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Groundwater Depletion in India—Institutional Management Regimes***

ABSTRACT

Historically, irrigation tanks served as important sources of groundwater recharge in the hard rock belt of India. Construction and maintenance of irrigation tanks were functionally linked with irrigation wells by groundwater recharge. Farmers voluntarily maintained the tanks because of an established tank maintenance system. Contemporary administrative and political changes have both promoted rapid exploitation of groundwater and discouraged maintenance of the tank systems that had sustained the vital groundwater resource. This commentary discusses India's water-governing institutions, the history of their decay, and the factors responsible for the present groundwater depletion. Corrective policy instruments are proposed to alleviate the problem, including groundwater regulation, electricity pricing controls, a correlative groundwater rights system, and the establishment of groundwater districts.

INTRODUCTION

Since the mid 1950s, modern techniques of groundwater exploration and pumping have created "instant irrigation" opportunities in India. The total area irrigated by wells grew by more than 150 percent between 1956 and 1986 in India. The Deccan Plateau, a region in Southern India, is

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currently threatened by a depletion of groundwater.[1] Allocating groundwater between uses, between users, between areas of origin and destination, and between generations is becoming a critical problem in the Deccan states of Karnataka (Mysore), Tamilnadu, Andhra pradesh, and Maharashtra.[2]

The Deccan Plateau has the largest number of irrigation tanks in India. In 1915, Karnataka State had 25,242 tanks, which irrigated 528,994 acres and accounted for 55 percent of the total irrigated area (Figure 1). After the reorganization of the states in 1956, there were 34,523 tanks, which irrigated 859,098 acres representing 49 percent of the irrigated area. In 1986, the area irrigated by tanks decreased to 805,220 acres, which formed 18 percent of the net irrigated area. Correspondingly, 29,812 wells existed in 1915 irrigating 74,430 acres, contributing 7.74 percent of the irrigated area. The number of wells increased to 448,118 in 1986-87. These wells irrigated 1,484,932 acres; 32 percent of the irrigated area.

THESIS

Historically, institutions were sufficient to maintain complex tank systems.[3] Although developed for surface irrigation, these systems also helped sustain undiminished aquifers.[4] Thus, tank institutions implicitly managed groundwater resources as well. As tank maintaining institutions declined, the recharge capacities of tank systems declined, and as opportunities for

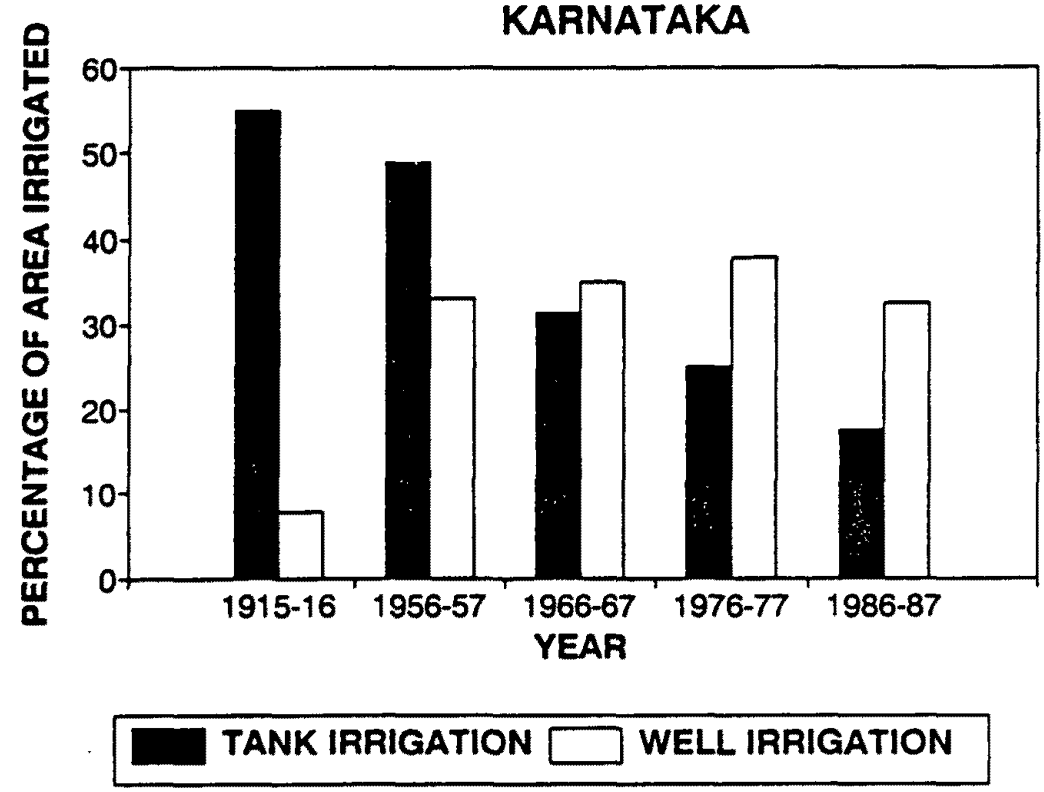
1. This groundwater-led agricultural development has had a greater impact on agricultural productivity than more spectacular surface irrigation projects. *See* B. Farmer, An Introduction to South Asia 183 (1983). Areas of rapid groundwater depletion are also present in California, Arizona, and Texas in the U.S.

