Electricity Prices:

A Tool for Groundwater Management in India?

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Foreword

Groundwater depletion problems are attracting increasing attention from policy makers, academicians and researchers in the country. Along with the problem of depletion, also growing are the debate over the energy pricing policies in the agriculture sector. The argument is that the subsidised electricity for agriculture pumping creates no incentive for farmers to use groundwater efficiently and leads to overexploitation of groundwater. As a result, indirect management using correct pricing of electricity has received top attention as a tool for groundwater management. The workshop on **"Water Management: India's Groundwater Challenge"** discussed a range of approaches for managing groundwater resources in the country. Some of the indirect management approaches such as electricity pricing and water pricing as potential tool for managing groundwater resources

This monograph contains 5 papers presented in the workshop which deal directly with potential impact of energy pricing on groundwater use. A summary of the key points discussed in the papers are covered in the preface by Marcus Moench. The papers by Mohanty & Ebrahim and Kumar & Patel, based on extensive field studies conducted in Saurashtra and Mehsana respectively argue that energy pricing doesn't have a major impact on water use. While The two papers follow, by Dr. Malik and Aroa & Kumar call for pricing to be used as a tool for managing groundwater resources. Finally, the paper by Nagraj and Chandrakanth estimates the willingness of farmers to pay pro-rata tariffs. Hope, this volume would help the field level NGOs, professional hydrologists and concerned government organisations get valuable insight into the viability of various supply based approaches and techniques currently being tried to address the groundwater depletion and scarcity problems in India.

G. Raju
Director

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Electricity Prices:
A Tool for Groundwater Management?

PREFACE

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This monograph contains a selection of papers that attempt to analyse the impact of electricity price changes on groundwater extraction in India Connections between electricity pricing policies and emerging patterns of groundwater overdraft in many sections of India have been the subject of substantial debate Electricity is currently provided at highly subsidised rates or, in some locations, free to farmers for groundwater pumping. In addition, in most locations where charges for electricity are levied, they are flat annual fees based on pump horsepower From an economic perspective, flat annual charges or the free provision of electricity creates a situation where the marginal cost of pumping is nearly zero (maintenance and capital depreciation being the only positive variable costs). In fact, where annual electricity charges are high, average costs decline as pumping increases. Economic logic strongly suggests that this creates great incentives for inefficient use of groundwater. Parts of this logic, along with a strong call for water pricing at the farm gate, are outlined in the papers by Arora and Kumar, R P S. Malik and by Nagaraj and Chandrakanth in this volume

The paper by Arora and Kumar and the one by R.P.S. Malik both call for price to be used as a tool for managing groundwater resources They point out, however, that pricing has potential equity impacts and needs to go beyond the narrow financial costs of generating and distributing electricity. Malik uses a natural resource accounting framework to estimate the prices needed to cause shifts between rice-wheat and maize-wheat cropping systems in Punjab and Haryana He emphasises the need to consider the resource cost of groundwater in setting prices and makes estimates for different combinations of flat and pro-rata tariffs that would make the less water intensive maize-wheat system competitive with the more water intensive rice-wheat system. Extrapolating from his Table 7 and excluding the resource costs (since these do not directly accrue to individual farmers), I find that a unit electricity price of Rs 1.25/kwh would be required to make maize-wheat and rice-wheat competitive based on the present value of returns compared to operating costs.[1] Arora and Kumar present less data to support their pricing arguments but do provide a brief history of price debates and alternative approaches for fixing electricity tariffs. Finally, the paper by Nagaraj and Chandrakanth estimates the willingness of farmers to pay pro-rata tariffs. They find that a significant number of farmers in parts of Karnataka where their study took place would be willing to accept consumption based charge structures, albeit at the low rate of roughly Rs 0.18/kwh (well below the generation cost of Rs 1+/kwh).

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[1] I also excluded the impact of increases in demand for rice due to removal of large rice producing areas in estimating the effect of rate changes For substantial crop shifts, this could be a major factor

While the economic logic of consumption based price structures is clear, whether or not changing the electricity pricing structure would change groundwater use incentives sufficiently to address emerging overdraft problems is, however, less clear. The net amount of groundwater extracted for irrigation is a function of crop selection, crop water requirements under given environmental conditions, irrigation efficiency (here meaning the efficiency of delivery to meet crop needs) and the amount of water extracted for irrigation that returns via seepage to aquifers Water or energy pricing could have a direct impact on two of these, crop selection and irrigation efficiency. Higher prices for water should encourage selection of less water intensive crops and more efficient water application practices. There is, however, a negative feedback between irrigation efficiency and return flows to aquifers. The importance of this will depend greatly on location In some areas, seepage back to aquifers is limited due to the depth to the water table, confining layers, runoff, or the presence of low quality intervening water In others, water not consumed by the plant returns to the aquifer and is available for future use. Savings via improvement in irrigation efficiency are only "real" to the extent that the former of these situations predominates. These issues, while not directly addressed by authors preparing papers for this monograph, provide an important element of context.

The detailed study of energy pricing and groundwater use by Mohanty and Ebrahim compares groundwater use by diesel pump owners (who effectively face a pro-rata price structure for energy) and electrical pump owners in Junagadh District, Gujarat. They found that diesel pump owners were more cautious in their irrigation practices, for example waiting longer before irrigating when there was a potential for rain. At the same time, they did not find great differences in water use. Furthermore, they found the marginal productivity of water to be positive for both diesel and electrical well owners and, based on that criteria, did not find great inefficiencies in water use. Overall, they observe that "while a pro-rata tariff will reduce water consumption, it may not result in sufficient conservation to significantly impact groundwater depletion". Based on this and other results of their survey they conclude that "while it may be true that altering the energy pricing strategy might change the efficiency of water use, a focus on this assumption can misdirect the search for groundwater management alternatives by restricting it to pricing policies only".

Similar findings to those of Mohanty and Ebrahim are outlined in the paper by Kumar and Patel In a study of Kheralu Taluk in Mehsana, they found that energy pricing did not have a major impact on water use decisions. Instead, "it is the degree of assurance of yield and comparative availability of water which decides irrigation water use". Scarcity was a common theme among the farmers they interviewed in deciding both crop choice and the balance between yield and water application.

Overall, while several papers in this monograph present logical arguments for using electricity pricing as a tool for groundwater management, they provide little actual data to suggest that pricing is likely to be an effective tool. In contrast, the field data presented by Kumar and Patel and by Mohanty and Ebrahim downplay the importance of energy prices in the overall cropping and water use equation At best, energy prices in the range it would be politically feasible to implement appear to be a convenient, but relatively limited tool for influencing water management decisions.

Energy Pricing and Groundwater Use: A Case Study

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ABSTRACT

This paper presents the results of a survey in Junagadh district undertaken to understand the effect of flat-rate electricity pricing on groundwater use The results suggest that flat-rate energy prices do not lead to inefficient use of scarce groundwater resources. A strategy for water management that maintains groundwater conservation as a distinct issue from electricity pricing is recommended by the authors as this approach lends itself to better aquifer level management. It is also proposed that an institutional structure based on community involvement may be an equitable option for managing scarce groundwater resources.

INTRODUCTION

This paper presents the findings of a survey undertaken in Junagadh district of Gujarat to understand whether flat-rate electricity tariffs are responsible for rapid groundwater depletion in Maliya taluka. The survey was conducted in four villages of Maliya taluka of Junagadh district. Junagadh district lies in the Saurashtra region of Gujarat. Agriculture is the main occupation of the region. The major crop grown in this region is groundnut. The region also grows substantial quantities of sugarcane, jowar and winter wheat and mangoes. During the 1950's water for irrigation was mainly drawn using human or animal power and the number of wells were very small However, supportive government policies, which made input and credit subsidies liberal during the 1960's and 1970's, made it possible for farmers to dig more wells and extract water using modern electric pumps. By the mid-eighties, many wells in Maliya went dry and their was a long term decline in water tables in the region. Finally, according to the 1986 report of the Government of Gujarat Maliya taluka was put in the "dark" category.

The first part of this paper attempts to characterise water use behaviour in the survey villages in order to test the following hypotheses as postulated by Moench (1992).

(i) Groundwater for irrigation is used inefficiently by farmers who operate electric irrigation pumpsets.
(ii) A large part of this inefficiency is due to flat-rate electricity pricing.

Some observations on managing a common-pool resource like groundwater are discussed in the subsequent parts of the paper. The focus in this paper is on efficiency issues which may or may not be related to the deeper issues of groundwater sustainability.

SAMPLE SELECTION

Approximately 60 farmers operating 5 HP electric and diesel pumpsets from an average depth to water table of 60-70 feet were interviewed in the months of July and August 1993 in four villages of Maliya taluka, namely Amrapur, Katrasa and Jallandhar and Virdhi These villages were selected for the following reasons:

i) these villages are in Maliya taluka which is designated as "dark" by the GWRDC (Gujarat Groundwater Development Corporation)[2]
ii) these are neighbouring villages in Maliya taluka and thus have similar topography and soil types.
iii) all the four villages have a significant number of both diesel and electric irrigation pumpsets;
iv) water quality is not a problem in this agricultural block and is thus not a complicating factor in water usage for agriculture.

AVERAGE NUMBER OF IRRIGATIONS FOR WHEAT AND GROUNDNUT CROP

Approximately sixty farmers provided information on the number of waterings required by wheat in the rabi season and for groundnut in the kharif season.[3] The results are summarised in Table 1.1 and 1 2 below.

Table 1.1. Average Number of Irrigations in Rabi for Wheat

	Pump (HP)	Sample size	Average waterings
Electric	5	35	14.5
Diese	15	20	12.8

Table 1.2. Average Number of Irrigations in Kharif for Groundnut

	Pump (HP)	Sample size	Average waterings
Electric	5	27	5.3
Diese	15	15	4.1

Note: These figures are for waterings required for groundnut crop if monsoon rains are insufficient.

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[2] A taluka is designated as "dark" when groundwater extraction to utilisable recharge for irrigation is 85 % and above

[3] Farmers who operate 5 HP electric pumpsets pay approximately Rs 0 15/kwh while diesel pumpset operators with 5 HP pumps pay approximately Rs 2 20/kwh Diesel/ crude oil costs Rs 8 per litre

From the above responses, it appears that electric pump operators are inclined to provide more waterings than diesel pump operators. Nonetheless, there may be some confounding influences. For example, the variation may also be a result of soil depth, as deeper soils may require more water. Or farmers who water more frequently do lighter irrigation applications. One of the respondents explained that land with a thin soil layer loses moisture quickly, and thus needs frequent watering to keep the roots of the crop moist. This necessity for moisture is particularly important during sowing and may necessitate some watering prior to the monsoons. Conversely, land with a thicker soil layer is better able to retain moisture as the deeper reaches are less affected by sunlight penetration. At the same time, such soils benefit from waterings of longer duration since they take longer to reach saturation and retain moisture longer.

According to the respondents it appears that shallow soils benefit from short but frequent waterings, whereas deeper soils benefit from longer but less frequent waterings. The latter method is likely to result in less water lost through evaporation and encourages deeper and thus hardier root growth, whereas the former is more susceptible to greater water loss and weaker root growth The adoption of one or the other method, however, seems to be determined by soil depth and not by a concern for minimising water loss.

It is quite possible that since electricity supply is limited during the day (available for only 10-12 hours a day) electric pump owners choose to water more frequently and for shorter durations than do diesel operators who can run their pumps continuously until soil saturation. A factor that is easily overlooked due to its subtlety is the possibility that diesel operators may be applying less water to their land. If electric operators are applying more water since their marginal cost of operation is zero, then is it not possible that diesel operators are applying less water to save on costs and in the hopes of rain? A look at crop yields in both the kharif and rabi seasons provides some insights.

Table 1.3. Productivity for Kharif (groundnut) and Rabi Crop (wheat) for 5 HP Electric and Diesel Pump Owners

	Average productivity (groundnut kg/ha)	Average productivity (wheat kg/ha)
Electric, N = 35	1552	2450
Diesel, N = 20	1460	2250

Note: N = number of respondents

The option of waiting for rainfall only exists for the kharif crop as little rain is expected in the rabi season. Thus it is expected that farmers who wait too long for the rains will suffer a loss in yield during the kharif season only, and those who apply less water will suffer a loss in the rabi season. The number of waterings by electric pump owners can serve as

a possible indication of water use inefficiency by them and perhaps also as an indicator of underirrigation and over-waiting by diesel operators. The data from Tables 1.2a-1.2e appear to present a case for overirrigation by electric operators.

MEASURING INEFFICIENCY IN INPUT USE: MARGINAL PRODUCTIVITY ANALYSIS

To understand whether farmers were using electricity inefficiently given flat-rate pricing tariffs we undertook a more rigorous analysis with our data set. In the second stage of the survey, detailed information on cost of cultivation of the two major crops, groundnut and wheat, was collected from farmers in Maliya taluka. Production function analysis was undertaken to calculate the marginal value productivity (MVP) of irrigation for 5 HP diesel operated tubewell and 5 HP electric operated tubewell The quadratic production function used for carrying out the regression analysis was as follows:

where

Y = Output of crop per hectare on farm

X = Irrigation hours per hectare

ESTIMATION OF MARGINAL VALUE PRODUCTIVITY

The marginal value productivity of diesel operated tubewells and electric operated tubewell irrigation was estimated with the help of regression analysis using the production function referred to above.[4] Marginal value productivity for the irrigation input is calculated as follows:

where

Y = Average of output of crop per hectare,

X = Average number of irrigation hours per hectare (for both diesel and electric pumps separately);

MP = Marginal product and the subscript HI/H refers to hours of irrigation per hectare

The results of the regression analysis are presented in the Tables 1 4 and 1.5 below

Table 1.4. Marginal Value Productivity of Irrigation in Groundnut

	Sample size	Average landholding (ha)	Average area irrigated (ha)	Crop yield kg/ha of	Marginal product water
5 HP Electric tubewells	N = 18	10.1	7.87	1450	5.36
5 HP Diesel tubewells	N = 12	6.89	5.50	1410	6.01

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[4] Fertiliser consumption cost per acre and labour cost per acre were also regressed on the dependent variable but were found to be statistically insignificant and therefore were dropped from the final regression estimate

Table 1.5. Marginal Value Productivity of Irrigation in Wheat

	Sample size	Average landholding (ha)	Average area irrigated (ha)	Crop yield kg/ha of	Marginal product water
5 HP electric tubewells	N = 20	11.31	8.08	2230	4.66
5 HP diesel tubewells	N = 15	6.06	4.84	2145	6.11

Marginal productivity analysis shows that both diesel and electric pump owners use their groundwater inputs efficiently since the marginal products are positive.[5] There is no overwatering of crops by either electric pump owners or diesel pump owners.

IRRIGATION PRACTICES AND THE DEPENDENCY ON RAIN

Despite our empirical results which present a case for efficient use of groundwater resources, Maliya taluka continues to experience severe groundwater problems. It is therefore important to understand the nature of the groundwater problem.

Junagadh district receives upwards of 45 inches of rainfall in a good year. The current year (1993) started off well with a promising rainfall of 10-15 inches. Farmers were encouraged by the rains and the majority planted groundnut on most of their land. The rains subsequently stopped and as of early August the second set of rains had not arrived. The majority of wells in the region range from 60 to 75 feet in depth, extending to perhaps a little over 90 feet where borewells are in place. If it does not rain, most of this water will be used for groundnut, which will require between 3 to 5 waterings depending on its stage of growth and soil depth. Consequently, little if any water will remain in the wells for watering wheat.

Given these conditions, a number of questions arise that may enable some inferences on water use behaviour:

(i) How long is a farmer willing to wait for rain before commencing irrigation? Are there differences between diesel and electric operators?
(ii) What are the advantages and disadvantages of commencing irrigation before most other farmers do?
(iii) Once farmers commence irrigation, are there any differences in water use behaviour between diesel and electric operators?

At the time of the survey (July-August, 1993), it was found that most farmers were willing to wait a few days and at the most one week before commencing irrigation. Of all the diesel operators interviewed only 2 (out of twenty) had started irrigating their farms. Apart from these two diesel pumpset owners, every diesel operator interviewed was hoping for rain so that he would not have to run his equipment and thereby save costs. In contrast, most electric pump operators had already commenced irrigation.

