devising an improved property rights structure for groundwater also can gain insights from NGOs. For example, if groundwater property rights follow the doctrine of correlative rights, community users will have to set up rules of access to groundwater to create a self-governing system. NGOs could assist such ambitious efforts on a pilot basis, beginning with very small, well-defined aquifers in villages with a record of successful collective action.

NGOs will need to increase their technical and organizational skills if they are to play a major role in organizing users' groups for tank and groundwater irrigation. There are numerous excellent NGOs in Karnataka and throughout India, but there are many others that cannot undertake such an ambitious project without first strengthening their capabilities. While it is critical to tap the creativity and talent of the NGO sector, it also is important not to demand more from it than it can realistically provide.

4. Conclusion: Farmers Revisited

If farmers want a reliable irrigation system, they will have to be prepared to absorb higher electricity costs, capital costs of efficient water delivery systems, and coordination costs of self-regulation through water users' groups. Although the popular debate is rarely framed in this way, farmers must choose between these two distinct scenarios.

Farmers will become interested in efficient irrigation methods either when (a) the cost of power rises or (b) groundwater is very scarce. As long as electricity is heavily subsidized, farmers will only be efficient when groundwater becomes physically scarce. It is precisely this effect that currently motivates farmers to invest in drip and sprinkler systems.

Evidence also suggests that if farmers understand the relationship between electricity pricing and reliability, they will be more willing to pay higher rates. Kerr (1992) found that farmers would prefer to pay higher flexible rates and have assured access to electrical power than to pay the low flat rate with an uncertain electricity supply. Only some of the largest farmers preferred the flat rates because they would have to pay the most under pro rata pricing. Unfortunately, it is large farmers who can exert political pressure against policy reform.

Moreover, if well owners understand the relationship between flat rates and declining water tables, they will be willing to switch to a pro rata pricing system. Again, only the largest, wealthiest farmers can afford the cost of continually deepening wells or drilling new wells when old ones can no longer draw water.

The prospects for groundwater users groups are not clear. Experiments to develop and nurture them should be a high priority for researchers and NGOs. As with drip irrigation, farmers will be increasingly receptive to such cooperative action as competitive, individualistic groundwater exploitation becomes increasingly costly. Similarly, changes in the specification of property rights will be needed to support these groups; otherwise powerful farmers who can afford to dig the deepest wells will resist.

Discussion Questions

1. Under what circumstances is groundwater use accompanied by negative externalities? Describe them and indicate who bears them.
2. Under what circumstances is groundwater use associated with positive externalities? Describe them and indicate who benefits from them.
3. What are the social and private costs of increasing groundwater scarcity?
4. Visit a nearby rural area and ask the farmers about groundwater management.
   a. Do they perceive scarcity or abundance?
   b. What do they perceive as their rights to groundwater and those of their neighbors?
   c. Are there local formal/informal groundwater markets? What are the terms and conditions in these markets?
   d. Have the farmers developed any local institutional arrangements to manage groundwater?
5. Can you think of ways in which pro rata pricing might be made administratively feasible? Discuss several alternatives and their strengths and weaknesses.
6. Discuss ways in which the doctrine of correlative rights can be a feasible basis for groundwater property rights under Indian conditions.
7. Shah (1993) has shown that flat rate pricing encourages groundwater markets, providing irrigation water even to farmers who cannot afford a well. This has obvious equity advantages. Is this situation likely to create a clash between equity and sustainability objectives? Why or why not? What can be done to minimize trade-offs between these two important objectives?

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8. Can you think of an alternative way to promote equity in groundwater management even if pro rata pricing is used?

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