2. Groundwater is not a precisely delineated resource. Groundwater is indivisible, unlike surface water, and as a result, it is difficult to define in terms of property rights. The property rights of groundwater in India are vague, and institutional arrangements requiring cooperation often do not exist, resulting in a competitive race to withdraw all water. In such a situation, farmers protect their rights by capturing the resource in the fastest possible way. For each farmer, the deferred use is subject to great uncertainty, as other farmers would not hesitate to capture the resource. According to Ciriacy-Wantrup, "[d]efinite property rights belong only to those who are in possession-that is who gets there 'fastest with the mostest.'" S. Ciriacy-Wantrup, 3 Resource Conservation: Economics and Policies 142 (1968). The high growth rate of the rural population, and existing income and asset inequalities in India make the groundwater problem even more complex. Seventy five percent of the cultivated area in India (and in Karnataka) is under rainfed agriculture. Farmers in these areas are constantly on the lookout for a stable source of irrigation. Consequently, misuse of the groundwater resource poses management problems for public policy and management.

3. For centuries, the irrigation system in the Deccan Plateau combined minor water storage structures such as tanks (reservoirs of varying dimensions from 0.025 acre to 100 acres), *katte* (small tanks providing drinking water), *kolalaravattige* (ponds providing drinking water to pilgrims and travellers), and percolation tanks (built exclusively for recharge) with the groundwater and the well system. The yield of wells greatly depends upon the recharge potentials of these water storage structures.

4. Djurfeldt & Lindberg, *Behind Poverty: The Social Formation in a Tamil Village*, in Scandinavian Institute of Asian Studies Monograph Series No. 22, 315 (1975).

FIG 1: EXPANSION OF IRRIGATION IN KARNATAKA



groundwater pumping expanded, aquifers were drawn down such that supplies became increasingly scarce. This commentary will focus on how the water institutions of the past were responsible for the growth of groundwater irrigation systems and how the decay of these institutions and the lopsided growth of groundwater-thirsty enterprises have led to groundwater depletion.

The nature of existing groundwater institutions, financial institutions, financial incentives, and technological factors are important elements that demand attention from a policy perspective. The discussion pertains to Karnataka State and is presented in four main sections: namely, i) the relationship between tank institutions and groundwater condition; ii) the decline of tank institutions, the rise of pump technologies, and the policies supporting them; iii) the overdraft problem; and iv) potential policy responses.

RELATIONSHIP BETWEEN TANK INSTITUTIONS AND GROUNDWATER CONDITIONS

One of the most important functions of tanks is to recharge aquifers. The recharge is facilitated by the systematic removal of silt. Tanks are the common property resources providing surface irrigation and recharging wells in the command area. If tanks are not properly maintained, they cannot sustain this irrigation system. According to The Imperial Gazetteer of India:

> [A]mong individual States, the first place [in tank construction and maintenance] may be given to Mysore [Karnataka]. Almost every valley contains a chain of tanks, the first overflowing into the second and so on until the terminal tank is filled.[5]

A great deal of effort went into creating series of many tanks, sometimes up to a thousand. These tanks are linked together, forming a continuous chain in such a way that no water on the catchment is lost during periods of drought. In the words of the army engineer Sankey:

> [T]o such an extent has the principle of storage been followed that it would now require some ingenuity to discover a site within this great area suitable for a new tank. While restorations are of course feasible, any absolutely new work of this description would, within this area, be almost certainly found to cut off the supply of another, lower down the same basin, and to interfere in fact with vested interests.[6]

Tanks historically were constructed by village communities, private individuals, and the State. Repairs and desilting operations were considered as important as the construction of new tanks. Institutional arrangements existed to avoid damage to surrounding trees, wells, and tanks.[7]

By 1800, a drainage system covering a total area of 16,287 square miles of Karnataka had been intercepted by tanks. The area where tanks and river basins were interconnected equalled 55 percent of the area of river basin catchments. Because the practice of desilting is no longer widespread, groundwater recharge and lateral flow have been reduced and hence, in many river basins, water flows for a limited period of three to four months. In contrast, during normal years water flow in rivers would be for six to nine months. This is another factor promoting well irrigation.

Traditional Institutions

More than half the tanks and most of the *Kolas* were built by the Hoysala rulers between the eleventh and thirteenth centuries, and most of the *Kattes* were built by the Mysore rulers in the seventeenth century.[8]

5. Mysore Gazetteer-Economic, Government of Mysore, Vol.III, 156 (1929).
6. Mysore Gazetteer-Economic, *supra* note 5, at 157.
7. A. Appadorai, 1 Economic Conditions in Southern India (1000-1500 AD) 295 (1936).
8. *See* G. Kuppuswamy, *Irrigation System in Karnataka—Dynastic Analysis*, 16 & 17 Karnatak Univ. Jr. 76 (1980-81). The term *Hoysala* is derived from the courageous act of a warrior by the name of *Sala*. The religious head of the warrior *Sala* directs him to kill (*hoy*) a lion in one stroke. *Sala* kills the lion and gets the name *Hoysala*. The *Hoysala* rulers contributed their might to the economic development of Mysore State.