The diesel operator is clearly cost-conscious as his operating expenses are higher. The startup or initial expenses for a diesel pump far exceed those for an electric pump as the machine needs tuning up, parts need replacement, and an investment in crude oil or diesel must be made According to the respondents, it is common for these initial expenses to range from a few hundred to over Rs.1000. For electric pumps the cost of startup is usually zero. Estimates of annual operating expenses for running the diesel pumps (operation, maintenance and fuel) by diesel operators ranged from Rs. 3500-7000 for irrigated land area between 1.2 and 6 hectares, whereas expenses for electric operators ranged from Rs. 1000-2072, land area being irrelevant. The initial expense factor, in addition to the high cost of crude/diesel, places diesel pump operators at a great disadvantage in comparison to electric operators. Diesel operators are hoping to avoid or delay a major expense by not irrigating until absolutely necessary, whereas electric operators do not face such a dilemma since they pay a flat rate regardless.

Apart from the initial expense issue, early commencement of irrigation plays an important role in groundwater balance. Farmers are clearly aware of the low water availability and also have some idea of aquifer storage and groundwater flow. They are aware that increased extraction by other farmers affects water levels in their wells When questioned on the possible reasons for the groundwater shortage in the region, almost every single farmer cited the tremendous increase in wells and thus of extraction as being the primary contributor to water scarcity. For example, the village of Amrapur had 243 wells in 1991 as compared to 100 in 1965, and has suffered a drop in its water table from approximately 30 feet to 75 feet.[6] Bromley (1989) claims that excessive pumping results from "the absence of reliable knowledge concerning the state of the aquifer, and the inability of farmers to be secure that water they save for tomorrow will not be extracted today by a neighbour".

THE ROLE OF ELECTRICITY PRICING

If water use behaviour can be characterised as in the preceding section, a number of questions on the role of electricity pricing arises:

i) What is the current electricity pricing strategy?
ii) How has it affected water use behaviour?
iii) Can electricity pricing encourage water conservation?
iv) If yes, then what sort of strategy/strategies might work?
v) What sort of response might such strategies elicit from farmers?

The current pricing strategy charges farmers an annual flat rate based on pump size (Rs. 192 per horsepower per annum for pumps up to 7.5 HP). Most of the electric pumps in

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[5] The price of wheat and groundnut are Rs 5 and Rs 10 per kg respectively The marginal cost of pumping water with a 5HP diesel pump is Rs 10/hour while the marginal cost of using a 5 HP electric pump is zero

[6] AKRSP(I) (1993)

the region studied have 5 horsepower motors, and thus are associated with an annual fee of Rs 960 payable to the Gujarat State Electricity Board (GEB). This fee was instituted in 1987 after intense pressure by the farmer lobby to eliminate the pro-rata pricing structure then in place. Part of the farmer lobby's strength came from the fact that most other states in the country had adopted flat-rate tariffs prior to Gujarat state

Marginal productivity analysis showed that the structure of energy pricing may not play a role in water use behaviour. Being a common pool resource, it is unlikely and unreasonable to expect that groundwater will be extracted in a manner that prioritises conservation. While the flat-rate pricing strategy eliminates the marginal cost component from water use by bringing the marginal cost of pumping to zero, we have no reason to believe that it encourages excessive use of groundwater in Junagadh.

GROUNDWATER AS A COMMON POOL RESOURCE

A pricing strategy to encourage water conservation must introduce a cost-conscious component into water use. An example may be of use here The village of Samadhiala, also in Maliya taluka of Junagadh district in Gujarat, organised a cooperative lift irrigation society (LIS) in 1986 with the assistance of a local NGO.[7] The society pumps water out of the Meghal River for irrigation purposes and distributes the water amongst its members for a fee based on the number of acres watered. Since the society is organised around a natural resource that must be carefully managed, it charges proportionately for that resource. The working details of the society are not of interest here, but rather the principle -- the pricing of a common pool resource.

The pricing of groundwater is problematic because there are no institutions or rules governing the use of the resource. Groundwater is invisible and not easily quantifiable Estimating the quantity of groundwater available in a region is difficult, particularly in unconfined aquifer regions. A decline in the quantity of groundwater is not easily observable, making protection of the resource difficult. In Samadhiala, the society is capable of rationing water depending on river flow and observable storage, but the same is not true for groundwater

As a common pool resource, groundwater extraction needs to be regulated either through a pricing mechanism that not only makes excessive withdrawal unattractive but also encourages water conservation, or through collective action through a heightened user awareness of aquifer behaviour and the consequences of depletion. Such an awareness, combined with the collection of reliable data on aquifers, can perhaps serve to make the resource more "visible" to its users.

STRATEGIES FOR GROUNDWATER CONSERVATION

There appear to be two options available for conserving groundwater resources:

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[7] Shah (1991)

i)the direct control of water through water pricing or physical regulation;
ii)the pricing of electricity which is used to extract that water.

DIRECT CONTROL OF WATER

In attempting to control water directly, one has the option of looking at recharge and/or extraction. In the long run increasing recharge through percolation tanks and checkdams may not be an adequate solution. While it may be necessary to implement such recharge schemes, which provide the additional benefits of erosion control, reduction of soil loss etc., sufficient recharge may not be achieved because as recharge increases, so does extraction. An example will clarify this point. Within the Saurashtra region of Gujarat, Junagadh district receives 35-50 inches of rainfall in a good year, and Jamnagar district receives 15-20 inches in a good year Yet the former district faces groundwater shortages which are at least as acute as the latter. The choice of crop partially explains this problem since Junagadh district grows more water-intensive crops as these fetch a higher price in the market. Moreover, support prices set by the government encourage the growth of such crops thereby encouraging excessive groundwater extraction. Thus, the greater the water supply is, the greater the extraction.

The other option for managing depleting groundwater resources is by regulating extraction, which can be achieved by:

(i) pricing of water;
(ii) marketable permits to extract
(iii) mandating water conservation

PRICING OF WATER

The pricing of groundwater is inherently problematic for it is the pricing of a common pool resource. Pricing of a common pool resource like groundwater means that one has to assign property rights to the resource Property rights are sanctioned relations among people that arise from the existence of things and pertain to their use (Furubotn & Pejovich,1972). A specific property right might be characterised by answering the question: Who can the holder(s) of the right exclude from modifying, transporting, or using a particular resource?

Who can a well owner exclude from using the groundwater? According to the Easements Act and Transfer of Property Act, farmers in India have private groundwater rights. It is not open to non-landowners. The government cannot prevent farmers from pumping groundwater on their fields. There are no public rights to groundwater. Groundwater is a free resource in India, but at the same time it is also a scarce resource Unless property rights are well defined, pricing of groundwater is not an option for mitigating depletion

MARKETABLE PERMITS TO EXTRACT

In a system of marketable permits, families within the aquifer region would be

allocated permits or "rights" to the extraction of a set quantity of water. All permits combined would not exceed the total allowable extraction from that aquifer. Trading of permits would be allowed, thus enabling the emergence of a water market. A marketable permit system however presupposes that a village level aquifer management exists in a village. Bromley (1989) recommends the establishment of village water management association and committees which appoint a village water master to run a groundwater management scheme. He also outlines the data that is necessary to collect on aquifer characteristics and adds, "Only through collective action on the demand side can the village avoid the inevitable slide into uncertain cropping owing to insecure water supplies. This message must constitute the very foundation of our work in the village".

The advantage of marketable permits for groundwater is that the landless would be included in the market as they would be allocated rights which they could sell.[8] This system would require some means of monitoring the quantity of water extracted and may thus require the use of water meters. While there have been problems with tampering of meters in the past, this option need not be ruled out. The development of a system of monitoring and enforcement which minimises meter tampering may be possible, as meters are widely used in urban centres. A system that employs members of the village in enforcement and maintenance of these water meters may prove more effective than one which is exogenously run.

The marketable permits system however attempts to address caste division and inequities by issuing tradable rights to all. But even this approach would require some form of organisation or management. It is conceivable that a water management association may come up with approaches to dealing with equity other than those mentioned here.

MANDATED CONSERVATION

An alternate way of directly controlling water extraction is by requiring the use of water conservation methods. In other words, the government could mandate the use of drip irrigation in all orchards and the use of pipes and lined channels in all irrigated farms. Subsidies could be made available for the adoption of such technologies, perhaps with higher subsidies being offered to the resource poor or low caste. The Government of Gujarat currently offers subsidies of this nature for the construction of biogas plants. Politically, however, the mandating of technology can make a government very unpopular, unless implemented carefully and with large subsidies.

CONTROL OF WATER THROUGH ELECTRICITY

The other option is that of controlling the electricity which is used to extract water through:

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[8] For discussions on marketable permits the reader is directed to an excellent paper by Hahn and Hester (1989)

(i) Pro-rata tariffs based on electricity usage.
(ii) Charges based on size of irrigated land area.
(iii) A combination of strategies.

PRO-RATA TARIFF

The pro-rata (PR) system was in place in Gujarat prior to 1987. The most obvious benefit of this strategy is pricing proportionate to electricity/water use. It discourages excessive electricity consumption thereby reducing groundwater extraction. The pro-rata system has however been criticised in terms of enforceability, as illegal electric connections and meter tamperings abound. Nonetheless, if an institutional framework can be established within which a pro-rata system can be implemented, the benefits would be obvious. It is also noteworthy that, as indicated by current practices of diesel operators, a pro-rata tariff alone may not be sufficient to encourage the adoption of water conservation methods such as channel lining, piping, or drip irrigation. So while a pro-rata tariff will reduce water consumption, it may not result in sufficient conservation to significantly impact groundwater depletion. In addition, as recent history has shown, a pro-rata tariff on its own is not likely to be accepted by the farmer lobby.

LAND-BASED TARIFF

A system of charges based on size of land area was suggested by a respondent.[9] He felt that electricity pricing should be proportionate to land area. "Land area" may be qualified to "irrigated land area" as farmers do not irrigate all of their land.

The Samadhiala Lift Irrigation Society operates on this concept since it charges per acre of watering. While this strategy is particularly appealing for it avoids a need for metering and does not provide special subsidies to the large landowner, it is also highly problematic. The primary failure of this strategy is that it does not discourage excessive groundwater extraction. It essentially amounts to a variable flat rate because a farmer who irrigates 10 acres of land pays a fee that represents the 10 acres and not the actual amount of water used. So although there may be an incentive to irrigate less land, there is no incentive to use less water while irrigating that land. In addition, such a strategy may encourage water-selling by the small farmer who has excess water in his well. He will pay a rate proportionate to his land area, and can sell water to larger landowners who either need more water or who wish to irrigate land which they have declared as "unirrigated". While water-selling may be desirable for the small farmer, unless it can be limited it will lead to overextraction.

COMBINATION TARIFF

Neither a flat-rate strategy based on horsepower, nor a more variable flat rate based on landholding achieve the objective of groundwater conservation. A metered system is more

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[9] Badrubhai of Katrasa

likely to reduce water extraction, but presents problems in implementation and is also likely to face a strong farmer lobby. But that is not to say that the option of metering should be ignored. Perhaps a form of variable flat rate that is adjusted by metering and other conservation incentives is possible. The tariff charged to each farmer could consist of a combination expressed as the following.

$$T = A*L + B*E - D(B*E)$$

also written as

$$T = A*L + B*E(1-D)$$

where

T - tariff
A - a variable flat rate based on irrigated landholding
B - a metered rate based on kilowatt-hours of electricity consumed
D - a reduction in the metered rate based on the adoption of water conservation techniques (a discount rate)
L - land area under irrigation
E - kilowatt-hours of electricity consumed

The basic charge consists of a variable flat rate based on land area (A*L), which is augmented by a metered charge based on the amount of electricity used for extraction (B*E), and is reduced by a discount rate that is intended to encourage the adoption of water conservation techniques, such as drip irrigation, channel lining, piping.

This form of tariff is suggested as an attempt to discourage excessive water use while building in an incentive to reduce further, and aims to be a sufficiently simple calculation for implementation. Since it appears that the reintroduction of metering is unavoidable if groundwater is to be conserved through electricity pricing, the tariff must include means through which the impact of a pro-rata component can be minimised The discount component attempts to fulfil this role.

Such a tariff may be able to encourage the widespread use of practices such as drip irrigation, channel lining, piping, etc. For example, a tariff that offers a high discount rate to orchard owners with drip irrigation may provide sufficient incentive to encourage wider use and awareness of drip and other technologies The financial incentive from the discount is two-fold since the adoption of the technology not only provides a discounted rate, but also reduces water usage thereby reducing the volume charged pro-rata. A farmer who drip irrigates all of his land could increase his discount and reduce his pro-rata component to such a degree that he essentially only pays the variable flat rate based on acreage These savings would, over the course of a few years, pay for the capital expenditure on drip equipment, and could reduce his water consumption.

Within the combined tariff there lies the obvious difficulties of calculating the discount rate D, which can vary for different water conservation technologies and for different soil and crop conditions. For example, since drip irrigation is likely to be more appropriate for a coconut grove than for a groundnut field, the rate D could be designed so as to be more likely to encourage drip irrigation in orchards and perhaps channel lining in groundnut fields.

While the above equation may be only a rudimentary form of a viable tariff, it is intended to illustrate the advantages of a combined tariff and also the inherent complexities. If electricity pricing is to be used as a groundwater conservation tool, then some form of a combined tariff is necessary since pro-rata, land-based, or horsepower-based tariffs in isolation do not seem capable of meeting conservation objectives.

INSTITUTIONAL OPTIONS

Whichever strategy is adopted, its implementation will demand meticulous attention. While it is not in the scope of this paper to provide a detailed outline of institutional options for implementation, a few thoughts are briefly noted. Within Gujarat, there appear to be three organisational structures potentially capable of implementing and monitoring a strategy:

i) Gujarat Electricity Board (GEB) or other such agency
ii) Panchayats
iii) Village level organisations/NGOs

The Gujarat Electricity Board is currently responsible for keeping track of electric water extraction mechanisms so that owners can be charged the appropriate flat rate. Obviously a structure is already in place for collecting this revenue. A metered system would require the installation of meters in addition to the monitoring of meters. The land-based component of a tariff would require additional information on irrigated landholdings, and occasional visits to fields to check on the data Whether or not the GEB would be interested in the additional fieldwork is uncertain, but the prospect of increased revenues may serve as an incentive.

Alternatively, the responsibility of tariff collection or groundwater management could be placed with a more localised village level institution such as the Panchayat. Panchayat executives would need to ensure that the revenues are collected and handed over to the GEB. The GEB would need to develop relatively accurate incoming revenue estimates, so as to cross-check these with actual collections.

Within villages there are often existing organisations intended to carry out particular tasks. For example, in villages where the Aga Khan Rural Support Programme operates, village institutions have been formed to administer and implement programmes, such as the Samadhiala Lift Irrigation Society. In villages connected to the National Dairy Development Board's milk grid, both local and regional milk producer cooperatives exist. Basically, a number of local organisations are in existence in many regions, which may be able to assist in the implementation of a strategy. Perhaps some of the most vital links can be established through networking with NGOs. As mentioned earlier, aquifer level management could possibly be achieved through village organisations supported by NGOs

The institutional options mentioned can be divided into two broad categories -- exogenous or endogenous. In the former category fall all of the options that are imposed from above. All of the electricity pricing strategies and some of the water control strategies fall into this category. The endogenous options include those, such as Bromley's proposal, that seek grassroots or village level solutions to groundwater problems. As experience has shown, farmers are not likely to respond well to forced change, and certainly not to ad hoc increases in electricity tariffs. While it may be necessary for the GEB to raise tariffs in order to operate efficiently, it is not true that tariffs must be raised to conserve groundwater.

Implementation from above is likely to aggravate the farmer lobby, which was able to succeed in 1987 to introduce the present flat rate to Gujarat, and is currently agitating against a proposed 300% tariff increase. There is no reason to believe that any imposed tariff strategy will be more favourably received. Conversely, a strategy that seeks to involve farming communities through a process of education on the need for water conservation and which also seeks to involve these communities in decision-making may be more acceptable. An inclusive approach that seeks farmer opinion and involvement on possible tariff or management structures and alternatives may be more likely to succeed.

EQUITY IN GROUNDWATER USE

The objective of ensuring equity in groundwater access may be answered by posing the question: Are the proposed strategies discussed above capable of providing groundwater access to both the resource-rich and resource-poor? Under the current flat-rate tariff all farmers with electric pumps of same horsepower pay the same tariff rate regardless of their wealth. Tariffs that charge more to resource-rich farmers are intended to charge more to those who can afford more, without disadvantaging the poor. The proposed strategies, though skeletal, are more likely to make water extraction affordable for the small farmer provided that the overall tariff for the small farmer is not beyond his means.

