

Groundwater markets in Gujarat, India

Shashi Kolvalli and David L. Chicoine

Markets for groundwater have emerged where well owners have surplus water and there is high demand for irrigation water. This has increased the return on groundwater investments and induced investment in mechanisms to reduce conveyance losses. Private sales of water overcome the problem of indivisibility of groundwater investments and have provided non-well owners access to groundwater. Although well owners are in a potential monopoly position, pricing is influenced by the fact that water has to be sold in the vicinity of the well. Water charges are determined by costs, monopoly rents and local tradition. The barrier to market entry is the investment required to construct a well irrigation system. Buyers of private groundwater have improved water control and hence increased agricultural production.

Water sales by well-owning farmers may have occurred as long as wells have been in existence but the first reports of widespread sales appeared in studies of well irrigation in the 1960s (Moorti, 1970; Patel and Patel, 1970). Since then concerns have been raised about the monopoly position of well owners and the impact of high-priced water sales on the poor (Asopa and Tripathi, 1975; Shah, 1985). Some insight into the operation of these markets in India is provided in the recent studies by Shah (1985) and by Bliss and Stern (1982). Shah characterizes the market as being imperfectly competitive with prices determined by the marginal cost of extraction and the elasticity of water demand. Prices were found to be higher where marginal charges for electricity use were higher and alternative sources of water poorly developed. Bliss and Stern found well-owning farmers in an Uttar Pradesh village to be charging

less than their monopoly position allowed and not practising price discrimination.

Charges for well water are many times the price irrigators pay for water from alternative sources, which are typically subsidized (ie. canal irrigation systems). The willingness to buy higher-priced water, often even if less costly alternative sources are available, may be attributed, in part, to the greater reliability of private well-water supply compared to canal supplies. The study reported in this paper provides additional evidence on the functioning of markets for groundwater in Gujarat, India. Data for the study were collected through field interviews of owners of irrigation wells in 1985 in the Kheda district of Gujarat.

In presenting the evidence on groundwater markets, the paper is divided into six sections. First, general background on groundwater irrigation and water markets in India is presented. Next, information on private wells and well owners in Gujarat is presented. The third part of the paper describes contracts between buyers, sellers and neighbouring landholders. Fourth, water sales and prices are presented. Next, rates of return from water sales are analysed, followed by a brief summary and conclusions section.

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Groundwater irrigation and water markets in India

Groundwater is a source of irrigation supply in India and is increasing in importance. Wells are owned either by individuals or by public institutions. Groundwater is extracted from both open or dug wells and tubewells. Tubewells are more common in northern Indian states because of unconsolidated rock formations. Tubewells are increasing proportionally over time. They made up 21.3% of the wells in 1979-80 compared to 5.6% in 1968-69.

Water from public wells is sold to farmers on an hourly basis. The majority of the wells, however, are owned by individuals. Of the 9926000 wells in India in 1979-80, only 36000 were public (Ministry of Irrigation, 1982). The number of private wells is growing rapidly. A little over half the tubewells in the country in 1950-51 were private. By the end of the 1970s nearly 98% of the tubewells were privately owned (Ministry of Irrigation, 1982).

Landholdings and 'surplus' well capacity

The capacity of wells and pumping mechanisms is often greater than the water needed to irrigate the landholding of well-owning farmers. Average holdings of well owners in two villages in Gujarat and Andhra Pradesh, for example, were found to be 11.67 acres and 6.99 acres respectively. They pumped an average of 78.31 and 22.75 season acres per year, respectively (Shah and Raju, 1986). The water pumped was more than enough to raise three crops on their own holdings in both cases.

Fragmentation of landholdings and location of parcels far from each other often preclude a well owner from irrigating all owned land from a single well. Hence 'surplus' capacity exists in individually owned wells because of the size of the well relative to landholdings and because of non-contiguous fragmented landholdings.