The presence of about 40,000 tanks in 26,826 villages is evidence of the ingenuity of past farmers and illustrates the importance attached to groundwater recharge efforts in the hard rock aquifers. Institutions governing such activities were largely religious in nature. Historically, construction of irrigation tanks was an act of piety conferring religious merit. Construction and maintenance of irrigation tanks were of fundamental importance for the prosperity of society, and were considered to be one of seven meritorious acts a person could perform in a lifetime.[9] This is evident from numerous inscriptions of old tanks and the remains of irrigation tanks and channels, some of which are still in use.[10]

Tenure

Inscriptions emphasize the importance of "charity" as an institution to revive breached and silted tanks. Tank maintenance (such as desilting and repairing tanks) was performed through gifts of land called *Bittuvatta* or *Kattukoduge*. In addition, individuals donated bullock carts exclusively for maintenance of the tank. Temples provided funds for such operations and leased lands to farmers to encourage the construction of tanks for land reclamation. Farmers who did not maintain their tanks would lose their right to two-thirds of the land leased to them in favor of farmers who maintained tanks at their own expense. Furthermore, this traditional land-tenure system earmarked a portion of crop production for tank maintenance.

The State had a strong interest in local power groups who ensured proper tank maintenance because a share of their produce was used as its revenue. Committees for "supervision of tanks," consisting of six members of the village assembly, were established in some villages. The intent was to invest endowments received from religious people for periodical removal of silt, and for repairs.

Local Self-Government

Local self-government (LSG) prevailed in Karnataka for more than 2000 years, and survived revolutions and political upheavals until the beginning of British rule in the sixteenth century. The major function of LSG was to construct public works and provide irrigation and drinking water. LSG involved local inhabitants with significant autonomy and a

9. Ganapesvaram Inscription of Ganapathi, 3 Epigraphia Indica 88 (1896). Karnataka State has the second largest number of such stone inscriptions in India. They describe the record of transfer of immovable property, judicial decisions, compacts or agreements among communities, dedication of images in temples, grants and donations by rulers and the general public, dates of construction of tanks, repair of tanks, wells, sluices, planting groves and so on. They are the chief source of evidences of the past. The epigraphical evidences make it abundantly clear that construction of tanks took precedence over that of temples. In addition, the practice of excavating and building wells, tanks, and reservoirs was considered as pious as the construction and renovation of temples.

10. A. Appadorai, *supra* note 7, at 202.

portion of its revenue was raised through local taxes. The revenue was spent on local services, rather than on issues of state concern. LSGs in many cases managed the *Bittuvatta*, lands to finance the maintenance of tanks.

Role of Temples

An organic link existed between temples (the religious institutions) and the construction and maintenance of irrigation tanks. Temples gained large areas of land through gifts and bequest of landed property from religious people, confiscation of lands from those who misappropriated temple property, and through transfers of land as a result of tax defaults for maintenance of the temple. It was customary for the temples to receive the first turn of water from tanks on the lands. The taxes (rent) on land leased out varied from one-fourth to one-half of the total crop production.

Temples maintained village tanks when they breached, and provided funds to villagers to maintain tanks by selling a portion of its land when villagers were unable to maintain them. Because temples owned land in several locations, they helped in maintaining harmony and contact among villages for all activities, including irrigation under the tank command. A contemporary example of the role of temples in tank management is the "water temple" of Bali, which controls 50 percent of Bali's agricultural land and sets the optimum rice planting every year.[11]

During the eighteenth century, local bodies created a "tank fund." Villagers were obligated to pay a local tax for tank maintenance, and fines were levied on those who disobeyed orders from state government. For instance, betel-leaf sellers were fined if they sold their leaves in places other than the local temple. In addition, the lands of those who defaulted on land taxes were taken over by local bodies and the proceeds were used to maintain tanks.

THE DECLINE OF TANK INSTITUTIONS, THE RISE OF PUMPING TECHNOLOGIES, AND THE POLICIES SUPPORTING THEM

The water well is a symbol of struggle and faith, and is the driving force for farmers in Karnataka. Their knowledge of the hydrological nexus of tanks and wells reflects the role of the institutions (such as LSGs and temples) and their tradition. The tanks exerted positive externalities by recharging the groundwater resource and also by providing tank silt, which farmers applied to their farm lands when the tanks were empty.

11. The system covers 74 square miles of rice with a "water temple" at every corner of the field. The head priest controls the network of water supply points and any change in the system must be approved by him. *See* Lansing & Kramer, *Bali's Water Temples Rescued by Computers*, 11(5) Hinduism Today 1, 18 (1989).

Declining Importance of Tank Irrigation

With the advent of an irrigation-dominated green revolution during 1966-67, the practice of applying tank silt and green manure was replaced by inorganic fertilizers, further reducing the importance of tanks. The decline in the importance of tanks is described by John Harris:

> The tank is of slight importance in village agriculture [in India] today, however. The fact that five of the richest farmers in the [Randam] village own lands which are mainly well-irrigated and are remote from the tank, compared with only two from the group of 'magnates' whose lands lie near the main sluice, shows how groundwater irrigation has now reduced the importance of control of tank water.[12]

The "sentiment of belongingness" of the tank moved further away from farmers, as the Government passed the Tank Panchayath Regulation (1911) to restore, repair, and maintain the tanks. This tendency of "leaving it to the Government" is prevalent in most parts of the Deccan Plateau. The tank *panchayaths* were institutions authorized to administer funds and to maintain tank registers. Farmers provided labor for earth work and turfing to stabilize the tank sides, and the Government paid for masonary. In spite of these measures, the restoration of tanks moved at a snail's pace and the results were unsatisfactory.