In our survey in Maliya we interviewed many small and marginal farmers who do not have wells and depend entirely on rainfed agriculture. Many Harijan and lower caste families in these villages have no wells and claim to have a yearly income of about Rs.2000-3000 (US $ 75-100), obtained primarily from working as labourers. Many landless farmers or labourers share a well for their drinking water needs, and depend on rainfall for agriculture. Access to groundwater necessarily implies access to wells and water extraction mechanisms. Tariffs on electricity or water exclude this group of farmers, and are only capable of addressing equity issues amongst those that already have wells, and who are consequently not the poorest in the farming communities.

Another aspect of equity in Maliya taluka relates to technological dualism. Many diesel pump owners complained of well interference. As water tables declined, resource-rich farmers installed expensive submersible technology which has affected the technical efficiency of diesel pumps in the area because of the overlapping "radius of influence" of the two. Generally, owners of diesel pumpsets will face problems when more submersible pumps with

higher horsepower operate in the area. First, farmers with diesel will be subjected to a decline in their well yields, and may be forced to switch to submersible technologies, or abandon irrigation if they cannot afford to make the initial high capital cost of installing a submersible. Second, installation of submersible by all farmers would increase groundwater draft, lowering water tables and imposing financial penalties through higher pumping costs. A related but no less important aspect of the equity debate is that the state wittingly or unwittingly favours one set of farmers over others The question raised is: "Why should the state subsidise some farmers (i.e., electricity pump owners) by providing cheap energy and not other farmers (i.e., diesel pump owners) when both get the same prices for their crops?" This seems to be inherently inequitable in itself.

The marketable permit and endogenous aquifer management strategies have the potential to include those that do not have wells. From an equity perspective, it appears that a endogenously developed conservation strategies may be better suited to meeting the objective of access to all. Imposed strategies are inherently incapable of being equitable.

CONCLUSIONS

The survey in Maliya taluka of Junagadh district indicates that the structure of energy pricing does not play a role in groundwater management. However, while it may be true that altering the energy pricing strategy might change the efficiency of water use, a focus on this assumption can misdirect the search for groundwater management alternatives by restricting it to pricing possibilities only. There are two distinct issues of concern here -- the management of groundwater and the management of power -- and they need not necessarily be considered in combination. What higher electricity tariffs via flat rate, or pro-rata, or a combination of both could however do is to improve the finances of the Gujarat State Electricity Board. It may, therefore, be useful to present co-management of groundwater and power resources separately rather than together.

The possible groundwater management strategies outlined in this chapter have been presented in isolation from the larger issues of agricultural systems and population pressures. This study, like most others, has not looked at groundwater within the context of an input to agriculture. Conventional agriculture is input intensive, with high-yielding crop varieties being responsive to large quantities of fertilisers and water. Increasing population places ever increasing demands on land to improve yields. Given these conditions, it is quite possible that aquifers carefully managed by conservation-conscious farmers will be unable to meet the demands of intensive agriculture. Basic crop water requirements may far exceed sustainable supply. The question of groundwater management, then, is not simply one of conservation, but one of an entire system of agricultural practice. Consequently, a sustainable and equitable groundwater management strategy is only one component of a sustainable and equitable agricultural system.

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Depleting Groundwater and Farmers' Response: A Case Study of Villages in Kheralu Taluka of Mehsana, Gujarat

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ABSTRACT

Groundwater depletion is emerging as a major problem throughout North Gujarat. Rapidly falling water tables pose a serious threat to irrigated agriculture and drinking water supplies. As the water table dropped and investment for wells and cost of extraction correspondingly increased, farmers have formed partnerships to share the cost of wells capable of tapping deeper aquifers. Extraction is uncontrolled. Kheralu taluka, one of the overexploited talukas in Mehsana District, has shallow phreatic aquifers. There, dropping water table have resulted in reduced well yields and many wells go dry in summer. Due to water scarcity there has been a major shift in cropping patterns over the entire taluka to less water intensive crops. Over the long run continued depletion of groundwater threatens the sustainability of agriculture and the communities depending on it. Given budget limitations and the lack of available surface water resources, governmental efforts to recharge groundwater on a large scale are not likely to be forthcoming. The legislation to control extraction has had little effect. Currently, local water management by user groups is being discussed as a sustainable solution to the emerging problems.

Field studies were carried out in 6 villages of Kheralu taluka which face acute depletion problems These surveys examined: i) historical development of groundwater; ii) historical cropping patterns; iii) crop economics; and iv) the impact of energy pricing on water use and irrigation practices. This paper discusses survey results with regard to: i) the impact of the groundwater problems on agriculture in the area; ii) farmers' responses; iii) potential local intervention strategies for groundwater management; and iv) policy implications.

I. INTRODUCTION

Groundwater forms the major source of irrigation throughout most of the northern arid and semi-arid sections of Gujarat. Mehsana district of north Gujarat is one of the most

intensively cropped districts of the state. It has one of the richest groundwater basins in the state. As there are no major or medium irrigation schemes existing in the area, 96% of the total irrigated area is served by groundwater (Phadtare 1981). During the last few decades, groundwater extraction in the area has been growing exponentially.

High rates of groundwater extraction have caused rapid water table declines. The fast declines have resulted in the drying up of most open wells. The annual rate of decline in piezometric levels increased from roughly 1 m/yr circa 1970 to an average of 2-3 m/yr (in some places 5-8 m/yr) during the last few years (Govt. of Gujarat 1992, Wijdemans 1994). Continuous water level declines have forced farmers to deepen their wells in order to sustain agricultural production.

Dropping water tables have resulted in increased pumping depths and poor well yields In many areas, the shallow phreatic aquifer has become dry and deeper aquifers are now being mined As a result the cost of pumping per unit volume of extraction has increased enormously. This is evident from the fact that groundwater pumping accounts for nearly 30 % of the State's electricity production (Moench 1992) Drilling tubewells to tap the deep aquifers requires investment levels beyond the capacity of poor farmers This combined with increasing recurring costs for well maintenance and energy have made agriculture less viable. Over the long run, continued groundwater mining threatens the sustainability of agriculture in the region and the communities which depend on it.

Attempts have been made to recharge groundwater artificially. The Gujarat Water Resources Development Corporation has undertaken artificial recharge experiments with the assistance of the United Nations Development Programme in Mehsana over the last two decades. Large scale projects could not take off however due to the lack of an obvious source of water to recharge and shortage of funds. In addition to recharge, efforts have also been made to control extraction. The Gujarat government passed a groundwater legislation to regulate groundwater development in the state in 1976. But the legislation was never enforced because of large social and political implications Wells are many and privately owned, making legal regulation of them difficult. Currently, local water management by user-groups is increasingly being debated as an avenue toward sustainable solutions to groundwater overdevelopment problems.

II. KHERALU TALUKA

Kheralu taluka in Mehsana district provides a good case example of the problems commonly faced by several talukas throughout much of northern Gujarat. Most groundwater development in the taluka is dependent on shallow phreatic aquifers and farmers have been greatly affected by dropping water tables. As a result, it was selected as a site for detailed research on groundwater problems and potential management options.

General Features of the Taluka

Kheralu taluka is located in the northern part of Mehsana district. The taluka has a geographical area of 952.3 sq.km. and contains 169 villages. The total population is roughly 24,600,000 (Census of India 1981). The taluka has widely varying topography.

Climate, Geohydrology and Groundwater Development Status

Out of Kheralu taluka's total geographical area of 952.3 sq km, 818.52 sq km have sandy soils underlain by alluvium and are suitable for groundwater exploitation. The remaining 134 68 sq km are underlain by hard rocks and have relatively poor aquifers. The taluka falls in the semi-arid climatic zone. Average annual rainfall (1955-1990) is 636 23 mm with a maximum of 1274 6mm in 1977 and a minimum of 199.2 mm in 1987 (GWRDC data)

Groundwater in Kheralu taluka occurs in alluvial and hard rock aquifers. Near the Aravali hills, a range of hard rock hills bordering Rajasthan in the north of the taluka, shallow unconfined aquifers dominate. Here a thin alluvial aquifer overlies hard rock. Thickness of the alluvial aquifer increases from 24 0 m at Dabhoda in the noth-east to over 50 m in the south-west of the taluka. Beyond the taluka boundaries, the alluvial wedge thickens to great depths under the central part of Mehsana district (GWRDC data). Groundwater flow generally proceeds north-east to south-west with the hilly tracts and coarse alluvial sediments at their base forming the recharge area for the entire Mehsana aquifer system (Phadtare 1981).

Recent resource estimates show that groundwater in Kheralu taluka is over-exploited While the average annual recharge is approximately 106 63 MCM extraction is 273.69 MCM (Govt of Gujarat 1992).

III. GEOGRAPHICAL COVERAGE AND GENERAL FEATURES OF THE STUDY AREA

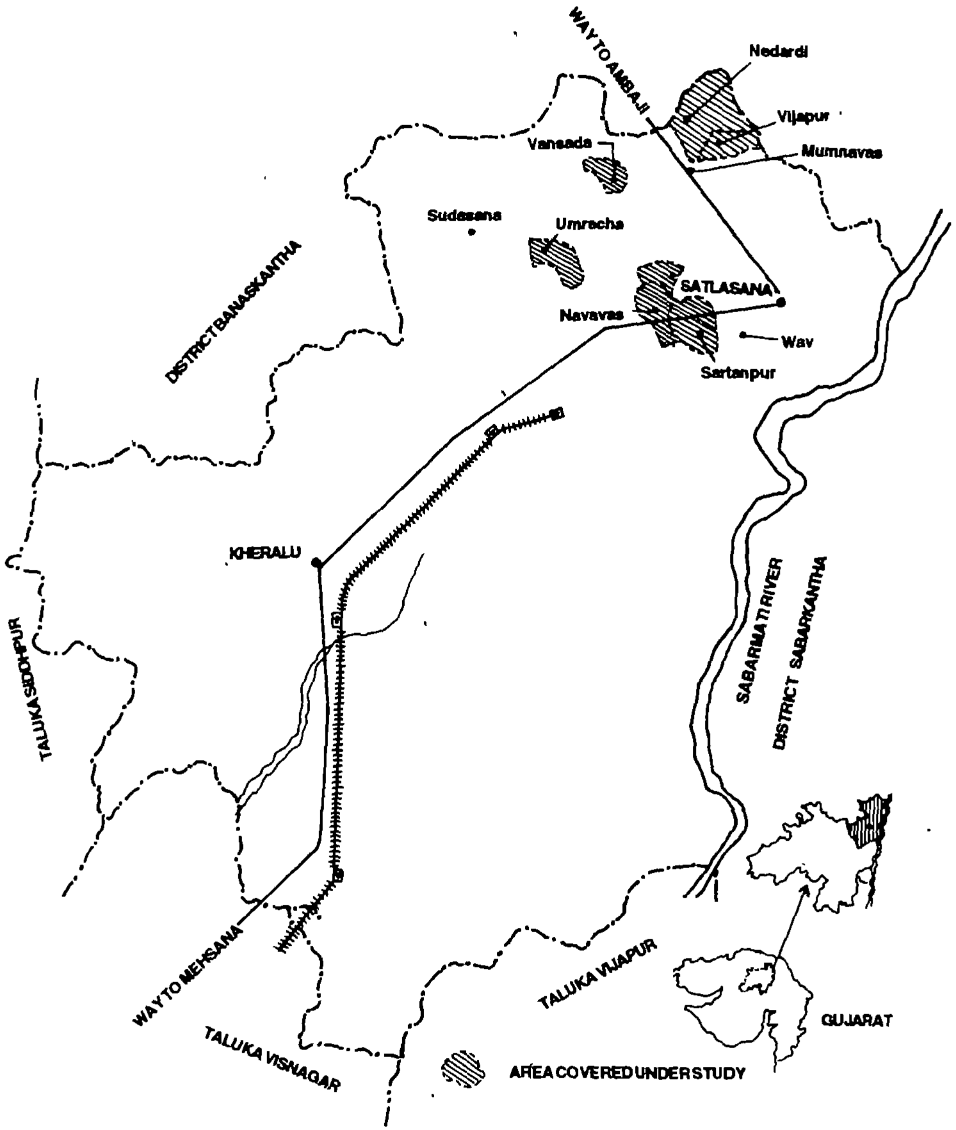
Six villages, namely Nendardi, Sartanpur, Umrecha, Vansada, Vajapur and Navavas, were covered under this study. These villages are located in the foothills of Aravalli ranges in the northern part of Kheralu taluka. All six have heterogeneous communities The geographical area and population of dominant communities of the villages are given in Table 1. Figure 1 shows the index map of the study area.

Table 1. Village Characteristics

Village	Geographical Area (hectare)	Population (1981 Census)
Nedardi	626.68	597
Navavas	203.75	829
Sartanpur	227.54	1071
Umrecha	306.02	677
Vajapur	177.80	803
Vansada	135 05	324

Fig-1

INDEX MAP OF STUDY AREA IN KHERALU TALUKA (MEHSANA)



The main sources of income in the villages are agriculture and animal husbandry Irrigation is from groundwater and depends on the shallow phreatic aquifer Pumping is mostly through open dug wells. In some cases, however, shafts have been drilled within existing dug wells. All wells are energised with either electric motors or diesel engines.

Crops are grown in all the three crop seasons. The main crops are castor, gawar and groundnut in kharif; wheat and mustard in rabi and bajara in summer Additional crops include 'kuri' and 'bunti' (local grain varieties) and fodder grown mostly in kharif.

IV. DATA

Studies were carried out on. i) groundwater development; ii) historical cropping pattern, iii) impact of energy pricing on water use, iv) irrigation practices; and v) crop economics.

Data on historical cropping patterns and wells were collected from the Village Panchayats. Additional data on pre- and post-monsoon water levels were obtained from the Gujarat Water Resources Development Corporation Data on: i) well details (type of well, depth, extraction mechanism, pump horse power, yield hours, etc), ii) irrigation water use (crops grown in different seasons, area cropped, number of irrigations for each crop and hours of irrigation per watering); and iii) crop economics were collected from individual farmers and well owners through direct interviews.

Historical Development of Groundwater and Changing Groundwater Scenario

Until recently, groundwater in the village was developed through open dug wells ranging from 25 to 50 feet deep. As late as the end of the 60's farmers in the area were using traditional water lifting mechanisms to extract groundwater Crude oil and diesel engines were introduced in the early 70's and diesel engines became very common by the mid 70's. By the early 70's, some farmers were using electrical pumps and the 80's saw the extension of the electricity distribution network and with it the common adoption of electrical pumpsets. The introduction of energised pumping techniques enabled increased exploitation of groundwater and resulted in water table declines *Additional extraction of groundwater during* the drought period (1985-87) caused particularly large drops in water table in the area. Many farmers deepened their wells. In Sartanpur village, there are 108 wells for irrigation only. Out of these 31 have been deepened at least once during the last 10 years, mostly during drought. In hard rock areas farmers drill vertical and horizontal bores at the well bottom to tap water. There are 34 wells in the village with vertical bores of which 14 have been deepened at least once

In order to understand the general trend of groundwater in the area over a period of time, data on water levels monitored in 3 stations in the area (Sudasna, Wav and Mumanvas) were collected and analysed. Graphical representation of the variation of reduced water levels (for the Month of May) at these 3 stations are shown in Figures 2, 3 and 4. These figures indicate an overall decline in water levels with sharp declines during drought.