Increased water demand and water markets

A substantial demand for irrigation water makes it possible for well owners to sell 'surplus' groundwater. The demand for irrigation water is derived from and hence dependent on the nature of agriculture practised. The demand is greater where farmers have been introduced to irrigated agriculture and have been practising improved agriculture using high-yielding varieties, fertilizers and pesticides. In fact, adoption of high-yielding varieties in many parts of India was accompanied by the development of groundwater irrigation (Abbie, Harrison and Hall, 1982).

The demand for water appears to be greater where farmers have already been exposed to

irrigated agriculture through canal irrigation. Canal irrigation may be presumed to have a demonstrative effect on the profitability of irrigated agriculture and the high marginal value product of water. Accordingly, markets have emerged in the states of Punjab, Haryana, Uttar Pradesh, Gujarat and wherever well owners have 'surplus' water in the southern states of Andhra Pradesh and Tamil Nadu and where alternative canal supplies are limited in quantity and/or are unreliable. Significant portions of the areas where groundwater markets have developed are also irrigated by canal systems and are the regions where 'green revolution' technology is widely used.

Since water is essential for plant growth, the demand for water is likely to be quite inelastic when natural precipitation is inadequate. The potential exists, therefore, for well owners to behave as monopolists and to capture monopoly rents from farmers needing water to avoid significant crop losses. A monopolist would charge a mark-up over and above marginal cost with the level of the mark-up being a function of the price elasticity of water demand (Varian, 1984). A monopolist would also practise price discrimination to take advantage of markets characterized by different demand elasticities. In the groundwater market discrimination can take the form of different prices for crops of different value, different prices during different seasons and different prices in different locations characterized by variation in the level of competition. However, there must be some barriers to market entry for a monopolist to remain a monopolist.

Wells in Gujarat and the sample of well owners

Information on private wells and the groundwater market was collected from well owners in the Kheda district of Gujarat. The state of Gujarat is located in western India. It is a fairly arid state with only 22% of the area irrigated. An estimated 134687 ha were irrigated in central Gujarat by the Mahi-Kadana project in 1982-83 (in a command area of 202065 ha). Of the 1715000 ha irrigated in Gujarat in 1978-79, 1346000 ha were irrigated by wells (Ministry of Irrigation, 1982). Nearly 26000 wells are estimated to be in the Mahi-Kadana command area alone.

The district of Kheda, which is irrigated by the Mahi-Kadana project, is fortunate to have abundant groundwater supplies available at fairly shallow depths. This is partly due to seepage from poorly lined surface irrigation canals. The recharge poten-

tial from rainfall and seepage from the canal irrigation system is estimated to be 78 322.37 ha m (Gopinath, Chary and Patel, 1978). Of this, 29 355.47 ha m are extracted by wells, leaving a net available recharge potential of approximately 48 966.9 ha m. Therefore groundwater is plentiful. Pumping capacity and power supply are the main constraints to greater use of groundwater irrigation in the district of Kheda.

Sample of well owners

Data on the private wells in Kheda district were collected from well owners as part of a larger study on conjunctive use of canal and well water (Kolavalli, 1986). Of the 187 sample farmers interviewed, 20 were well owners. The farmers were from seven villages. The average landholding of well owners was 3.43 ha, compared to an average of 1.4 ha for all the 187 sample farmers. Land fragmentation was a problem for all farmers. For well-owning farmers the average number of parcels owned was 3.6 and the average size of the largest parcel was 1.1 ha. Because of fragmentation, well owners were not able to irrigate all of their land with water from their own wells. Seventeen irrigated some of their land with canal water, two purchased water from public tubewells and 14 (nearly two thirds) purchased water from other private well owners.

Generally, well owners were comparatively better off. All of them owned bullocks and nearly half owned tractors. In contrast, only 10% of all sampled farmers owned tractors. Seventeen of the well-owning farm households also had income from off-farm employment, and two were involved in trading.