British rulers paid little attention to irrigation development. The introduction of tenurial reforms further weakened the traditional centers of village control and resulted in the deterioration of tanks.[13] The institutions of *Bittuvatta* or *Kattukoduge* in Karnataka, and *Kudi Maramut* in Tamilnadu broke down. Thus, customary obligation of collective efforts in maintaining the tanks deteriorated, worsening the condition of tanks. The tanks ruined during the rule of Haidar Ali and Tipu Sultan required massive investments to repair during the eighteenth century. Though individual works improved, no significant advance was made because of a lack of recognition of the interdependent mechanism between tanks and the necessity of correcting them in a series.[14] The Public Works Department (PWD) created a Minor Irrigation unit in 1955-56 vested with the task of tank maintenance. However, tank maintenance has not been given adequate budgetary allocation at the State level or in the PWD. Furthermore, PWD officials are not interested in overcoming this problem since there is neither commitment on their part to manage tanks nor does their future in the profession depend on how well they serve.[15] The PWD

12. J. Harris, Capitalism and Peasant Farming 130 (1982).

13. *See* A. Vaidyanathan, *Water Control Institutions and Agriculture: A Comparative Perspective*, 20(1) Indian Econ. Rev. 57 (1985); A. Sarda Raju, Economic Conditions in Madras Presidency 1800-1850, 113-120 (1941).

14. *See* Mysore Gazetteer-Economic, *supra* note 5, at 159.

15. A. Vaidyanathan, *supra* note 13, at 60.

makes greater budgetary allocations towards new constructions (dams, public buildings, and highways) and the officials have a greater interest in these activities. In some tanks, under the social forestry program of the Forest Department, fuel wood species are planted, reducing tank capacity and making desiltation very difficult. At present, farmers seldom desilt the tank bed.[16] By failing to do so, they are losing a good, inexpensive source of nutrients and also reducing the groundwater recharge capacity of tanks.

Thus, the institution of obligatory tank maintenance by the community crumbled. Hence the groundwater values of the tank institutions did not emerge until after these tank institutions declined and groundwater exploitation increased. This is imputation of values to past institutions that did not matter at the time they thrived.

Change in the Type of Water Lifting Devices

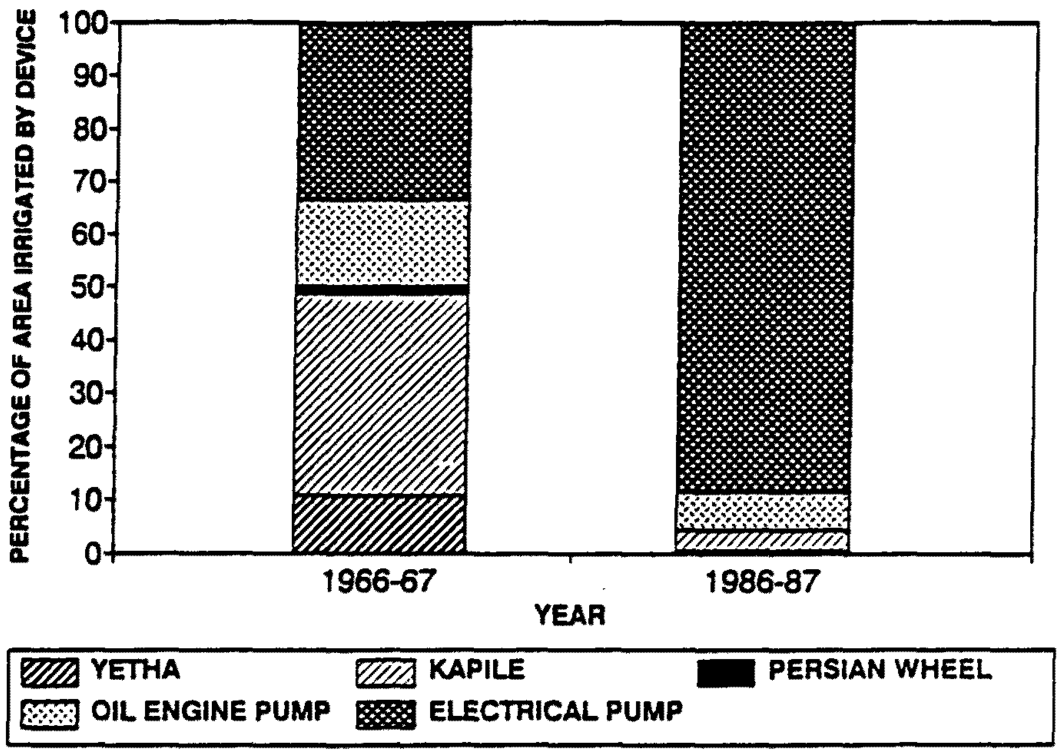
Traditionally, the groundwater economy was dominated by water lifting devices called *Kapile* (a pair of bullocks that move back and forth lifting water from a well in a leather pouch), *Yetha* (a long piece of wood which slides around a pivot with a bucket in one end to lift water by a person walking up and down on the wooden piece), and the Persian wheel (a series of small buckets attached in a circular way which is connected to a pair of bullocks). These devices were labor intensive and formed a major portion (62 percent) of all lift irrigation devices in 1966-67, irrigating 50 percent of the total area irrigated. These devices allowed sufficient time for recuperation of the water in wells. In recent years (1986-87), labor intensive devices have formed only ten percent of all water lift devices and irrigated only about five percent of the total area irrigated by wells. About 80 percent of the wells were fitted with electrical irrigation pump (IP) sets, which irrigated 88 percent of the total area irrigated by wells (Figure 2).