Fig-2

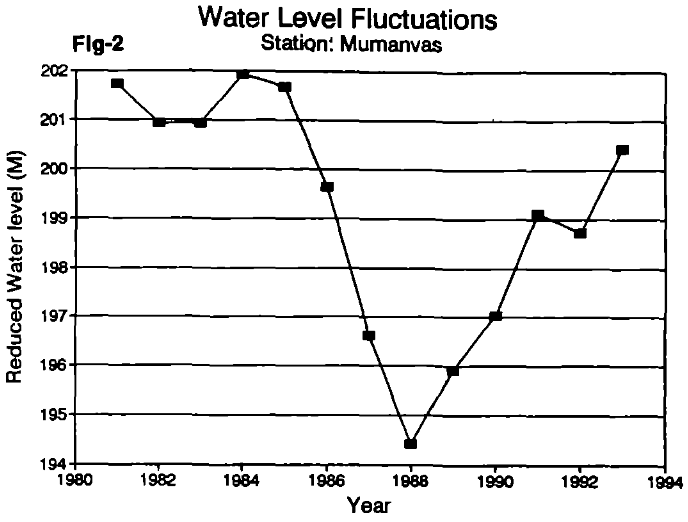


Fig-3

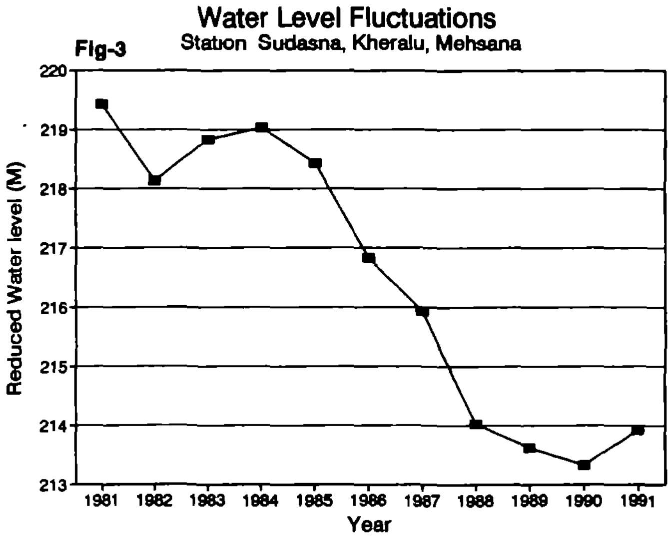
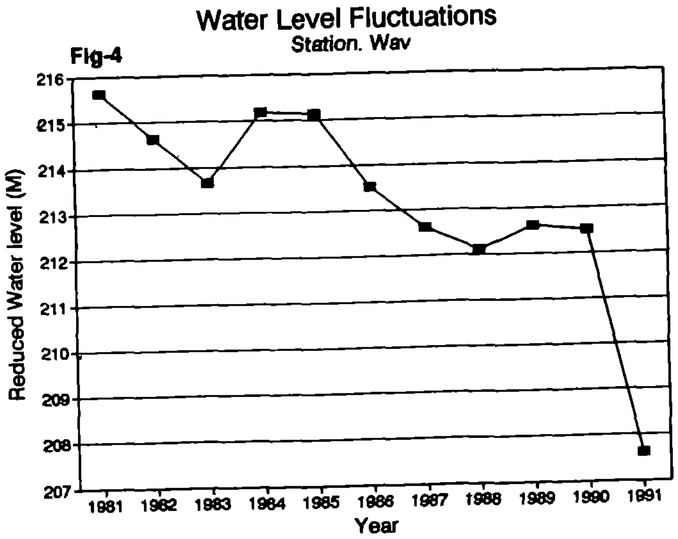


Fig-4



Crop History

Thirty to forty years ago when groundwater was initially developed, the study area had very high water tables. Initially, wells were used to irrigate rice and sugarcane. Over a period of time, as extraction both in the study region and other areas increased, water levels started falling. Farmers had to abandon rice and sugarcane and switch over to coarser crops such as 'kuri' and 'bunti', groundnut and maize. These crops were completely rainfed. Farmers also grew bajara during the monsoon. Although groundwater was available in abundance, extraction was limited as water had to be lifted mechanically using traditional water lifting devices. The number of wells was also limited. The advent of crude oil and diesel engines and subsequently electric motors facilitated increased access to groundwater and farmers started taking winter and summer crops in addition to traditional monsoon crops. Wheat became the major winter crop while bajara and groundnut were grown in summer. The irrigated area also increased. With the water levels continuously dropping the yield of wells declined sharply. In the early eighties farmers started experimenting with less water intensive oil seed crops such as castor and mustard. These command good market prices as well as require less water. As a result, the area under them has expanded continuously. Every year more and more area under groundnut and wheat is being replaced by castor and mustard.

Crop Economics

The economics of five major crops grown in the villages (wheat, mustard, groundnut, bajara and castor) was studied For this data on area cropped, area irrigated, number of irrigations, irrigation hours, inputs (labour charges, fertiliser and fuel) and yield were collected and analysed. Considering only variable costs, crop economics is worked out in the following manner:

Net profit = Amount of money fetched from sale of crop output - Labour charges - Fertiliser charges - Energy cost

Diesel energy cost (ECD) = No. of irrigations for the crop (NI) * No of hours of irrigation per watering (NIH)) * Hourly fuel consumption.

For electric wells since the electricity charges are on a flat rate basis the following formula is used to allocate the total annual electricity charges among all the crops grown in the well command

Let us say crops A1,A2 ... An are grown during the year in 3 seasons.

For crop A1, the percentage energy cost =

$$(NIA1 * NIHA1 / \sum_{i=1}^{n} NIA_i * NIHA_i) * 100$$

where i= 1,2,3 ... .. n.

The cost of pumping for different crops is worked out for all the sample wells.
The results are presented Table 2. for i) average yield/acre and ii) average profit/acre for diesel and electric wells for all these crops.

Table 2.

Name of Crop	Yield/Acre in Kg. Diesel	Yield/Acre in Kg. Electric	Profit/Acre in Rs. Diesel	Profit/Acre in Rs. Electric
Groundnut	568.0	535.0	3809	3707
Castor	903.0	845.0	4848	4220
Wheat	1231.0	1150.0	1445	2121
Mustard	503.0	536.0	2243	2998
Bajara	768.0	754.0	-294	598

The data presented in the Table indicate that for all the crops studied, except mustard, the average yield per acre is higher for diesel as compared to electric wells. The average profit per acre is higher in favour of electric wells for wheat, bajara and mustard For groundnut and castor the profit per acre is higher in favour of diesel wells. Though the average profit per acre from bajara appears negative for diesel wells, the fodder value of crop residues which has not

been included in calculating the economics forms a major reason farmers give for growing the crop. The fodder produced is nearly 1000 kg/acre and is worth roughly Rs. 1000.

Energy Cost and Water Use

In order to examine the impact of energy pricing on water use, a comparative study of water use by farmers owning diesel and electric wells was made. For this, data on the number of waterings given to different crops were collected for a sample of diesel and electric wells. The sample wells were selected to control for depth, yield, soil type and other conditions. Care was also taken to see that all the sample wells have the crop under their command for which comparison was done.

The percentage energy cost with respect to total input cost for different crops was worked out for all the diesel and electric wells and averages were compared. Although cost per hour of pumping is the correct yardstick for comparing energy costs, the electricity charges in Gujarat are assessed annually based on pump horsepower and do not depend on the actual amount of pumping. Hence percentage energy cost with respect to total input cost is used for the purpose of comparing energy costs.

The average number of irrigations for different crops by diesel and electric wells are given in Table 3 Its graphical representation is given in Fig 5

Table 3. Average No. of Irrigations

	Castor	Wheat	Mustard	Bajara	Groundnut
Diesel	8.25	10.67	5.91	11.00	1.63
Electric	7.87	9.30	4.50	9.16	2.25

Comparisons of percentage energy cost and hours of watering/acre for different crops between diesel and electric wells are shown in Tables 4 & 5 respectively.

Table 4. Energy Cost (as percentage of Total Input Cost)

	Castor	Wheat	Mustard	Bajara	Groundnut
Diesel	26.01	35.55	23.80	48.07	13.98
Electric	12.35	17.83	13.63	23.92	6.51

Table 5. Hours of Watering/Acre

	Castor	Wheat	Mustard	Bajara	Groundnut
Diesel	69.75	139.0	39.8	114.5	8.8
Electric	70.80	115.5	36.6	88.5	18.3

The data in Table 3 indicates that for all the crops studied, except groundnut, the average number of irrigations under diesel wells is higher than for electric wells even though the energy cost is much higher in the case of diesel wells (see Table 4)

The following facts could have contributed to the difference:

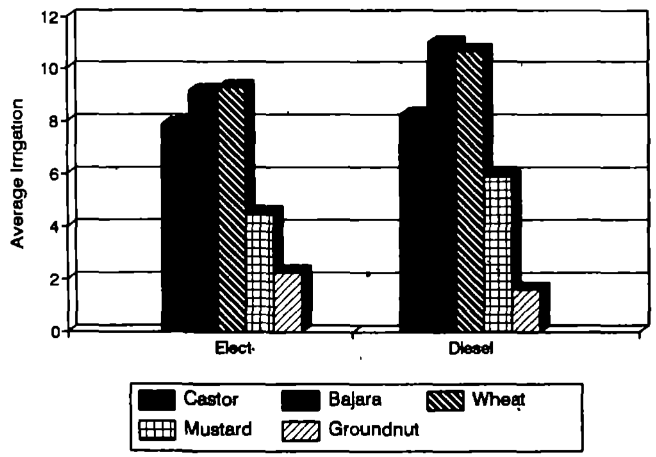
(a) In the case of diesel wells there is absolute control over the use of water. Farmers are able to irrigate when and where it is needed and hence have higher assurance that they will achieve increased yields. This is supported by the figures given in Table 2 which show that for all the crops except mustard the yield per acre is more from lands irrigated by diesel wells than by electric wells.

(b) Comparatively higher availability of water in a few cases of diesel wells. (Though the sample wells were supposed to have more or less the same yield, it was quite difficult to get ideal samples). This argument gets strengthened by the farmers' view that the number of waterings is largely determined by water availability.

Irrigations for Different Crops

for diesel & electric wells

Fig-5



In the case of groundnut, a monsoon crop, diesel well owners give fewer irrigations on average than electric well-owners and the hours of water per irrigation are much higher with electrical wells. The reason for this could be that farmers with diesel wells take maximum advantage of rainfall to minimise diesel expenses. Since there is very little non-monsoon rainfall, this approach is not possible with the other non-monsoon crops.

The hours of watering per unit area are higher in favour of electric wells for mustard, castor and groundnut (see Table 5) and lower for wheat and bajara. However the difference is not statistically significant. Hence there is no evidence that on an average the total irrigation water deliveries differ significantly with type of extraction.

Irrigation Practices

(a) Conveyance

Field observations indicate that irrigation practices largely depend on field conditions and land ownership levels. In large fields farmers use concrete pipelines. This not only helps reduce seepage losses but significantly reduces pumping time. In undulating lands farmers use rubber pipes to deliver water to upper fields.

(b) Field Application of Water

In all the villages surveyed, most farmers use small border irrigation. In this system, the field is divided into small blocks of roughly 10 x 10 feet using soil bunds with separate inlets. Water is allowed to flow into individual blocks until ponding occurs. Once a block is ponded, the inlet is closed. In cases where the soil is very loose and sandy, blocks tend to be larger. This method of irrigation helps farmers to obtain uniform water application throughout the field. Although this system is more efficient than flooding, the problem of over-irrigation is also inherent in this method.

Results and Discussion

The overall findings of the study are as follows:

(a) The availability of water has a strong impact on water use. Many farmers minimise the number of irrigations at the cost of crop yield because enough water is not available.

b) Two main factors influence crop selection by farmers· crop water requirements and profit. Farmers prefer to grow crops which require less water and give higher profit. However, bajara and wheat, though less profitable, are grown by farmers to meet domestic requirements. In addition, the fodder from bajara is quite significant for livestock.

(c) Energy pricing is not found to have any impact on water use. It is the degree of assurance of yield and comparative availability of water which determine levels of irrigation. As water is scarce, higher levels of irrigation ensure higher crop yields. Higher yields, in

turn, compensate for increased energy costs. In cases where uncertainty exists over the availability of water and thus crop yield (groundnut in kharif), farmers with diesel wells use water more cautiously because of the high energy cost.

(d) The reasons farmers give for investing in water conservation technologies such as plastic and concrete pipelines are easy conveyance and reduced pumping time.

VII. POTENTIAL POINTS OF LEVERAGE FOR MANAGEMENT

Supply Side Interventions

The area is covered by shallow alluvial layers overlaying hard rock. It falls in the main recharge area of Mehsana aquifer system. The shallow phreatic aquifer with moderately high permeability offers good potential for artificial recharge efforts. As the specific yield of aquifer is low, small rise in recharge would be reflected in terms of larger increase in groundwater levels. Also, the area is drained by a large number of ephemeral streams which form micro-watersheds and constitute the catchment of Sabarmati river. If these micro-watersheds are treated, the captured water could recharge the groundwater in the area. This will result in reduced peak flows (flood flows) in the Sabarmati river which otherwise would run waste into the ocean.

End-Use Interventions

While opportunities for supply side intervention are very limited due to lack of water sources there are a variety of things which could be done to reduce use and bring down extraction. These include:

a) Crop Selection

From the analysis of cropping patterns it was found that farmers in the area are widely growing less water intensive oilseed crops such as castor and mustard. At the same time water intensive crops such as wheat and bajara are also grown by every farmer to meet their food and fodder requirements though they are not very profitable. Farmers need to be encouraged to shift completely to oil seeds. Creating alternative sources for fodder could change farmers' priorities for choosing crops.

Shift from agriculture to horticulture would be a viable alternative to reduce the demand drastically. However horticultural crops take 3 to 4 years to yield. Hence only farmers with moderate to large landholdings could be expected to be the target groups for this.

b) Improving Conveyance and Irrigation Efficiency

Most of the farmers in the area, especially small and marginal farmers, are using open channels for conveyance of water in their fields. This causes a lot of seepage and evaporation losses. These losses are very high as the soils are mostly loose and sandy and climate is semi-arid. Also the large thickness of soil zone literally permits no seeping water to percolate and reach the groundwater table. Hence the net amount of water which could be saved by preventing seepage and evaporation losses through the use of water conservation technologies would be substantial.

The use of drip systems could save substantial amount of water which is lost in evaporation, seepage and infiltration. However the introduction of this technology calls for large investments. Also farmers need to shift to horticultural crops to use such systems effectively.

Policy Implications

Some of the above suggested alternatives to address the problems would mean changes in the present government policies. On the end-use side crop changes could be affected through the use of market mechanisms such as providing market support for low water intensive crops and denial of the same for high water intensive crops.

Small and marginal farmers cannot afford the use of water conservation technologies due to heavy initial investments required. Hence there need to be large incentives for them to adopt such technologies. The National Bank for Agriculture & Rural Development (NABARD) has been using control of credit flows as a leverage to control groundwater extraction. Subsidised credits for the purchase of efficient water application systems is one of the incentives. This could be tried out in situations similar to that of the area under study where credit flows for well development are already stopped.

VIII. CONCLUSIONS

Studies indicate that the area has suffered long term depletion of groundwater. In addition to that there has also been short term sharp declines in the water table in the area during droughts. The local response to long term depletion was in the form of shifts in cropping patterns and the use of energised mechanisms for extraction of groundwater. The responses to short term depletion include widespread investment for deepening and construction of new wells. Farmers investing large sums for deepening of wells is a common phenomenon in the area. Also the farmers were found to be selecting the crops judiciously and using water very carefully.

The supply side interventions like local recharge activities, and end use changes like the use of efficient water use technologies, are potential leverages for the management of groundwater in the area..However in order to evolve effective local management strategies detailed research studies should be carried out. Such studies should quantify: i) the amount of water that could be recharged through local recharge efforts under the existing physical conditions and the cost ;ii) the wastage in current use practices and iii) the actual savings in water which could be achieved through efficient water use practices.

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Electricity Prices and Sustainable Use of Groundwater: Evaluation of Some Alternatives for North-west Indian Agriculture

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ABSTRACT

The north-west rice growing region in India has drawn heavily on its natural resources - mainly groundwater - to achieve the current level of agricultural production and to earn the distinction of being called the "granary" of the country. It is widely believed that availability of electricity for irrigation pumping at highly subsidised rates charged on an annual fee basis has in large part been responsible for encouraging a pattern of agricultural development in the region which, as the rapidly falling water tables now suggest, cannot be sustained in the long run. The paper therefore attempts to analyse the efficacy of electricity pricing and tariff structure as possible management tools to influence groundwater withdrawal decisions of the farmers and to promote sustainable use of groundwater.

Recognising that resource depletion can often be a slow process and that the impact of changes in policy environment on resource use may not be discernible immediately or in the short run, the paper envisages a 20-year time frame for quantifying the extent of resource depletion and valuing its cost under alternative electricity pricing regimes. The estimated resource cost is accounted for in the Natural Resource Accounting (NRA) framework to work out quantitative measures of sustainability.