The well and distribution system

Wells owned by the sample farmers are of three types: tubewells, dug wells and dug cum bore wells. Dug cum bore wells are dug wells where drilling has been done to increase the water supply. Of the 20 wells in the sample 11 were tubewells, eight were dug wells and three were dug cum bore wells (two farmers owned more than one well). The average well depth was 37.8 m with a range of from 15 to 90 m. Thirteen wells had pumps powered with 20-HP electric motors, one was powered with a 40-HP motor and only one had a motor with less than 10 HP. Five of the sample well owners were partners in water companies that sold water. One of the water sellers installed a pump and distribution system on a well leased from a neighbour.

Well irrigation systems in the Kheda district in Gujarat had elaborate water distribution systems. All of the sample well owners had gravity distribu-

tion systems to their fields and the fields of customers. Water is generally pumped to a sump from which underground lines originate. Underground lines consist of 225 to 300 mm concrete pipes laid about 1 m below the surface. The system may consist of a single or several lines leading off from the sump, depending on the quantity of water pumped and the well location compared to the fields irrigated. The direction of the flow is changed at distribution centres. Outlets or air vents are located every 50 m. Outlets can be closed and have vent pipes extending up to 2 m or more above ground. When outlets at lower levels are closed, water can be forced to fields above well grade because of head created in the sump.

Although initial costs are substantial, there are clear advantages to underground distribution systems compared to less expensive alternatives such as over-the-field ditch networks (Patel and Patel, 1969). Underground systems are more efficient, saving as much as 20–30% of lifted water. Seepage is minimized and other water losses are more controllable. Thus investing in underground pipelines would be economically viable even at seepage rates as low as 5.2% (Shah and Raju, 1986).

Underground line gravity-pressured distribution systems are especially beneficial to well-owning farmers whose land is fragmented and water has to be transported through adjacent fields. Underground systems do not use any cultivable area. Inconveniences in carrying out farming operations are minimized. In addition, water can be delivered to fields at grades above the wells.

Well owners in the Kheda district were asked the total cost of their system when installed. Most of the wells owned by the sample farmers were nearly 20 years old, but motors and pumpsets were typically purchased more recently. Average system costs in nominal rupees are presented in Table 1.

The investments are approximate and are presented only to give a general estimate of the cost of private irrigation systems. Some well owners were able to provide detailed information while others approximated their total outlay. The costs incurred

Table 1. Investments in wells and distribution systems.

Item	Average cost (Rs)
Well	13 083.33
Pump	19 150.00
Distribution system	16 655.56
Other costs	5 494.44
Total	54 383.33

Source: Kolavalli (1986).

in the construction of distribution systems are a major portion of the amount spent (about 30%). Current costs range from Rs 10 to Rs 15 per foot depending on type of material. The capital now needed to build a complete system, including well, motor and pump, distribution system, and a pump house is estimated to be about Rs 100 000.

The well owners' decisions on the size of wells, the capacity of water extraction mechanisms and the area covered by distribution systems are influenced by the prospect of water sales. 'Surplus' capacity appears to be planned by well owners. There are two major reasons why farmers invest in 'surplus' capacity. First, farmers could simply buy what others are buying irrespective of their own requirements, and this behaviour may yield 'surplus' capacity. That may explain, for example, the predominance of 20-HP motors. Second, water selling increases returns. The opportunity to sell water probably attracts investments that otherwise would not have gone into groundwater development. Initial speculation was that investments were made in wells primarily for the purpose of irrigating owned fields and that excess water was sold to neighbouring farmers. But evidence on the returns to well ownership in the Kheda district provides some support for investing in 'surplus' capacity as a good business practice.

Contracts between buyers, sellers and intervening landholders

Well-owning farmers in the study villages reported contractual arrangements with neighbouring landowners, most of whom were water customers, for both construction of distribution systems and water sales. It is not uncommon for well owners to have much of their distribution system in neighbours' fields. The average length of distribution systems was about 300 m with an average of nearly 225 m laid in neighbours' fields.