Credit Incentives

Well irrigation and ancillary enterprises have received credit incentives and support from the State and Federal government since the nationalization of commercial banks in 1969. Term loans with lower interest rates (7 to 10 percent) and longer repayment periods (10 to 15 years) were advanced for small and large farmers. Institutional credit for well irrigation increased 16-fold from 18.30 million rupees in 1968-69 to 317

16. M. Venkatareddy, Irrigation Management-Warabandi System, A Case Study, Institution of Engineers, Paper from Sir MV Seminar on Water Management in Karnataka, Bangalore, 13 (1988); discussions with Ramachandrappa, Agricultural Officer and water diviner, Department of Agriculture, Davanagere, July 10, 1989. There was one recent instance of desilting a tank by the local body at Nelamangala, Bangalore District. The motivation was for developing fisheries in the tank since the income from fishery was a good source of revenue to the local body.

FIG 2: SHIFT FROM LABOR TO CAPITAL INTENSIVE WATER LIFT DEVICES



million rupees in 1987-88. Credit for horticulture increased almost 100-fold from 1.23 million rupees to 121 million rupees. Since most horticultural enterprises depend on well irrigation, institutional credit for horticulture is inclusive of finance for wells. During the period 1968-1988, the percentage of wells drilled or sunk with institutional credit support increased from 26 percent to 50 percent.[17]

Finances

The National Bank for Agricultural and Rural Development (NABARD) has been providing the largest share of refinance to the well-irrigation sector. On the one hand, the NABARD refinances increased six-fold for well irrigation, while on the other, there was a drastic reduction in the loan repayments of farmers from 87 percent in 1968-69 to 46 percent in 1986-87 in Karnataka. The large proportion of default was a result of a fall in the water table and an expectation that the government would waive interest payments on the cooperative loans.[18] The high repayments during 1983-84 and 1987-88 were a result of such a remission.

17. From the Demand and Collection Statements of Karnataka State Cooperative Agricultural and Rural Development Bank, Bangalore, 1968-69 to 1987-88.

18. R. Deshpande, M. Chandrakanth & H. Chandrashekar, Expost Evaluation of Dug Well Investments in Hard Rock Areas of Karnataka (Kolar District Report), Institute for Social and Economic Change (1984).

Electricity Tariff Policy

Prior to 1982, farmers were required to pay for the electricity used to lift groundwater from wells, and meters were installed to measure electricity consumption and for billing farmers at subsidized rates based on a pro-rata use of electrical power. After 1982, a fixed payment per year based upon horsepower (hp) of the IP set used at the time of installation was introduced in most of the States of India (flat-rate policy). This was a populist measure that provided incentives to farmers to invest in the groundwater resource, regardless of the size of the farmers' land. Hence the marginal cost for electricity and groundwater consumption became zero. In Karnataka, farmers using a five hp set would pay 60 rupees per hp per year, and those with a five to ten hp set would pay 75 rupees per hp per year irrespective of the quantity of electricity consumed (flat-rate policy). On an annual basis, a centrifugal IP set consumes 3,000 units and a submersible IP set consumes 10,000 units of power,[19] and the costs associated with these technologies are 2,316 rupees and 7,720 rupees respectively for the State. The farmer, however, pays only a flat fee of 385 rupees per annum.