The results obtained clearly indicate that it is nearly impossible to achieve the desired objective of sustainable use of groundwater by continuing with the current tariff structure based on charging for electricity on a flat rate (FR) basis. The results obtained also signify that a necessary precondition to achieve the desired objective is that the electricity be charged either on the basis of unit price (UP) of electricity or on the basis of some combination of FR and UP. In other words the basic consideration in fixing tariff structure should be that farmers must face, even if partially, the unit price of electricity.

INTRODUCTION

Groundwater resources in large parts of Punjab and Haryana are showing clear signs of overdevelopment. Of the 118 development blocks in Punjab and 108 in Haryana, about 56% in Punjab and 29% in Haryana have been classified as "dark". [10] Another 16% of the

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[10] According to the prevailing norms an area is classified as "dark" when its annual draft of groundwater exceeds 85 percent of its annual recharge; it is "grey" when the ratio of draft to recharge is between 65 and 85 percent; and "white" when this ratio is less than 65 percent

blocks in Punjab and 15% in Haryana have been classified as "grey" (Table 1). The water table in large parts of the region is falling rapidly. Leading agricultural scientists and planners in the region have expressed grave concern over the dwindling groundwater balance and the impending threat it is posing to the sustainability of agricultural production in the foodbasket of India (Prihar et al. 1990, Randhawa 1989, Johl 1986).

Overdevelopment of groundwater resources in this semi-arid region of north-west India with an annual average rainfall of about 600 mm has largely been the consequence of intensive cultivation of available agricultural land, large scale diversions in cropping pattern towards cultivation of water intensive rice-wheat cropping system, and installation of a large number of private tubewells. In Punjab and Haryana, the number of tubewells increased four-fold during the two decade period from 1970-71 to 1990-91, both in terms of absolute number as well as in relation to net sown area (Table 3). In addition, the area under rice and wheat as a proportion of gross cropped area in Punjab has increased from about 47% in 1970-71 to more than 70% in 1990-91 while in Haryana the corresponding increase in the proportionate area under rice and wheat has been from 28 to 60% (Table 2). Rice, which occupied only 659 thousand hectares in 1970-71 in the region, now occupies more than 2700 thousand hectares A finer classification of the distribution of "dark" and "grey" blocks suggests that the proportion of "dark" and "grey" blocks is much higher in those districts where rice is a major crop as compared to those districts where rice is not grown on such a widespread scale (Table 1). Thus, while 89% of the blocks are classified as either "dark" or "grey" in rice growing districts, only 29% of the blocks fall in this category in the districts where rice is not a major crop

Overdevelopment of groundwater resources as a consequence of large scale shifts in cropping pattern towards rice-wheat and enormous growth in the number of private tubewells can in large part be attributed to the development policies of the government. The large scale shifts in cropped area towards rice-wheat cropping system have predominately been a consequence of increases in relative profitability as compared to alternative cropping systems. The change in relative profitability has come about due to a combination of technological breakthroughs and intervention of the State in input and output pricing and in market support. Interventions in output prices have primarily been in the form of adjustments in the parity between procurement prices of alternative crops, while interventions in input prices have involved subsidies for electricity, fertilisers and farm credit. The impressive increase in the tubewell numbers has been helped both by massive power subsidies and by the provision of concessional institutional credit for installation of tubewells.

Development policies so pursued were dictated by the then prevailing foodgrain shortages and also to meet the expected increase in demand for foodgrain production to feed the ever increasing population. In the endeavour to increase food production, policies ignored potential effects on natural resources and the environment. The consequences of neglecting these effects are now being felt in the form of yield plateaus for some crops and constraints on further development of common property resources such as groundwater in highly productive areas of the region. As a result the efficacy of pursuing such development policies to meet future demands for agricultural commodities is doubtful.

The inability of the current development policies to support a sustainable pattern of agricultural development can, in large part, be attributed to the norms we adopt in measuring the impact of development policies The current measures of the impact of development policies generally evaluate the success of these policies in terms of such indicators as additional agricultural output accomplished, increase in farm profitability, additional employment generated, etc. These measures do not take into consideration "external effects" on natural resources. In addition, economic and environmental effects are often viewed as separate. Natural resources are therefore not valued as any other man-made asset with the result that their loss entails no debit charge against current income that would account for the decrease in potential future production from use of these resources Underlying this anomaly is the implicit and inappropriate assumption that natural resources are so abundant that they have no marginal value This is however a misunderstanding -- whether or not natural resources enter the market place they do make important contributions to long term economic productivity and so are strictly speaking economic assets It is therefore absolutely essential that the costs and benefits of using natural resources are properly accounted for A clear distinction must be made between true income generated and that derived from drawing down capital assets by resource degradation (Faeth 1993, Malik and Faeth 1993, Malik 1993a, Faeth et al 1991, Repetto et al. 1989) The consequences of development policies for natural resources and the environment are therefore absolutely essential to consider if "sustainable" patterns of development -- those which meet the needs of today's population without compromising future generations -- are to be achieved (WCED 1987)

While the problem has been well recognised in the literature, little effort has been made to translate and give due weightage to sustainability concerns in policy formulation One important obstacle to planning for sustainable development has been the problem of quantifying the long term effects of development policies on the use of natural resources and incorporating these effects in an economic analytical framework Natural Resource Accounting (NRA) methods provide a relatively simple framework of analysis to account for the depleting natural resources Through quantifying the cost of depleting natural resources within traditional economic analysis frameworks, it is possible to arrive at a quantitative measure of sustainability (Repetto et al. 1989, Ahmad et al 1989)

Using a natural resource accounting framework the present paper demonstrates how the long term effects of depleting natural resources can be quantified and accounted for to work out more meaningful measures of farm profitability The paper compares two alternative farming systems: rice-wheat and maize-wheat. The former has large water requirements (about 2200 mm for rice and 480 mm for wheat) which results in overdevelopment of groundwater resources and water table declines. It thereby poses a threat to the sustainability of agricultural production in the region while the latter, due to relatively small water requirement (320mm for maize and 480mm for wheat), does not cause any significant decline in water table.

Recognising that electricity prices serve as a proxy for the price of irrigation from groundwater sources and that current electricity pricing policies have been an important

contributory determinant in augmenting the relative profitability of rice-wheat and thereby in promoting and encouraging an inefficient and unsustainable use of groundwater, this paper attempts to explore the efficacy of alternative electricity pricing and tariff structures as possible public policy instruments to promote more sustainable patterns of groundwater usage. Specifically, the paper attempts to analyse the implications of different possible modifications in electricity pricing and tariff structures for irrigation pumping on the sustainability of groundwater usage Alternatives evaluated include:

(i) Increasing the price of electricity charged from the farmers without any change in the prevailing tariff structure based on charging for electricity on a flat rate (FR) basis;
(ii) Shifting to a tariff structure based on unit pricing (UP) of electricity; and
(iii) Shifting to a tariff structure based on some combination of flat rate and unit pricing (FRUP) of electricity.

Appreciating that resource depletion can often be a slow process and that the impact of changes in the policy environment on resource use may not be perceived in the short run, it follows that any purposeful analysis must explicitly take time dimensions into consideration The study therefore envisages a twenty-year time frame for quantifying the magnitude of resource depletion and valuing its cost. Furthermore, since farm size greatly influences the amount of water required and therefore economics of groundwater extraction, estimates in the present study have been derived for a representative 2-hectare farm.

THE DATA

The study is based on primary data collected from a sample of 120 farming households from the rice growing districts of Karnal and Kurukshetra in Haryana. Households were selected according to a well defined statistical sampling scheme (for details see Malik 1993b). The information collected relates to the year 1991-92.

ESTIMATING THE RESOURCE COST OF GROUNDWATER

The resource cost of groundwater has been estimated as the likely increase in farmer's cost of pumping irrigation water consequent upon decline in water table during the time frame of the present study. The estimation of resource cost of groundwater thus requires information on (i) the current and likely future rates of decline in water table and (ii) the changes in capital and operating costs of pumping equipment as a result of decline in water table

The average prevailing depth to water table in the study region works out to 15 metres below the ground surface. Conservative estimates for the rate of decline in the water table imply that throughout the region it is falling by approximately 1 metre per year (for fuller details on methodology, assumptions and data used for estimation of these parameters, see Malik 1994).

On the basis of available data it is difficult to estimate the likely rate of decline in water table in future years. Much will depend on changes that take place in agriculture· the number of additional tubewells installed; changes in the relative prices of inputs and outputs; institutional changes and the private profitability of extracting groundwater as depth to water table increases. So long as the marginal revenue from pumping an additional unit of water is more than the cost of its extraction, farmers are likely to continue extracting groundwater regardless of depth. As the water table falls, farmers are likely to respond by installing higher capacity pumps while continuing to extract the same quantity of groundwater. It is thus fair to assume that unless radical changes take place in agriculture watertables in the region will continue to fall at rates of at least 1 metre per year throughout the time frame of the present study. Thus, if one starts with a water table of 15 metres, the water table in year 20 is likely to decline to 35 metres.

The most important economic implication of water table declines, from the farmer's point of view, is an increase in the capital and operating costs of pumping. Under actual farming conditions it has been observed that farmers do not have to change their pumping equipment with every decline in water table At a given level they generally invest in a somewhat higher capacity pumping equipment than is warranted for their immediate needs so that they do not have to change equipment with every minor variation in water table [11] In this way, farmers continue to use the same equipment over a range of water table depths without having to incur significant additional capital and operating costs

On the basis of data collected from sample households we estimate that the farmers generally do not change their equipment for water table declines of up to five metres However with every five metre decline, they need to install higher capacity pumping equipment and consequently incur higher capital and operating costs. We present, in Table 4, the estimated capital and annual operating costs of pumping equipment for each five metre drop in the water table over the 20-year time frame of the present study.

RESOURCE COST OF GROUNDWATER

The per hectare resource cost of groundwater using three alternative values for discount rate works out to Rs.28079, Rs 22643, and Rs 18431 with a discount rate of 6%, 8%, and 10% respectively (Table 5)

RELATIVE ECONOMICS OF THE ALTERNATIVE FARMING SYSTEMS

The relative economics of alternative farming systems rice-wheat and maize-wheat have been evaluated by incorporating the estimated resource cost of groundwater in the NRA framework The Net Financial Value (NFV) for a given farming system has been calculated as the difference in the farm returns using the traditional concept of farm profitability, i e., returns

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[11] Another factor that contributes to decision about such a choice is the tendency on the part of the farmer to extract larger quantities of water in the shortest time because of uncertainty about/restrictions on the availability of electricity

over operating costs plus the resource cost of groundwater The estimated values of the farm returns, resource cost of groundwater and the net financial values for the two farming systems for the 20 year simulation period using three alternative values of the discount rates are given in Table 6.

Results obtained clearly bring out the implications of including and excluding the resource cost in making a financial comparison. Thus if one were to compare the economics of the alternative farming systems based on a simple comparison of farm returns (returns over operating costs), returns from cultivation of rice-wheat are 54% greater than those from maize-wheat. If one were however to take a more pragmatic view of farm profitability and take into account the cost of depleting natural resources as well, though cultivation of rice-wheat still continues to be more profitable, the difference in the margin of returns between the two farming systems declines to between 27% and 30% depending on the choice of discount rate

PLANNING FOR A SUSTAINABLE PATTERN OF AGRICULTURAL DEVELOPMENT

The analysis presented above demonstrates that even after accounting for the costs associated with groundwater depletion, cultivation of rice-wheat remains more profitable than maize-wheat. However due to fast depleting groundwater, any large scale cultivation of rice-wheat cropping system is clearly unsustainable in the long run. Planning for a sustainable pattern of agricultural development requires efforts directed at arresting or at least slowing down the rate of decline in the water table

The two most important avenues for reducing groundwater usage involve: (i) adoption of more efficient irrigation management practices for rice-wheat and/or (ii) diversion of at least a part of the area from rice to an alternative less water intensive crop. While some scope for conserving irrigation water through the adoption of efficient irrigation management practices does exist, the savings are not likely to be large enough to significantly alter the rate of decline in water tables. Any significant savings in water use can thus come about only through diversions in the cropping pattern away from rice Large scale diversions can be brought about primarily through altering the profitability of alternative crops. The most important policy instruments available to planners for this are those affecting prices of inputs and/or outputs

As discussed earlier, large scale cultivation of water intensive crops such as rice, and exploitation of groundwater on massive scales in the study region have, in large part, been facilitated by the availability of electricity for irrigation pumping at highly subsidised rates While the prices of various inputs and outputs have varied substantially over the last few years, the price per kwh of electricity for irrigation pumping charged from the farmers has either remained constant or changed only marginally Thus while the revenue realised per kwh of electricity sold by the State Electricity Board (SEB) to the agricultural/irrigation sector increased from Rs.0.19 to Rs.0 25 between 1985-86 and 1991-92, the real cost of supplying electricity to the agricultural sector during the same period increased from Rs 0 70 to Rs 1.23 per kwh (Govt. of India 1992,1986). The continually widening gap between the social and market prices of electricity has resulted in mounting losses for the SEB and increased the subsidy burden at an alarming rate It has also encouraged inefficient use of energy and groundwater. Enough justification thus exists for increasing the tariff on electricity for irrigation pumping. Such a measure will both promote efficient use of resources and facilitate the SEB to improve electricity supplies while overcoming huge annual deficits. The extent to which increases in the price of electricity and/or changes in tariff structure can reduce groundwater extraction and help slow down the rate of decline in water tables is unclear. This will depend primarily on the magnitude of shifts in crop pattern away from rice that such a measure can bring about. So long as cultivation of rice is more profitable than cultivation of alternative crops, increases in electricity price are unlikely to cause significant changes in cropping pattern and groundwater withdrawals

In the following paragraphs we attempt to estimate the likely magnitude of increases in electricity prices and/or adjustments in tariff structures required to make wheat-maize farming systems competitive with rice-wheat on the margin

IMPACT OF CHANGES IN THE PRICE AND/OR TARIFF STRUCTURE OF ELECTRICITY

Farmers in the study region currently have a choice of an electricity tariff structure for irrigation pumping based either on flat rate (FR) or unit pricing (UP) In practice, more than 95% of the farmers have opted for FR Under FR the farmers are charged an annual fixed sum of money depending on the horsepower of the motor installed. The charges do not vary depending on supply restrictions, the number of hours during which the electric motor is put to use, or the amount of groundwater that is withdrawn The FR charges also do not vary progressively with the size of the motor used

Apart from the electricity tariff structures for irrigation pumping based either on FR or UP, it is possible to formulate a very large number of alternative tariff structures based on combinations of FR and UP. The power pricing structure need not be fixed once and for all. It should in fact be dynamic in nature and be able to effectively address the changes in economic and social objectives Thus in areas where severe overdevelopment of groundwater has taken place, the tariff structure must focus primarily on promoting sustainable use of this natural resource. In the following paragraphs we therefore attempt to identify and evaluate the efficacy of the existing and some of the feasible alternative power tariff structures for promoting a sustainable use of groundwater.

IMPACT OF INCREASING THE PRICE OF ELECTRICITY: FR TARIFF STRUCTURE

The system of FR electricity pricing for irrigation pumping was introduced mainly to overcome the problems relating to electricity thefts, the huge cost of collecting electricity dues and problems related to metering Whatever the merits of such a tariff structure, the prevalent

FR of Rs 29/BHP/month[12] is considered to be very low in comparison to the cost of electricity generation and supply. It is also widely believed to have been largely responsible for overdevelopment of groundwater in the region and its inefficient use.

To estimate the magnitude of changes in electricity price required to make rice-wheat and maize-wheat farming systems competitive under the current FR tariff structure, we increased the price of electricity from the current level of Rs.29/BHP/month in stages of Rs.10/BHP/month. The results obtained (Table 7) indicate that the two cropping systems, rice-wheat and maize-wheat, become financially competitive on the margin when the prevailing price of electricity based on FR tariff is raised to Rs.109/BHP/month. Thus to promote a sustainable pattern of groundwater usage the electricity price under the prevailing FR tariff structure will need to be raised by 275%.

IMPACT OF SHIFTING TO TARIFF STRUCTURE BASED ON UP OF ELECTRICITY

In contrast to FR, UP of electricity has widely been advocated by academicians and donor agencies as a method to improve the efficiency and sustainability of energy and water use Since comprehensive data for estimating farmer water use response to changes in electricity prices are not available it is not clear how much effect such a pricing system in itself will have (Moench 1993).