Contractual agreements for distribution systems between well owners and neighbouring farmers (customers and others) are informal and enforced by tradition. It is customary for farmers in the Kheda district to permit well owners to install and maintain underground lines on their property without any compensation for easements. The fact that they do not lose any cultivable land and they gain potential access to irrigation water may be sufficient compensation. Since well owners are larger farmers, with substantial socioeconomic status in the village, adjoining landowners may also be under some social pressure to be accommodating to well owners in the installation of distribution systems.

Contractual arrangements for the sale of water are less clear. There do not appear to be any non-economic barriers in the market for well irrigation water. Well owners are generally willing to sell water to anyone, limited only by the distribution system. But need arises for prioritization because of seasonal supply shortfalls. This is especially true during summers when power shortages are common and pumps can operate for only limited periods. Well owners' fields and the fields of farmers who depend completely on well water typically get first priority. Other farmers who supplement canal water with purchased well water are supplied water as available. In general, and not unexpectedly, customers appear to have difficulty getting water from well owners during the summer (hot) season when well owners' own demand is highest.

Water sales, charges and investment capital

There are two categories of irrigation water sellers among the 20 sample well owners: well owners who irrigate their fields and sell surplus water and those in the business of selling water. Well owners selling surplus water reported selling two thirds of the water they were extracting.¹ On average this is equivalent to water pumped in 1300 hours. Assuming electric pumps are operated for 2000 hours annually, about one third of the total pumping time (700 hours) is devoted to irrigating the fields of well owners. Well owners in the business of selling sold all of the water extracted. However, part of the water may be sales to members of the water companies.

Water sales are primarily on credit. Water was sold on credit by all of the well owners interviewed. The terms of credit, however, differed. Ten of the well owners generally collected water charges at the end of the growing season. Seven of them gave credit for a period of one to two years. Three well owners extended credit for only one or two irrigations. None of the well owners in the sample demanded advance cash payments, but a few customers complained that some well owners do insist on advance cash payments. Farmers with fields in the fringes of two or more distribution systems had the option of buying water from more than one supplier. In one village there appeared to be tacit agreement between well owners not to sell water to farmers who had not paid water bills owed other well owners.

¹This seems rather high compared to the 40% observed by Patel and Patel (1970) in Uttar Pradesh. But Shah's 1986 survey of one of the seven villages included in this study indicated share of water sold to be as much as 80%.

Water charges

Sample well owners determined water charges by one of two methods: per hour of pumping or per kilowatt hour (kWh) of electricity utilized for pumping.² Nine of the 20 water sellers charged for water based on electricity used and these were all in one of the seven villages (Anklov). These charges ranged from Rs 1 to Rs 1.25 per kWh of electricity and averaged Rs 1.14 per kWh of electricity. Charges based on the duration of pumping set by the other 11 well owners averaged Rs 17.38 per hour and ranged from Rs 16 to Rs 20. Well owners and customers may find it advantageous to base charges on electricity use because accurate records are available and conflicts on how long the pump was run can be more easily avoided.

There is less variation in charges based on units of power used than in charges based on per hour pumping. Seven of the nine well owners who based charges on electricity use charged Rs 1.25 per kWh (power was then supplied to well owners at Rs 0.64 per kWh).

Variation in charges can be attributed, in part, to differences in pump delivery capacity, distribution systems, and thus water received in the fields. Farmers were generally aware of wells and distribution systems where water flow was relatively low and, as a consequence, less water per hour reached fields. Owners of such systems had to charge less per hour. Accordingly charges were found to be uniform in most wells with 20-HP motors and similar distribution systems.