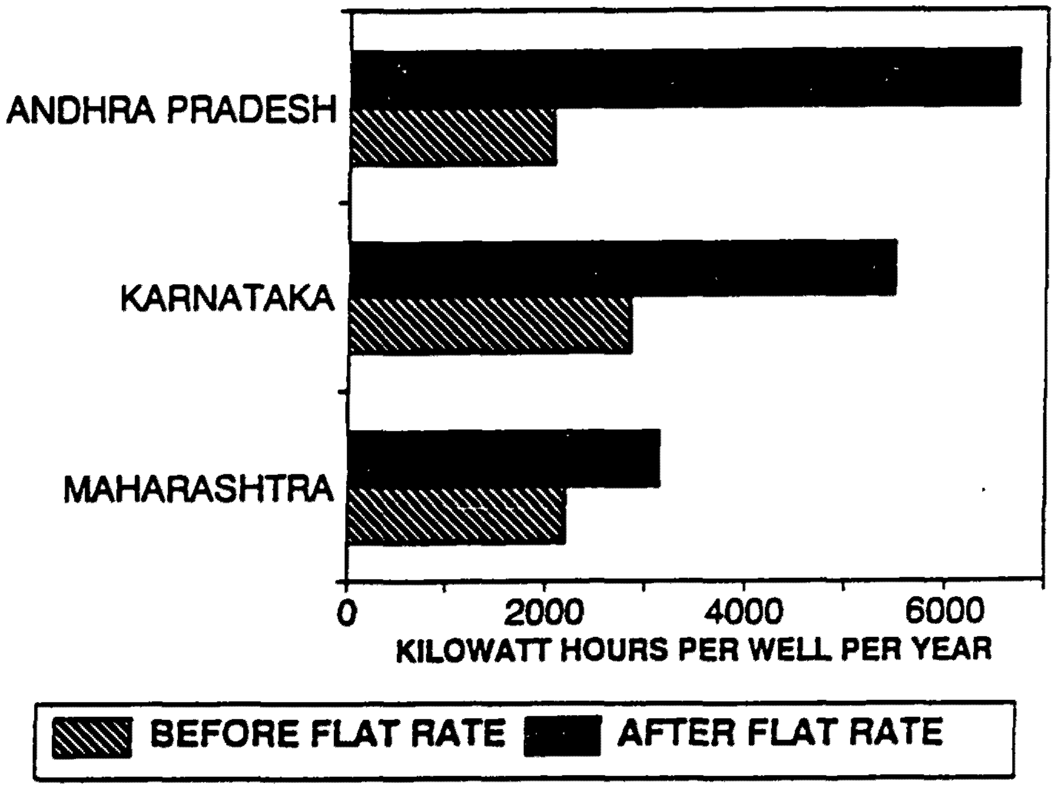
The production of electricity in the State is far below demand. Because of a scarcity of power, load shedding is used. Power is supplied during different parts of the day and night in eight hour slots. Farmers tend to use more powerful IP sets to exploit the supply of groundwater. Energy consciousness is diluted because of the flat rate policy. In several cases, the galvanized iron delivery pipes (old technology) are rusted,[20] reducing the pump efficiency. The Karnataka Electricity Board has had little success in persuading farmers to use high density polyethylene pipes to save power and improve discharge efficiency. Supply of power during the night increases the use of electricity, and the use of groundwater, since farmers do not have devices to monitor irrigation. During field trips by the senior author, farmers expressed difficulties in managing the irrigation system at night due to poor lighting, problems with field snakes, and so on.

The consumption of electricity by IP sets almost doubled after 1982 when the State decided to shift from a pro-rata policy to a fixed-rate charge. Andhra Pradesh and Maharashtra, Deccan neighbors of Karnataka, displayed similar trends (Figure 3). Farmers started investing in groundwater resource irrespective of their size of holding. The power consumption of the IP sets in the state increased from 390 million kilowatt-hours (kwhs) in 1976 to 2,404 million kwhs in 1987—a six-fold increase.

19. P. Narasimhamurthy & A. Sundareshan, Energy Conservation in Submersible Pumpsets, paper presented at All India Seminar on Conservation of Electrical Energy and Minimization of Losses in Power System, University of Rourkee, Rourkee, April 23-24, p. 5, 1988. The units of electricity are related to kilowatt-hours. One rupee is equal to $0.06 (Feb. 1990).

20. P. Narasimhamurthy & A. Sundareshan, *supra* note 19, at 7; discussion with A. Sundareshan, Executive Engineer, Karnataka Electricity Board, Bangalore, Feb. 5, 1989.

FIG 3:ELECTRICITY USE BEFORE AND AFTER THE FLAT RATE POLICY IN DECCAN STATES



Though the sale of electricity to IP sets formed about 29 percent of the total sale of electricity in 1987-88, the income realized by the Karnataka Electricity Board represented only four percent of the total revenue generated, reflecting the anomaly of the flat-rate policy. The National Council of Power Utilities noted that power supplied to the agricultural sector sells for 0.14 rupee per unit. The average cost of production, however, is approximately 0.772 rupee per unit. This is the main reason for the financial losses suffered by the state electricity boards in India. The sale of power to the agricultural sector represents 21 percent of the total sales, and the losses of state electricity boards as a result of such sales are on the order of 14,400 million rupees. About 80 percent of the losses of the state electricity boards are a result of low power tariff to agriculture.[21]

THE OVERDRAFT PROBLEM

The water table is the barometer of groundwater potential. Between 1946 and 1986, the water table in various parts of Karnataka fell from

21. N. Vasant, *Finances of State Electricity Boards*, 5(4) National Council of Power Utilities J. 18-26 (1987).

approximately 25 feet below the surface to 160 feet below the surface.[22] The total area irrigated with labor intensive devices declined from three acres per well to one and one-half acres, and that by centrifugal IP set declined from about five to three and one half acres. A great majority of (hand) dug wells have been converted to dug-cum-bore (DCB) wells. The DCB wells are equipped with centrifugal IP sets or submersible IP sets. Bore wells are becoming more popular because they irrigate more land (5.72 acres per well on an average) than other water lifts. Another problem of dug well construction is that at least six months are required to determine the amount of water yield from the well. In contrast, it requires only a day to drill a bore well and to determine the water yield.

During the period 1966 to 1986, the number of wells with centrifugal pumps increased by more than 275 percent, while the number of dug wells using *kapile*, *yetha*, or Persian wheel decreased by 237 percent. At present, the total cost of installing a 150 foot bore well is around 40,000 rupees.[23] With the rapid increase in the bore wells, the area overdrafted increased by 900 percent. Based upon the groundwater assessment, the State Department of Mines and Geology (DMG) declared in 1988 that 24 *taluks* were overexploited (where overexploited means a discharge above 65 percent of recharge).[24] At present, corrective zoning is adopted in areas where overexploitation is a problem. Finance for well irrigation is rationed in *taluks* where discharge is below 85 percent and no new loans are provided for well irrigation where discharge is above 85 percent. At the present rate of groundwater use, about 62 out of 175 taluks would qualify as over-exploited by the year 2000.