To analyse the economic implications of switching over from FR to UP, we worked out the number of hours required to pump the required amount of irrigation water for the two cropping systems - rice-wheat and maize-wheat Using the size of pumping equipment and the prevailing UP of electricity (Rs 0.35/kwh) we worked out the corresponding cost of electricity for pumping the given amount of irrigation water. The results obtained suggest that even after switching over to UP, the cultivation of rice-wheat continues to be more profitable than maize-wheat (Table 8). The difference in the NFV between the two farming systems does however narrow from 29% obtaining under the FR tariff structure to 12% under UP Experimentation with parametric variations in UP of electricity suggests that an increase in the prevailing UP by Rs. 0 20/kwh to a level of Rs.0.55/kwh makes the two farming systems competitive.

IMPACT OF SHIFTING TO A TARIFF STRUCTURE BASED ON A COMBINATION OF FR AND UP (FRUP)

In the foregoing analysis we have essentially focussed on adjustments in electricity price under two alternative tariff regimes - one based on FR and the other on UP. The two tariff regimes however need not necessarily be viewed as either/or options. In fact a tariff structure based on a combination of FR and UP, FRUP, may be more practical in achieving the desired objective. To analyse the implications of switching to tariff structures based on a combination of FR and UP, the relative economics of the two farming systems were reworked using a range of alternatives. For the base solution we started with an electricity tariff of Rs.10 /BHP/month as FR and a UP of Rs 0.25/kwh.

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[12] This flat rate has since been increased to Rs 39/BHP/month from the 1992-93 season

The results obtained suggest that under FRUP the rice-wheat farming system continues to remain more profitable than the alternative maize-wheat farming system (Table 9). However the difference in NFV between the two farming systems narrows in comparison to the currently prevalent tariff system based on FR.

To estimate the extent of increase required in FR and/or UP to make the two farming systems financially competitive under FRUP we parametrically varied the FR and UP of electricity. The alternative scenarios analysed include: (i) successive increases in UP by Rs.0.10/kwh without any increase in FR, (ii) successive increase in FR by Rs.5/BHP/month without any change in UP; and (iii) simultaneous increase in FR and UP in various combinations. The results obtained suggest alternative adjustments in FR and/or UP required to make the two farming systems financially competitive Thus the NFV of rice-wheat and maize-wheat approximately converge at: (i) an FR of Rs.10/BHP/month and a UP of Rs.0.55/kwh; (ii) an FR of Rs 25/BHP/month and a UP of Rs.0 25/kwh; (iii) an FR of Rs.15/BHP/month and a UP of Rs 0.45/kwh; and (iv) an FR of Rs.20/BHP/month and a UP of Rs.0 35/kwh (Table 9).

SUMMING UP

We present in Table 10 a summary of the adjustments in electricity prices required under alternative tariff regimes to promote sustainable groundwater use in north-west Indian agriculture. A perusal of the results clearly indicates that it is nearly impossible to achieve the desired objective by continuing with the current tariff structure based on charging for electricity on a flat rate basis. The results also suggest that the necessary pre-condition to achieve the desired objective is that electricity be sold either on the basis of a unit price or on some combination of unit price and flat rate In other words, the basic consideration for determining the electricity tariff structure for irrigation pumping should be that farmers must face, even if partially, the unit price for electricity The choice of switching to an appropriate tariff structure would depend on a host of factors such as convenience and cost of metering, billing, collection of dues, etc. It would also need to be politically and socially acceptable.

The suggested alternative tariff regimes apart from promoting sustainable use of groundwater are likely to ease pressure on demand for electricity in the agriculture sector because of farmers switching over from the heavily irrigated rice to moderately irrigated maize crop. The extent to which such adjustments in electricity prices will help ameliorate the financial position of the SEB will depend on how proficiently it is able to utilise the surplus electricity released by the agricultural sector

CONCLUSIONS

The north-west rice growing region in India has drawn heavily on its natural resources to sustain the current level of agricultural production This cannot be sustained in the long run and the region must diversify its cropping pattern The results have illustrated the necessity and relevance of taking into consideration the impact of development policies on the use of natural resources and proper accounting for these consequences in a Natural Resource Accounting framework so that the relative crop economics are neither distorted nor overestimated and a sustainable pattern of development can be pursued.

Due to interactive causal relationships between water and power resources, a change in the way one is maintained is likely to have an effect on the other As a result, efforts aimed at promoting a sustainable pattern of groundwater usage must be directed at co-management of both the resources. Electricity prices for agricultural/ irrigation sector in India are decided on an ad hoc basis generally under political compulsions and set aside rational energy pricing and usual market principles. As demonstrated, removing or at least partially offsetting such anomalies through adjustment in tariff structures can help promote sustainable usage of groundwater resources. While it is true that any attempts to suddenly alter the electricity prices/tariff structures are likely to be met with stiff resistance, a gradual and slow initiative has to commence so that chances of eventual social and political acceptability are enhanced We do not know whether the suggested alternative electricity prices under different tariff structures are consistent with the long run marginal cost of providing electricity. Even after such adjustments in prices, however, pumping irrigation water using electricity as the source of energy is likely to remain cheaper than diesel. For example, as demonstrated, under the tariff structure based on unit price of electricity (UP) an increase in price of electricity to Rs 0.55/ kwh can help promote a sustainable use of groundwater. Even at this price of electricity pumping with electric tubewell is cheaper than with a diesel engine in which case the corresponding equivalent cost work out to Rs 1 70/kwh (Table 11). Even if the electricity prices were to be raised to a level where irrigation with an electric motor becomes competitive with a diesel engine, technology switches may not take place because of technological limitations with diesel engines in pumping water from greater depths.

While it is true that the burden of adjustments in electricity prices will fall disproportionately on resource poor farmers and may deny them access to groundwater, such effects cannot be abetted because of inherent contradictions between equity and sustainability

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Table 1. Distribution of Dark and Grey Blocks

	Punjab	Haryana	Total
All districts			
Total number of blocks	118	108	226
% Blocks classified as			
-Dark	56	29	43
-Grey	16	15	15
-White	28	56	42
Rice-growing districts			
Total number of blocks	82	31	113
% Blocks classified as			
-Dark	72	61	69
-Grey	16	29	20
-White	12	10	11
Non-rice growing districts			
Total number of blocks	36	77	113
% of blocks classified as			
-Dark	19	16	17
-Grey	17	9	12
-White	64	75	71

NOTE : The classification for Punjab relate to the prevailing position as on 30 June 1989, while for Haryana the position is as on 30 June 1991.

Table 2. Proportion of Gross Cropped Area Under Rice and Wheat (%)

	Area								
	R	W	R+W	R	W	R+W	R	W	R+W
Year	Punjab			Haryana			North-West		
1970-71	6.9	40.5	47.4	5.4	22.8	28.2	6.2	32.2	38.4
1975-76	9.1	39.1	48.2	5.6	22.5	28.1	7.4	31.4	38.8
1980-81	17.5	41.2	58.7	8 9	27.1	36.0	13.6	35.1	48.7
1985-86	24.0	43.5	67.5	10.4	30.4	40.8	18.0	37.7	55.7
1989-90	25.8	43.5	69.3	11.4	32.8	44 2	19.5	38.9	58.4
1990-91	26.9	43.6	70.5	11.8	32.8	44.6	20.4	39.0	59.4

R = Rice W = Wheat

Table 3. Growth in Number of Tubewells

	Punjab		Haryana		Total N-W	
	No of TW(000)	TW/1000 Ha NAS	No of TW(000)	TW/1000 Ha NSA	No of TW(000)	TW/1000 Ha NSA
1970-71	192	47	104	29	296	39
1975-76	450	108	205	57	655	84
1980-81	600	143	332	92	932	120
1985-86	662	158	406	112	1068	137
1989-90	765	183	458	127	1223	157
1990-91	800	190	498	138	1298	166

Percent of NAI Irrigated by Wells and Tubewells

Year	Punjab	Haryana	Total N-W
1970-71	55	37	49
1975-76	56	41	50
1980-81	57	45	53
1985-86	62	47	56
1989-90	62	51	58
1990-91(P)	60	49	55

Table 4. Capital and Operating Cost of Pumping Equipment at Different Depths to Water Table (2-hectare Farm)

Year	Depth to water table	Motor BHP	Capital cost of equip.	Annual operating cost		
				Repair & maint.	Elect.	Total
0	15	10	11730	1020	3480	4500
5	20	15	16790	1460	5220	6680
10	25	17.5	19260	1675	6090	7765
15	30	20	21735	1890	6960	8850
20	35	25	27025	2350	8700	11050

Notes:
1. The capital cost of equipment includes the cost of accessories
2. Repair and maintenance cost has been taken as 10 percent of the capital cost of the motor.
3. The cost of electricity has been computed at the rate of Rs.29/BHP/month

Table 5. Resource Cost of Groundwater - Simulation Period, 20 Years (2 hectare Farm)

Cost	Discount rate (%)		
	6	8	10
Capital	30596	25048	20698
Operating	25562	20238	16164
Total	56158	45286	36862

Note : The per hectare resource cost is calculated by dividing the above cost by 2.

Table 6. Net Financial Values of Alternative Farming Systems - Simulation Period, 20 Years -Reference Solution

	Farming system								
	Rice-wheat			Maize-wheat			Percent diff.		
	Discount rate (%)								
	6	8	10	6	8	10	6	8	10
Returns over opert. cost	158358	135549	117441	102647	87863	76125	54	54	54
Resource cost of groundwater	28079	22643	18431	0	0	0			
Net financial value	130279	112906	99010	102647	87863	76125	27	29	30

Table 7. Net Financial Values of Different Farming Systems - Flat Rate Electricity Tariff- Discount Rate, 8 percent ('000 Rs./hectare)

Farming system		Flat rate electricity tariff (Rs./BHP/month)								
		29	39	49	59	69	79	89	99	109
	PVR	136	130	124	118	112	106	100	94	88
Rice-	RCG	23	25	28	31	34	37	39	42	45
Wheat	NFV	113	105	96	87	78	69	61	52	43
	PVR	88	82	76	70	64	58	53	47	41
Maize-	RCG	0	0	0	0	0	0	0	0	0
Wheat	NFV	88	82	76	70	64	58	53	47	41

NOTE :
PVR = Present value of returns over operating costs
RCG = Resource cost of groundwater
NFV = Net financial value
The results are insensitive to the choice of discount rate

Table 8. Net Financial Values of Different Farming Systems - Electricity Tariff Based on Unit Price (UP) - Discount Rate, 8 Percent ('000 Rs./hectare)

Farming system		Electricity tariff (Rs./kwh)	
		0 35	0.55
Rice-Wheat	PVR	135	126
	RCG	23	27
	NFV	112	99
Maize-Wheat	PVR	101	98
	RCG	0	0
	NFV	101	98

Table 9. Net Financial Values of Different Farming Systems - Electricity Prices Based on a Combination of Flat Rate and Unit Price (FRUP)- Discount Rate, 8 Percent ('000 Rs./ hectare)

Farming system	FR (Rs/BHP/month		UP of electricity (Rs /kwh) 0.25	0.35	0.45	0.55
Rice-wheat	10	PVR	134	129	125	120
		RCG	23	25	28	30
		NFV	111	104	97	90
Maize-wheat		PVR	96	95	94	93
		RCG	0	0	0	0
		NFV	96	95	94	93
Rice-wheat	15	PVR	129	127	122	117
		RCG	25	27	29	32
		NFV	104	100	93	85
Maize-wheat		PVR	93	92	91	90
		RCG	0	0	0	0
		NFV	93	92	91	90
Rice-wheat	20	PVR	119	114	109	104
		RCG	26	28	31	33
		NFV	93	86	78	71
Maize-wheat		PVR	90	89	88	87
		RCG	0	0	0	0
		NFV	90	89	88	87
Rice-wheat	25	PVR	116	111	106	101
		RCG	27	30	32	34
		NFV	89	81	74	67
Maize-wheat		PVR	87	86	85	84
		RCG	0	0	0	0
		NFV	87	86	85	84

Table 10. Adjustment in Electric Prices Under Alternative Tariff Structures Required to Make Two Farming Systems Financially Competitive - Summary Results

	Option	Tariff	NFV ('000 Rs) R+W	M+W
1.	Ref.soln.	Rs.29/BHP/month	113	88
2.	FR	Rs.109/BHP/month	43	41
3.	UP	Rs 0.55/kwh	99	98
4.	FRUP	FR- Rs 10/BHP/month UP- Rs.0.55/kwh	90	92
		FR- Rs 15/BHP/month UP- Rs 0 45/kwh	92	91
		FR- Rs.20/BHP/month UP- Rs 0.35/kwh	85	89
		FR- Rs.25/BHP/month UP- Rs.0.25/kwh	88	87

Note : R -Rice, W - Wheat, M - Maize

Table 11. Approxiamte Comparative Cost Per kwh of Energy Using Electric Motor and Diesel Engine.

<u>Irrigating one hectare of rice-wheat with electric motor</u>

1.	Size of electric motor	10 BHP
2.	Number of pumping hours	568
3.	Electricity consumption	10 * 0 88 * 568 = 4998 kwh

<u>Irrigating one hectare of rice-wheat with diesel engine</u>

1.	Size of the diesel engine	10 HP
2.	Number of pumping hours	682
3.	Diesel Consumption per hour	2.5 litres
4	Price of diesel	Rs 5/litre
5	Cost of diesel per hectare	10 * 682 * 2.5 * 5 = Rs.8525

<u>Comparative cost</u>

Implicit cost of providing 1 kwh of equivalent energy with diesel	Rs.8525/4998 = Rs.1.70

Note : The number of pumping hours using electric motor have been worked out on the basis of crop water requirement, depth to water table, size of the equipment, discharge rate, etc. The equivalent pumping hours for irrigating with a diesel engine have been worked out on the assumption that, due to difference in efficiency between electric motor and diesel engine, the latter will take approximately 20 percent more time.

Use of Correct Pricing as a Fiscal Instrument for Sustainable Use of Groundwater

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ABSTRACT

Minor irrigation, particularly from groundwater sources, has assumed increasing importance over the last three decades. At present, levels of groundwater exploitation are overstepping the limits imposed by our current wisdom Although the National Water Policy mentions that the scarcity value of the resource should be taken into account, this is not reflected in the energy and other subsidy structures encouraging groundwater development.

Options that are widely discussed for sustainable management of groundwater include: nationalisation, differential subsidies, cropping pattern standardisation, regulation, management at the village or panchayat level, and imposition of water rates

This paper examines the above options with particular focus on water pricing issues. It concludes that the key fiscal instrument which can lead to sustainable management of groundwater is the right pricing at the farm gate Controls and regulations in themselves have not been able to achieve desired environmental standards, especially since we are dealing with public goods Answers can only be found in the correct pricing of groundwater and using pricing as a tool for achieving sustainable management of the resource.

INTRODUCTION

Agriculture is a major plank of the Indian economy and irrigation is one of its mainstays. Constituting an important sector in the rural and semi-urban society, decisions regarding irrigation investments have been influenced by many "non-economic" or "political" factors. While the net sown area in the country has increased from about 119 to 140 MHa in the period from 1950 to 1986-87, the net area irrigated has seen more than a double-fold increase from around 21 to 43 MHa. The share of gross irrigated area to gross sown area has also gone up from around 17% to about 31% in the same period. If we look at the growth of irrigation from different sources in this period, some interesting trends become visible.