Well owners have an opportunity to exercise price discrimination. Discrimination can take the form of higher charges for water used on more profitable cash crops or higher charges during the summer when other sources of water are not available.³ However, prices charged for water in the markets of the Kheda district were found to be uniform throughout the year and for all crops. The only

differences were in terms of credit extended to buyers and the small credit differences between sellers were in only one of the seven villages. To some extent this variation reflects the more reliable surface water because of improved canal irrigation supplies. All well owners in any particular village generally charge the same price irrespective of the number of sellers in the area. Well owners facing limited competition because of no other nearby sellers charged prices similar to those charged by sellers in more competitive markets.

Irrigation water charges appear to have increased over the years as the cost of electricity has increased. There does not appear to be any collusion on the part of owners. An increase in charges by any one well owner after an increase in power charges is typically followed by other sellers.

However, water charges appear to be higher than marginal costs of pumping. It has been argued that charges for power in the state of Gujarat should be fixed rather than use-based so that marginal costs of pumping would be zero. This would lead to lower per unit irrigation charges and possibly increased water sales (Shah and Raju, 1986). But marginal costs of water sales are not zero. Not all credit sales in the Kheda district were completely recoverable and hence were written off.⁴ Accordingly the marginal cost of credit sales is non-zero even with fixed power charges. Also, expanding the number of customers on existing well and distribution systems clearly makes timely supplies even more difficult than they are currently.

Investment capital

The scarce factor that makes the monopoly position of well owners a possibility is the capital required to construct a well irrigation system and enter the market.⁵ Given a competitive market for capital with equal access and abundant groundwater, there should be a sufficient number of wells to restrict monopoly rents. Limited access to capital by farmers may limit entry and thus create monopoly market conditions.

The availability of credit from cooperatives and banks is generally thought to have greatly aided the increase in the number of private wells (Asopa and

²Just as in the case of tenancy a share of the crop is also taken as payment for water in some parts of India. Land is also leased out with rent covering charges for land as well as water. Another method is a fixed payment in kind in which payment depends on the crop. Against these fixed payments crops are given a certain number of irrigations generally accepted to be adequate. Conversion of these fixed charges into hourly costs yields charges ranging from Rs 20 to Rs 25 per hour.

³Shah (1985) notes that until the late 1960s most well owners charged more for cash crops. This was eventually abandoned because buyers used surreptitious methods to transfer water from grain fields to tobacco fields, for example. Government tubewells still charge more for irrigating cash crops.

⁴One of the well owners indicated that he had stopped selling water to members of a particular caste because they were known for not paying their water bills.

⁵Current well owners enjoy monopoly status in states where there are some regulations to curtail groundwater extraction through denial of institutional credit and power supply to wells built within a certain distance of existing wells.

Table 2. Costs of operation and revenue.

Item	Average cost (Rs)
Power	14 555.00
Repair	3 117.00
Labour	2 683.00
Other costs	352.00
Total costs	20 707.00
Number of hours sold	1 367.37
Revenues from sales	24 323.33
Net revenue	4 616.33

Source: Kolavalli (1986).

Tripati, 1975), but the sample of well owners in the seven villages identified the important role of household savings in financing wells and distribution systems. Farmers interviewed indicated that 66% of the capital invested in wells came from household savings and only 15% was borrowed from banks or other credit institutions. In addition, 5% of the investment capital was borrowed from moneylenders and 14% borrowed from relatives. In total, about 80% of the capital used to put in existing wells in the Kheda district was reported to have come from the private savings of either well owners or their relatives.

Well owners' returns from groundwater sales

Well owners provided information on sales in either hours of pumping time sold, percent of water sold or rupees. These data were converted to hours by using the performance of the average system. Well operating costs reported are also well owners' estimates of average annual outlays. Annual well operating costs and water revenues are presented in Table 2.

The estimates of operating costs and revenues from water sales give only a rough approximation of the profits of well owners. As reported in Table 2, net returns are about Rs 5 000 per year. Comparing this with the average investment from Table 1, profits from water sales are roughly 10% of the average investment in private wells.⁶ This does not

appear to be unreasonably high. Returns from irrigating fields owned by farmers selling water would have to be added to these estimates to compute total returns. Returns from water sales combined with returns from irrigating owned fields appear to make investments in groundwater an attractive business undertaking.