Distribution of Wells in Karnataka

About 50 percent of dug and DCB wells and 44 percent of bore wells are owned by small farmers (defined as those holding five acres or less). This is evidence of an improvement in the bargaining power of small farmers in securing institutional finances and raising private sources of funding for sinking wells. The demand for sinking irrigation wells by

22. From (1) records of the water levels in observation wells maintained at the office of the Director of Mines and Geology, Government of Karnataka, Bangalore, (2) records of Ramachandrappa, Agricultural Officer and Water Diviner, Davanagere, and (3) interviews with farmers of Bijapur, Mandya, Kolar and Chitradurga districts. In several parts of the Deccan, the steep fall in the water table is attributable mainly to the overexploitation of groundwater. *See* W. Olsen, *Man-made 'drought' in Rayalaseema*, 22(11) Econ. Pol. Wkly. 441 (1987).

23. The cost due to poor quality installation, delay in obtaining the electrical connection from Karnataka Electricity Board, and lack of adequate power supply would substantially add to this initial development cost.

24. National Bank for Agricultural and Rural Development, Status Paper on Minor Irrigation in Karnataka, NABARD Zonal Office, Bangalore 19 (1989).

small farmers is motivated by markets for enterprises such as mulberry-silkworm rearing, betelvine, dairying, rice, and sugarcane and vegetable cultivation. These enterprises have been responsive to irrigation, have well-developed markets, and remunerative price structures. They are best suited for small farmers, and demand intensive management efforts. Though sugarcane and rice require heavy irrigation, farmers preferred to grow them for agronomic and economic reasons. Sugarcane production requires about 96 acre-inches of water per acre for an annual crop and 35 percent of irrigated sugarcane is irrigated with groundwater. In addition, approximately nine percent of irrigated rice area is irrigated using well water, requiring 46 acre-inches per acre per crop of four months duration. Farmers prefer to grow rice using groundwater irrigation because rice (a) is a staple food, and prices are stable; (b) is vulnerable to attack by few pests; and (c) gains value after storage because grains improve in quality with age. Similarly, sugarcane is a preferred crop since farmers are assured remunerative prices by sugar companies and labor management is relatively easy.

Insurance Scheme

At present, credit institutions are providing well loans to farmers only when location of the new well is at least 600 feet from existing wells and when groundwater availability certification from recognized geologists is shown. However, this rule does not prevent farmers from drilling wells with their own sources of finance. Substantial investments of 30,000 rupees to 40,000 rupees ($1,800 to $2,400) per well in groundwater exploration are being made by at least 20 percent of farmers by selling part of their land and/or other assets (in absence of formal financial support). Because the rate of failure to strike groundwater is quite high, such sizeable investments are wasteful and should not be forfeited in the interest of the economy. Farmers successful in striking groundwater tried in at least two points at varying depths ranging from 100 to 250 feet.[25] This depth to groundwater is an indicator of the extent of investment necessary in exploration.

In the current insurance scheme, a premium of 17.5 percent is charged. Large farmers pay two and one-half percent, while the state and central governments pay seven and one-half percent each. Small farmers pay nothing. If the yield of borewells is less than 800 gallons per hour (gph) at the time of drilling, then the insurance covers the loss suffered by the Karnataka Agro-Industries Corporation Ltd., the authorized drillers for the farmer borrower. During 1988-89, only 64 percent of sunk borewells

25. From the records of Karnataka Borewell Driller's Association, and Ramachandrappa, Agricultural Officer and Water Diviner, Davanagere.

were successful and compensation paid formed 176 percent of the premia received.

POTENTIAL POLICY RESPONSES

At present, there is a "spacing" regulation applicable only for borrowers of funds from credit institutions. A minimum distance of 600 feet between wells is a prerequisite for applying for funds. Again, this rule does not apply to farmers who can provide their own source of finance for well drilling. Apparently this rule assigns property rights to groundwater, more to those farmers who have access to credit than to those who have no access. Even in the case where a small farmer could get a well loan, the neighboring farmer can drill a deeper well that could deplete the groundwater resource of his/her peer. Hence, there is neither security against physical uncertainty nor against tenurial uncertainty. The long term effects of well interference as a result of borewell pumping on nearby borewells and dug wells have already been reported in Gulbarga, Mysore, Bidar, Belgaum, Chitradurga, South Kanara, and the Dharwar districts. In these areas, the groundwater level dropped by 27 feet between 1973 and 1984. The failure rate of borewells with a discharge of 1600 gph and below ranged between 42 and 74 percent. Those borewells with discharge of 800 gph and below failed between 26 and 50 percent of the time.[26] To alleviate the problem of groundwater overdraft, DMG proposed a model groundwater legislation bill during 1987. The legislation proposes to introduce permits for extraction and use of groundwater in a notified area from the groundwater authority. Furthermore, no civil court would have the jurisdiction to entertain or decide proceedings on matters which the State groundwater authority is empowered by legislation to control. The State legislature, however, has yet to examine the provisions and accord its approval. From the senior author's discussions with farmers and legislators, it was apparent that both groups would stall the implementation of legislation because it regulates the extraction and use of groundwater. While the farmers expressed that they would hold a protest, the legislators preferred not to regulate because of the fear of losing the next election. Farmers have a feeling that tanks can only recharge shallow dug wells rather than bore wells. Since electricity is free, they want to drill deeper borewells and expressed that borewells provide a perennial water source.