> **"When power is used inefficiently, it truly is lost in the sense that it is dissipated as heat. But when water is used inefficiently, it usually is not lost - it just flows to some other user. Thus, proponents of the development model contend that most of the additional demand for water in the future must be met by development of additional water supplies, that water conservation alone would not suffice." - David Seckler, "Designing water Resource strategies for the twenty first century".**

Fig. 1. Percentage Area Irrigation by Source

Canals (both government and private) were the major source of irrigation in the 1950's when tubewell irrigation was just beginning. This phase continued until 1960 when tubewell irrigation took off. After this period the area irrigated by canals more or less stagnated while that from tubewells grew rapidly. By 1975-76 the percentage area irrigated by wells (tubewell and other wells) exceeded the area commanded by canals. The trends are graphically presented Figure[13]

Fig-1

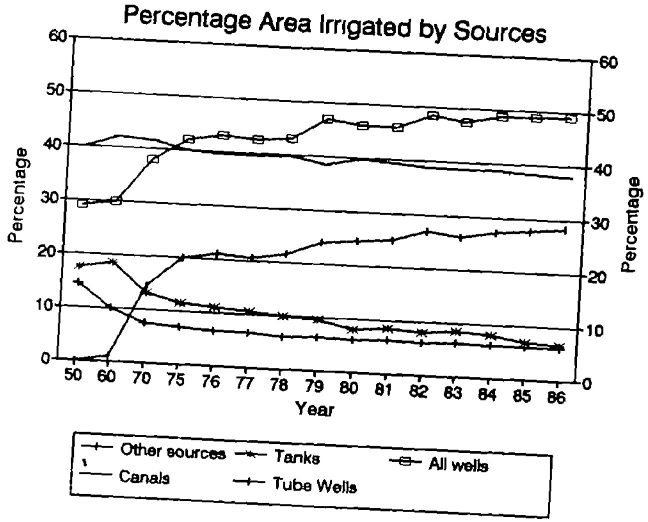

Fig. 2. Irrigation Potential of Different Projects

If we look at this rising trend in groundwater irrigation (irrigation by wells and tubewells) in combination with the existing status of the resources, a rather alarming picture comes to the fore. Since statistical figures are available for schemes under major and medium projects and those under minor irrigation, the broad trends for canal irrigation from the major and medium projects and those for tubewell irrigation from minor schemes can be drawn. Since these sources constitute a substantial portion of the respective schemes, such a generalisation should not be out of place. For the country as a whole, the ultimate irrigation potential through major and medium projects is 58.4 MHa Of this, a little over 50% was realised by 1987-87. In comparison 72% of the ultimate minor irrigation potential had been created by 1986-87. Thus

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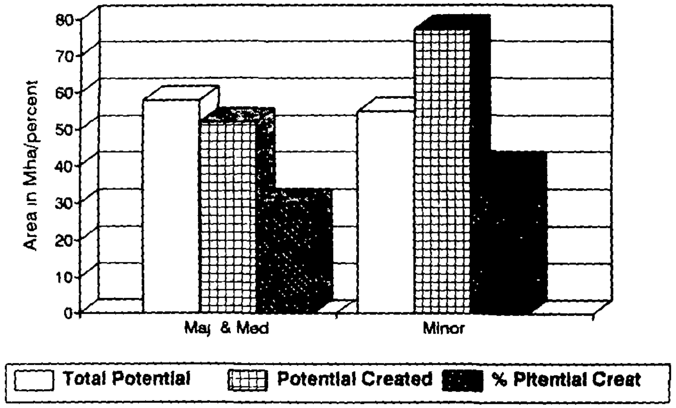
[13] Source Agricultural Statistical Compendium, Vol 1, 1990, Techno Economic Research Institute, New Delhi

though the impetus for minor irrigation came much later than the other schemes, the ultimate potential is being approached much faster. In fact, in Uttar Pradesh, the MI potential created -- 13.79 MHa. -- is more then the stated ultimate potential of 13 2 MHa.[14] This can be interpreted to mean either that the estimates for maximum potential are inaccurate or that we are exceeding the limit of sustainable exploitation.[15] Many other states are also fast approaching this condition. The agriculturally advanced states of Punjab, Haryana and Gujarat fall in this category Arid regions, such as Rajasthan, are also in similar straits.

Irrigation Potential of Different Projects

Fig-2



The above section highlights the extent of exploitation of available water resources under major and medium irrigation schemes What also come out is the increasing importance of minor irrigation -- specifically tubewell irrigation -- over the last three decades. The rates at which exploitation has grown have been much more accelerated in the case of tubewell irrigation than in the case of canal irrigation

Having highlighted the rising importance of tubewell irrigation, it is important to note the relative lack of management experience in comparison to canal and surface sources. The amount of interest and research that has gone into devising management principles for sustainable groundwater irrigation is relatively little when compared to the voluminous research available on canal management. Substantial lessons to be learnt from tubewell irrigation management will thus have to be derived from that of canal irrigation. Since most irrigation policies have also been geared with a major emphasis on surface sources, this sector is analysed in some detail in this paper in order to gather pointers which might be relevant in the case of tubewell irrigation.

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[14] Ibid

[15] "Current wisdom" with regard to groundwater potential has been a matter of debate There has been questions, for instance, on the CGWB methods of working out the potential for the VIIth plan

This paper is organised as follows. The first section provides a brief history of irrigation from independence until the present. In section two, the nature of the existing sources, their management constraints and opportunities, and their performance are analysed. Section three provides a brief analysis of options for sustainable groundwater management. Section four outlines approaches to setting water rates that have been traditionally propagated as a means to manage water resources. Section five elaborates on the need for alternative approaches to valuation of irrigation water and the use of water pricing as a fiscal instrument to better manage groundwater. The paper concludes with a listing of the problems and prospects that go with the suggested new approach.

HISTORY

In the early British period, irrigation works were treated as commercial undertakings Pricing of water was designed to ensure a prescribed return on capital after meeting working expenses A gestation period of 10 years was accounted for Even in this early phase exceptions were made on the grounds of protective irrigation works in areas prone to famine where revenue was not the governing concern.

After independence there was a total reversal of the British principle and irrigation came to be viewed more as a part of the necessary infrastructure for agricultural development rather than as a commercial undertaking. The State took it upon itself to provide subsidised water inputs to boost agricultural production. Various studies done by the government during this period quantified the benefits associated with the provision of irrigation including both direct returns such as double cropping, crop diversification, higher yields, larger income, more employment, etc and indirect returns from processing industries, retail trade and transport. Social costs and benefits were identified in order to present an economic or political justification for lowering water rates in irrigation systems. However, detailed social cost-benefit calculations and determination of internal rates of return at the planning stage and at the post-project stage were rarely done, if at all.

The major changes incorporated in the period after independence, in response to the above thinking, are enumerated below·

(i) The minimum financial return expected on capital was reduced from 6% to 3 75% from April 1949 onwards

(ii) The criteria for approval of irrigation projects were changed from financial to economic benefit (1964). Projects with a benefit-cost ratio above 1.5 were acceptable No financial return on capital was expected (no similar switch was made from financial to economic costs, however).

(iii) Exceptions were made for drought affected areas in 1972 where a benefit-cost ratio of 1 was acceptable.

The above were mainly Central government decisions and came in to play when Central clearances for major and medium projects were required. For smaller projects, the states could take their own decisions and did so, for instance, in setting minimum acceptable benefit-cost ratio.

The financial situation that resulted from these policy changes was a cause for concern for many in government and academic circles. Various commissions and committees were formed to look into the subject of water rates. These include, to name a few, the Maharashtra Irrigation Commission (1960-62), the Nijlingappa Committee (1964), the Conference of State Irrigation and Power Ministers (1970), the National Commission on Agriculture (1976), and the Public Accounts Committee (1983). All of these called for upward revision of rates for providing irrigation water. They did, however, differ on the criteria for determining these rates.

The second irrigation commission in 1972 recognised the deteriorating position of irrigation work and concluded that the projects required an adequate return on investment. It was also concluded that since the benefits of irrigation do not accrue to the entire farming community, the burden for providing irrigation should not fall on the general taxpayer It has thus been realised that the projects must at least pay for their running costs in financial terms.

An expression of the emerging concerns is found in the 8th plan document. This says· "Water charges collected for irrigation do not cover even working expenses not to speak of depreciation charges. While just prior to independence, public irrigation schemes showed a surplus of 7.92 crores after meeting working expenses, interest charges and setting off losses on unproductive work, estimates for 1987-88 put the annual loss of irrigation systems to Rs. 1705 crores". The gap between the annual working expenses and receipts from water rates stood at Rs. 400 crores. The groundwater irrigation situation is similar. Here "water rates reflect only one-sixth of economic water rates" (Though what economic water rates are has not been clarified, we assume that economic water rates refer to rates which cover all costs, O/M, depreciation, interest on capital and a return percentage.)

Economic considerations have assumed great significance because of rapidly accumulating deficits. Lack of funds has resulted in decreasing investment on the upkeep and maintenance of old systems. This results in increasing breakdowns, decreasing reliability, fewer beneficiaries willing to pay even existing water rates and, ultimately, further decreases in revenue The entire system becomes less and less self sustaining. Another aspect, which has largely been neglected, is the impact of these subsidies on the resource base.

All these concerns have finally been voiced in the National Water Policy of 1987. It made two important points in relation to water rates. First, rates should reflect the scarcity value[16] of the resource. Second, they should cover the operation and maintenance charges and

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[16] Scarcity value ideally would include the rent of water resource lying unexploited plus the extraction cost plus the margin due to the difference in supply and demand

part of the fixed cost. It was recognised that all these need to be achieved over a period of time.

In brief, the focus of water charges has over the years gone through almost a cyclic change. The objective of providing irrigation water shifted from revenue generation to meeting an important infrastructure requirement, essentially a responsibility of the state. Then came the realisation that the schemes should be able to pay for themselves. While the National Water Policy does mention that the scarcity value of the resource should be taken into account, it fails to elaborate on the issue, explaining neither what the term refers to nor the mechanisms to put it to practice. In particular, the costs and benefits of particular use patterns are not accounted for either with regard to impacts on the resource or the future of society.

THE NATURE OF IRRIGATION SOURCES

In this section we deal with the two sources which have dominated the irrigation scene in India. Amongst the sources of surface irrigation, we focus on canals. This is done because the share of irrigation from other surface sources, primarily tanks, is decreasing. In groundwater irrigation we focus on tubewells. Although other wells are also important sources of irrigation, they are not discussed for three reasons. First, their share in irrigation is decreasing. There was a ten percent decrease in area irrigated by wells other than tubewells between the 1960's and the 1980's. Second, wells other than tubewells are largely private with no state support in the form of subsidies. Third, the very nature of the source for many dugwells (driven by draft power or other such means) makes irrigation using these technologies less of a concern with regard to the resource itself and the larger financial or economic situation.

Surface Irrigation (SI) (canals)

Since surface irrigation has been in use for a long time, trends in use and impacts on the environment are relatively well known. Some salient features associated with surface irrigation are discussed below.

The foremost are the pressures on surface irrigation from the demand side or, in other words, from the user of the system These have manifested themselves in the completely unregulated way in which the water is used. The word unregulated here refers to the lack of control over the volume of water applied regardless of the physical characteristics or requirements of the receiving area In short, water is often used with complete abandon. This has resulted in over application of irrigation in a number of cases, leading to waterlogging, soil alkalinity and other problems. Additionally, increased irrigation has enabled the increased use of chemical fertilisers and has led to a loss of soil quality It has also enabled farmers to emphasise high yielding varieties which has resulted in a loss of considerable germplasm and biodiversity besides making many crops more susceptible to pest attacks. The state of Uttar Pradesh alone has an area of 12 lakh hectares afflicted by soil alkalinity ("Making Usars Bloom", U.P Government). Such soils should not be irrigated through surface water methods

but should utilise groundwater in order to lower the water table which is one of the causes of alkalinity. However the wide disparity in surface and groundwater charges makes the use of the former highly attractive. Thus, wherever possible the *usar* areas are cultivated using canal waters Though this might give increased production for a few years, the rising water table can only result in an unsustainable growth path. This is not to say that the lack of proper drainage facilities (which should have been created by the government) is not to blame but that a more controlled use of water might have averted or reduced such a damage.

The second set of constraints come from the supply side and can be broadly categorised as those arising from the pricing of canal water, from the relative reliability of supply and from the non-exclusive nature of the resource. To elaborate, canal water rates are low and are set on an area basis for the entire season irrespective of number of irrigations. Though there are some differences from crop to crop and season to season in some states (not all states have such differentiation), these are irrelevant as they fail to establish any relation between actual watering and required watering for any given crop [17] Essentially there are no cost incentives to economise in the use of water.

The supply of canal water is highly unreliable, especially in tail-end sections This has given rise to a tendency among farmers to irrigate their fields to the maximum possible extent whenever water becomes available. This has its repercussions in the form of reduced productivity as compared to potential. The second trend is the increase in private groundwater markets. We will not debate the issue of whether these markets are beneficial or not in this paper, but would only like to point to the fact that rent seeking gets enhanced when there are large scale subsidies for the creation of private resources. The implications of this for equity need to be kept in mind.

Water from canals does not have the property of exclusivity. Once it is released, no person in the command of a system can be stopped from using it irrespective of whether payment is made or not. Also the volume of water used by any particular individual cannot be controlled. Regulation is certainly not possible via state bureaucracies It may, however, be possible at village level through water users organisations.

Another point of significance, though it may be a digression from the topic being discussed here, is that the construction of surface systems has not always been done in areas which are water- scarce or lacking in other sources of irrigation. For instance, the command of the Sarda canal includes 10 districts which had prior well developed irrigation facilities (NCAER 1959). Despite receiving over 80% of the supply developed by the project, there has been no significant increase in the net area sown in these districts. What has resulted is the old systems falling into disuse due to abundant availability of low cost water from the public irrigation system The Narmada Sagar Project is in a similar situation in some sites, for

example, where its command area overlaps with that of the Mahi Canal Project in the Kheda district of Gujarat which is already water-surplus Although the extent of such overlaps for all the schemes implemented so far is unknown to us, a concern that comes to the fore is not just the colossal waste of capital and water resource but also the accompanying degradation of land primarily from waterlogging.

In short, the above section highlights the various problems faced in canal water irrigation Although it is a cheap source of irrigation for the farmers, a number of environmental problems have arisen precisely because it is cheaply valued These have been aggravated by administrative problems of regulating the use at the field level, which can possibly be handled through water user groups. Unreliability of supply is another factor contributing to unsustainable use but, as has been pointed elsewhere in the paper, the quality of service rendered is directly related to the funds available (in a government set up.) In effect, this aspect is to some extent built in the value or in this case to the price that is put for water

Groundwater Irrigation (GW)

This section focuses on tubewell irrigation The analysis presented differentiates between the tubewells that are run on diesel versus electricity. A further distinction is made between private and public sources as they have substantial differences in terms of water availability, use, regulation and pricing.

The following focuses on the implications of current pricing policies on the status of groundwater resources. As has been highlighted at the beginning of the paper conditions are changing at a rather rapid pace and are already a cause for concern in some states.

To begin with, we present some characteristics of the source. Extraction of water through tubewells has become a mechanism for privatising a resource which was traditionally regarded as commonly owned. In the case of privately owned tubewells, which are bored on private land, the resource has itself become private, i e access is controlled by the landowner. Though tubewell boring could have remained a common property, in practice it is not. In the case of public tubewells, the wells themselves are relatively easy to control, a factor which is often not the case in common property resources (CPRs). For instance, where wells are concerned, the principle of exclusion can be readily followed whereas this is an important bottleneck in the case of canal management. Thus while access remains common, control can be similar to that of a private property. It is here that scope for effective management is really high. However, most studies done on public tubewells paint a really sorry picture about the state of affairs A study done for the districts of Faizabad and Bahraich in U.P [18] reveals that where public tubewells are of recent origin, development of private groundwater has stagnated. On the other hand, where public tubewells have been operating for a long time, private groundwater development is very high. This points to the deteriorating condition of many public tubewells On the other hand, it may also point to a rising awareness about the advantages of tubewells to individual owners.

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[17] There has also been very little work done/sponsored by irrigation departments to test conventionally adopted norms of different crops and to develop (on a large scale) newer methods of water application which will help conserve the available water.

[18] Niranjan Pant, "New Trends in Indian Irrigation"

Another major advantage with tubewells is the ease with which water use can be regulated. Efficient resource use is thus much more possible with tubewells than with canal systems. When compared to surface irrigation groundwater irrigation has additional distinct advantages in the form of higher degree of assurance, timeliness and user control. The only uncertainty is in areas where the supply of electricity is erratic.