Summary and conclusions

The evidence from private well-owning farmers suggests that water sellers are unable to take full advantage of their monopolistic position. One of the reasons may be the simultaneous existence of many markets in rural areas. Water sellers and buyers are also participants in other markets such as those for land (tenancy) and labour. A buyer in one market may be the seller in another. How these linkages affect the functioning of the groundwater market needs to be studied. However, the returns to investments in wells are still attractive. The extent to which higher returns offered by markets have influenced investments in different parts of the country still needs to be established. Well owners invest in systems to minimize crop losses and as sound business decisions. Buyers use water prudently because it is sold on a volumetric basis and priced higher than water from other sources.

Capital appears to be a major constraint for the emergence of water markets in groundwater-abundant areas. The impact of water markets on the rural poor and rural inequality in the long run is of interest for formulating policies for developing groundwater resources and should be the focus of future research. The lack of investment capital was reported to be a primary barrier to market entry and private savings of well-owning households and their relatives was the most important source of investment capital. One policy option is to provide subsidized loans to smaller farmers. The evidence presented suggests that in many cases private groundwater investments will be competitive only if some water is sold in a groundwater market.

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Nile water management and the Aswan High Dam

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The Aswan High Dam has made a tremendous contribution to the economic and social development of Egypt by controlling floods and significantly reducing the impacts of droughts. Since the Nile provides 97% of Egypt's water requirements, efficient utilization of its waters is obviously essential for Egypt's future. This paper reviews control of the Nile's flow by the Aswan High Dam during the 20-year period 1968-88, and makes some recommendations as to how best to utilize the Nile waters, especially during extended drought periods.

Egypt, said the great Greek historian Herodotus, is the gift of the River Nile. This statement, though made more than 2000 years ago, remains valid today. If anything, Egypt's reliance on using the available waters of the Nile for agricultural production, hydroelectric generation and other socioeconomic purposes has increased many times over since Herodotus' time.

Only about 4% of Egypt's land area is habitable; the rest of the country is desert. Water availability is thus a most important constraint upon the expansion of the country's cultivable area. This fact becomes of special significance when it is considered that among all African countries Egypt has the lowest per capita arable land availability. This was estimated to be 0.08/ha per person in 1985 (Biswas, 1986). With a population that has already reached 51 million, and is still continuing to increase at a fairly rapid rate, the availability of an adequate quantity of water on a reliable basis for domestic, agricultural, industrial, power generation and other purposes is already a

serious problem, and is likely to become even more serious in the future.

Since Egypt is a highly arid country with very limited rainfall, the Nile, its only river, provides 97% of the country's water requirements. The balance, only 3%, comes from groundwater and rainfall. Under these conditions Egypt has no alternative but to ensure that the waters of the River Nile are used both rationally and efficiently on a continual basis.

The River Nile and Aswan High Dam

The Nile is an international river shared by nine countries - Egypt, Sudan, Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi and Zaire. Its catchment area covers 2.9 million km², which represents nearly 10% of the land area of Africa. The fact that it is shared by nine countries makes its management and development more complex than it otherwise might have been.

So far as Egypt is concerned, 86% of the river flow originates from the Ethiopian plateau in the southeast, at elevations of 2000-3000 m above mean sea level. The balance of the flow, 14%, comes from the Equatorial Lake Plateau in the south, at elevations of 1000-2000 m above mean sea level.

Within Egypt the Nile waters are controlled by two dams at Aswan and a series of barrages, as shown in Figure 1. The Aswan Dam, completed in

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The authors gratefully acknowledge the constructive comments and suggestions made by Dr Asit K. Biswas, President, International Water Resources Association, in connection with an earlier version of this paper.