Corrective Policies

The institutions governing surface water are not strictly applicable to the groundwater resource because property rights for groundwater are

26. National Bank for Agricultural and Rural Development, *supra* note 24, at 12.

vague. Policy instruments should consider the security and flexibility of the resource. Some of the options available to policy makers are the following:

1. *Maintain tanks by desilting*. The revival of the institution of community management of tanks is crucial. The other option would be to make it mandatory for farmers under a tank command to maintain and desilt tanks and strengthen the budgetary allocation of PWD for tank maintenance. Incentives could be provided to farmers who desilt the tanks, build conservation structures for recharge, and use water conservation techniques in cultivation. The density of wells could be tied to the quality of tank management for recharge (creating additional incentive).
2. *Impose conservation requirements* such as, a) drip and/or sprinkler irrigation systems, b) low-water consuming crops, c) improved discharge efficiency through use of quality electrical pumps and delivery pipes, and d) installation of correct capacity pumps.
3. *Price electricity on pro-rata basis*. Electric meters and water meters should be installed to measure groundwater use on farms. Even if the cost of administering the metering work is considerable, it would give information on the amount of resource used. This information could be used to fix incentives and impose penalties, and provide a basis for prescribed amounts of water. This would provide flexibility of water rights by facilitating the transfer from lower to the higher remunerative use. Price discounts could be offered for conservation efforts and for those who consume the right quantities prescribed for the crop in the region and penalties could be charged for those farmers who overirrigate the crops according to the prescription. This should also encourage use of prescribed pump sizes.
4. *Time electricity supply for improved water management*. Supply during the dark hours has resulted in excessive use of groundwater because of the difficulty in managing the irrigation. Supply during the daylight hours would help conserve water and also enable the farmers to monitor the water use.
5. *Price electricity depending on the type of crop*. Electricity for high-water crops (rice, sugarcane, maize, vegetables, mulberry, fodder) should be priced more than that for low-water crops (groundnut, sunflower, sorghum, ragi). This would dissuade farmers from growing high-water consuming crops using groundwater. If farmers persist in growing these crops using well irrigation, it may be necessary to ration the supply of electricity, as is often done for urban power consumers.
6. *Regulate credit in light of the groundwater basin*. This would impose recharge requirements for all the borrowers who apply for loans to sink wells. Furthermore, charging higher interest rates in areas where necessary would discourage new drilling and deep-

ening existing wells, which would help prevent well interference. Subsidies on credit for irrigation wells should be removed in areas where overdraft is observed.

7. *Regulate well drilling agencies.* Permits should be obtained by the well drilling agency, rather than farmers, before sinking wells. This would make management for the groundwater authority easier, as the drilling agencies are few in number (about 300).
8. *Make an efficient irrigation system part of the loan program.* Including sprinkler and/or drip irrigation equipment in the component of well loan would serve as a package for conservation and planning for proper water use. The use of quality materials during installation could be mandatory for sanction of a loan.
9. *Regulate the depth of drilling and spacing between wells.* The DMG has information on the depth to the water table in different aquifers. This information is of use in regulating the depth of drilling and space between wells in order to prevent cumulative well interference.
10. *Establish groundwater districts.* This would help groundwater basin management bodies enforce the above system of correlative water rights to balance the recharge and discharge and help prevent long term overdraft of groundwater.[27] Rates at which groundwater is withdrawn and replenished to the aquifer need to be determined to choose the permissible rate of overdraft. The selected rate of withdrawal could be shared among farmers based upon individual quotas. The quotas could be set depending upon on the need of farmers, based on the number of members in a farm family rather than on the size of their farm. Farmers who consume only part of their quotas would not forfeit their rights. This provides them with opportunities to take conservation measures and reduce pumping below quotas. Farmers would prefer to enjoy a right to their secured annual quota rather than a right to an unsecured annual quantity of groundwater which may be even larger than their quota.

CONCLUSION

At present, groundwater is economically scarce and legally unbound in the Deccan Plateau. As groundwater overdraft is widespread and threatens water supplies, it is necessary for society to assert its rights to safeguard groundwater supplies. The thesis of interaction suggests correlative policies for groundwater and tank management. The policy picture derives from the historical understanding of the relations between tank institutions

27. Due to wide variation in groundwater in hard rock aquifers, site specific information is necessary for groundwater development. Information from experienced farmers, water drilling agencies, and local water diviners have to be supplemented with the information from Department of Mines and Geology and Central Ground Water Board to help in establishment of groundwater districts.

and aquifer conditions. One policy is the revitalization of tank systems for surface irrigation, groundwater management, and silt fertilization. That is, tank investments become more attractive when their groundwater and soil fertility effects are considered. Another policy is the removal of subsidies—electricity and credit—for pump irrigation. A third is to establish groundwater districts to enforce a system of correlative rights through groundwater quotas. The fixing of stringent groundwater quotas based on the needs of the farmers would enable them to secure a predictable annual quantity of water.