Coming to the cost of tubewell irrigation, we find that the level of subsidy involved in the setting of electricity rates for tubewells is quite high. Not only is power subsidised, even the laying of power lines is subsidised. Added to this is the subsidy which is given on the purchase of pump sets, electric or diesel This amounts to a fairly large burden on the state. An estimate made by B D Dhawan put the hidden subsidy in electric pump sets in the range of Rs.40,000 to Rs.60,000 per pumpset run on thermal power and probably higher for pumpsets run on hydroelectric power Because of the subsidies, current hourly costs are much lower for electric tubewells than for diesel-run tubewells

Electricity charges vary between states with a few states metering the electricity and a majority of them charging lumpsum for the year. While the former has not really been effective as people resorted to theft of electricity, the latter encouraged unrestrained use of water. The same cycle of over usage in the case of surface water has thus been set in motion also in the case of groundwater. Moreover, the situation has been aggravated since here the total volume of water extracted is totally in the hands of farmers, irrespective of whether wells are state owned or private. Also, extensive extraction of water has resulted in declines in the water table necessitating the use of bigger pumps and extraction from greater depths. Increasing costs have in a number of cases meant that farmers are no longer able to continue irrigation and are forced to revert to forms of dryland agriculture The net result is that while a judicious use of water would have resulted in increased production on a sustainable basis, in a number of areas, this is not happening.

In brief, despite inherent advantages of user control and greater amenability to management there has been a spurt in rent seeking, overexploitation, and in general unsustainable use of groundwater. One of the major reasons is that policies have been geared toward encouraging the use of groundwater, with subsidised pricing being one of the tools which has been successfully used to this end. In economic terminology if the extraction costs are less than the value of the resource in the ground (or water rent) then it pays an individual to extract the maximum water possible in a shorter time The net impact is overexploitation of a limited resource. Overexploitation has, in turn, resulted in people being forced to revert back to the old practice of dryland agriculture after they could no longer meet the costs of lifting water from the receding water tables.

OPTIONS FOR SUSTAINABLE MANAGEMENT

The preceding analysis points to the exceedingly important role that pricing seems to have played in the exploitation or overexploitation of groundwater resources. In this section we analyse other options and see whether following them can ensure sustainable management. Briefly, these options are

(i)Nationalising the groundwater, i.e moving the ownership rights over groundwater from individuals to the state.
(ii) Differential subsidies, i e. subsidising the poor for the use of groundwater and taxing the rich and affluent.
(iii) Standardising the cropping pattern depending upon water availability in an area.
(iv) Making more stringent rules to control extraction under the present property regime
(v) Handing over the maintenance and collection of dues to village level institutions like Panchayats, etc
(vi) Changing the water rates and the system of charging based on actual use instead of crop and area covered, to include the opportunity cost of water.

We start with the premise that any management system (under any control regime) should basically set out to achieve the following

(i) enhance productivity
(ii) ensure equity in the current time frame
(iii) ensure sustainability of the resource or in other words, ensure inter-generational equity.[19]

We examine the options mentioned earlier with reference to the abovementioned checklist.

(i) Nationalising groundwater would essentially mean transferring ownership and management responsibility to the state. While water is technically state owned, we discuss whether access to the resource should also be brought under state control. This would mean that all tubewells would be state owned. The condition of such tubewells has been elaborately presented earlier The situation can appropriately be summed up in the words of the 8th five year plan "Due to non-availability of power, poor O/M and lack of field channels, these public tubewells are generally under-utilised". A transfer of ownership, thus, does not seem to hold well, going by precedents. Through a transfer of the access right, a monopoly no doubt would be created which definitely is a more conservationist regime than the current oligopoly. But a simultaneous transfer of management responsibility would increase political interference. This would lead to a total neglect of any maintenance of the irrigation infrastructure by the people themselves. With the state unable to invest much effort in this, the net result would be a progressively deteriorating infrastructure. Instances like this have been cited in the case of tank management in Karnataka which passed on from the people to the government.[20] Thus while creating a state monopoly over groundwater resource extraction might result in bringing down the extraction rates, there are no indications that such a system would improve efficiency or quality of life as well A mere transfer of ownership cannot ensure that the policies are translated into ground realities. A case in point is the state ownership of reserved and

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[19] Tushaar Shah, "Groundwater Markets and Irrigation Development - Political Economy and Practical Policy"
[20] T Somashekhar Reddy, "Tank Irrigation in Karnataka"

protected forests where, despite all regulations to control felling and removal by local residents, illicit felling to meet fuel and timber requirements remains largely unchecked. It thus becomes clear that this option does not seem feasible on the criteria of enhanced productivity or of present and inter-generational equity.

(ii) Differential subsidies are likely to have positive equity impacts. They will enable the rural poor to have access to groundwater resources that they would otherwise never be able to acquire. This is a current practice to some extent. Current subsidies for well boring and pumpsets are available contingent on minimum landholdings. Policies do not, however, differentiate power subsidies on the basis of land ownership These are uniformly available and constitute a much larger component of the total subsidy for groundwater irrigation. However, the subsidy principle by nature is marred by the phenomenon of rent seeking, whereby the powerful try to corner the benefits available through corrupt practices and then capitalise on this by operating the asset so acquired through local markets Thus, not only are the poor deprived of subsidy benefits but they may also have to pay a much higher price than what they would otherwise pay for access to the basic resource. In the case of groundwater, for example, many wealthy farmers have obtained electricity connections and are able to benefit from the power subsidies. Their poorer neighbours, who have not been able *to obtain* electrical connections, face falling water tables (which damages their ability to extract water from older animal powered wells) and now must purchase water from the wealthy farmers.

Spreading ownership to more resource poor farmers could imply that farmers who were earlier growing crops with less water requirement would switch to higher water requirement crops since now water would be available at only extraction costs to them This could result in a net increase in the demand for water The repercussions on the sustainability of the resource are thus open to question

(iii) Standardisation or regulation of cropping patterns (assuming that we are able to arrive at a proper crop mix based on the water available, the type of crops needed, and the ability of the farmers to grow the recommended crops) could help achieve lower extraction rates. This would chiefly be accomplished by reducing demand for water. However, unless such practices generate returns above the opportunity costs of growing other crops, implementation by farmers is highly improbable. Crop choices are governed by demand locally, nationally and internationally. The rural parts of India no longer have a sustenance economy alone where crops were purely grown for self consumption. Farmers tend to maximise gains (economic gains and not just financial) Hence it would be difficult to implement a standardised package of crops to be grown.

(iv) Making water extraction rules more stringent in the current socio-economic and political context would achieve little. This is because even the rules which are currently in place are difficult to enforce. In fact a large part of them are not implemented.[21]

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[21] The regulation about the minimum distance between two tubewells is seldom if ever complied with

The remaining two options, namely handing over maintenance and collection of dues to village level *institutions and changing* the water rates to include the opportunity cost of water, as has been elaborated in the preceding pages, seem to be favourably directed to the sustainable use of groundwater It would not be out of place to say that the two are in fact complementary and the former would help in the more effective implementation of the latter. The formation of village level institutions to manage the groundwater can bring in the perspective of long term sustainable use as well as equity. This would of course have no meaning without having the appropriate pricing policies which can make the use and extraction sustainable from both the state and the society's points of view Development of appropriate local institutions is a question which a lot of researchers are grappling with and to which they have not been able to come out with solutions that can be largely replicated Pockets of successes such as the Pani Panchayats in Maharashtra and Sukhomajri in Haryana are available as examples. None has, however, been replicated so far despite numerous efforts The fixation of water rates thus assumes great significance in the light of the above.

We now look in greater detail at the pricing determinants in the current scenario.

APPROACHES TO THE FIXATION OF WATER RATES

In the preceding pages, one factor that has constantly emerged as being of crucial importance is the rates that are charged for irrigation water. In this section we review two approaches for setting water rates which have been widely advocated The first is based on costs, and the second on benefits -- more precisely on benefits to the irrigation community. We review the pros and cons of the two approaches and try and find a way to fill existing gaps.

Before elaborating on the above it is interesting to look at views on water rates stated as far back as 1938 Then, the U.P Irrigation Rates Committee, 1938 ("Criteria for Fixation of Water Rates and Selection of Irrigation Projects", NCAER, 1959), stated that:

> "The value[22] of water is a function of the cost of supply and the increase in produce value from the land irrigated. The former determines the lowest financially sound rate, and the latter the uppermost permissible limit between which water rates can vary, and a fair rate is one which yields adequate profit on outlay on the one hand, and offers sufficient inducement to the cultivators on the other, but prevents them from extravagance or waste "

What clearly emerges form the above is that though the committee uses the word "value" to indicate the usefulness of the resource, it has a very restrictive view of this value Value was limited only to the financial returns obtainable from the resource and its use. It attaches no significance to the economic benefits that accrue to society as a whole. These include among other things an insurance against weather risks (i.e. drought proofing), flood control, preservation of soil against erosion losses, fish conservation, etc. While the financial

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[22] Emphasis is ours

benefits are no doubt important, the economic benefits are no less so Any skewed valuation of the resource whether in favour of the former or the latter will ultimately result in less and less attention being paid to the other benefit stream. This is a particularly dangerous situation if the economic benefits are ignored It is increasingly recognised in the world at large that it is important to view a resource in its entirety if we want to maintain any order in our ecological and economic world. Sustainable use is possible only if we view the resource as a whole and not just a sum of its parts

A second point that emerges is the recognition that rates play a crucial role both in encouraging irrigation as well as in regulating use of the resource to prevent overexploitation and waste. These roles, however, are expected to be performed with the prescribed limits of maximum and minimum rates as determined by the imputed benefits and cost recoveries. There was a noticeable change on this particular front after independence when it was felt necessary to subsidise agricultural production.

The (CWC) advanced several arguments in favour of levying water charges:

(i) Water is a scarce resource and the levy of water charges can help communicate this point,
(ii) The state receives a fair share of the enhanced earnings irrigators receive through the provision of irrigation services,
(iii) Since irrigation systems are not distributed over the entire community, the cost of water should be recovered from the users, and
(iv) Water rates can be a useful tool for the management of water ("An Overview of Water Rates for Surface Irrigation", CWC, 1993).

We now examine in detail the two approaches to pricing mentioned earlier

The Cost Approach

This approach is based on the principle that the returns accruing to a particular project or the irrigation sector in totality must at least cover its financial costs This approach ensures, to some extent, that propositions which are not financially self sustainable will be ruled out, especially where resources are scarce and are faced with multiple demands. It is practically more feasible to focus on financial rather than economic costs as it is much more easy to impute and calculate all the direct related expenses which make up the financial cost of the project than it is to calculate broader economic costs Estimating financial costs generally do not pose problems of data availability or collection and there is no ambiguity about the price calculations done on this basis. However, there are certain drawbacks to the approach which need to be tackled if this is to be a meaningful yardstick for determining prices. Foremost among these is the fact that the approach takes into consideration only direct financial costs and totally ignores the economic cost to society A number of elements that thus should contribute to total cost get totally ignored. To mention just a few:

(i) Cost of resource usage by a few has a large marginal social cost in the form of environmental or external costs which need to be added to the overall cost.
(ii) Depletion of resource leaves less for the next generation This next generation should be compensated in some way or else the use should be so regulated as to avoid the problem of overexploitation These costs need to be added to the total
(iii) Water rent needs to be included.
(iv) In river basin schemes, there are high environmental costs like costs of submergence, rehabilitation, destruction of other resources, etc These costs need to be added while calculating the right price.

Failure to include these costs results in the resource being used as a free good and in management problems similar to what have become evident in other CPRs like the forests

In addition to the above limitations, the simple approach of making water prices reflect the financial cost of the project has serious implications. This would, for example, take all the inefficiencies of the system (like cost escalations of the projects) as legitimate expenses and hence make the farmer pay for faults which were in no way committed by him. Thus to have a water rate which is more at the mercy of the efficiencies or inefficiencies of the project executing authority and not of those of the farmers themselves seems unfair.

The Benefit Approach

This approach is based on the principle that the cost that a farmer incurs in the form of a water rate should be correlated to the benefits he is able to derive from the final production This takes care of two factors.

(i) First, this system relates the water charge to the increased ability of the farmer to pay, to some extent. This of course is related to a number of factors which govern his living expenses (Irrigation Policy in South-east Asia, IRRI, Philippines, 1978) and hence the surplus that is available for investment in agriculture. Even so this method is more sensitive to a farmer's earnings than the cost method.

(ii) Second, it allows for the state to have a share of the increased production due to the creation of an irrigation infrastructure. Some of the abovementioned deficiencies of the cost approach get eliminated by this

For the net benefit approach, two methods have been suggested as a basis for benefit calculations. One, suggested by the NCAER(1959), set rates at a percentage of the net additional benefits. The other, recommended by the two Irrigation Rates Commissions set up by the U P. Government in 1939 and 1948, involved fixing rates on the basis of a proportion of the increase in the value of gross produce from the land irrigated.

Regardless of whether the approach is based on net or gross benefits, it faces many practical problems, primary among them being that it has never been ascertained what

components of an agricultural system, which are linked to water availability, a farmer would put a value to. An example would be the elimination of the weather risk. It has never been a part of the calculations as to how much money a farmer is willing to pay as a premium for crop insurance against rainfall failure. In addition, there is the issue of identifying the set of beneficiaries Is it only the direct user, i.e. the farmer or others too? To elaborate, all the beneficiaries of the system are not being charged in this case. For instance, those benefitted by ground water recharge on the downstream side of a storage structure are not charged, nor are those who benefit from flood control, from infrastructure development, from enhanced production, *and so on.* As a result, cost is not distributed evenly according to benefit. Irrigation serves a region as a whole and part of the benefits flow back to the government in various forms. Land revenue increases if additional area is brought under the plough, land revenue is stabilised, costs for famine relief are reduced, and land value increases in the areas served by the irrigation network and in the neighbouring areas as well. Apart from these benefits to the state, there may be net indirect receipts realised by the various departments such as railways, post and telegraph, and excise (NCAER 1959). Other beneficiaries include agricultural businessmen and the general food consuming public (Environmental Decision Making, Volume 2). Thus, those who should be charged cannot be restricted to just a narrow spectrum of farmers who can easily be identified as the direct beneficiaries of the system, but should also include all the others listed above and many more that may be identified.

Some objectives of river basin schemes are not revenue oriented at all such as flood control, fish preservation, wildlife protection, etc. Even if a cost is attributed to these, there is *no direct method* by which benefits can be capitalised (NCAER 1959).

Finally, it is very difficult to determine the precise contribution that water makes to the net income of a farmer. The contribution of other factors of production like fertiliser, soil amendments, HYV seeds and improved agricultural practices needs to be clearly known since all these factors are linked to each other and act as complements While this may be possible to estimate in laboratory conditions, it is highly impracticable under field conditions. The method also requires a lot of data on area irrigated, crops grown, yield, prices, cost of cultivation, etc. These are not only cumbersome to handle but there are data collection issues. In addition, this method builds in the imperfections of agricultural markets, defective agricultural pricing, etc. Unless these issues are effectively resolved it is unlikely that India should proceed along these lines

What seems evident from the above is that both approaches have inherent drawbacks in that they include only financial benefits and costs and totally ignore the economic aspects. Also the concern for regulating the use of water for *long term sustainability* has been neglected so far in the approaches which have been suggested.

NEED FOR AN ALTERNATIVE APPROACH

The preceding pages try to throw light on gaps in existing systems and the proposed systems for pricing irrigation water It is also clearly evident that the key fiscal instrument

which can lead to sustainable management of groundwater is the right pricing of the water at the farm gate.

The existing and proposed rate structures do not include the following:

(i) Environmental or external costs/benefits
(ii) Scarcity value of the groundwater resource
(iii) Total investment cost or production benefits
(iv) Reflection of the true extraction costs
(v) Marginal social cost due to resource usage by few
(vi) Imputed value of factors like crop insurance against rain failure
(vii) Reflection of willingness to pay for usage of groundwater (can be derived from existing private markets)
(viii) Bequest and Option Value

It is apparent that market prices would be a true reflection of resource scarcity. At the same time, private markets would depend on supply and demand and not necessarily reflect ability to pay for marginal groups. Therefore, to convince policy makers that the true value of water is also reflective of the peoples' willingness to pay, we need to have a fresh look at the valuation methodology of the resource.

If we treat water as an exhaustible resource, i.e overexploitation can lead to depletion which may be irreversible, it is important to identify a price which would ensure a sustainable use keeping the farm gate pricing principle intact. This price should include the factors not taken into account in the current pricing policies This would entail finding the total economic value of water.

To end we would like to emphasise that controls and regulations in themselves have not been able to achieve desired environmental standards, especially since we are dealing with public goods. Answers can, to a large extent, be found in correct pricing as a tool for achieving sustainable management of groundwater. Though the above analysis does not fully address the crisis of unsustainable use of groundwater, we are in agreement that a combination of pricing and the creation of local institutions can really be a most effective mix for achieving a more sustainable use pattern.

Electricity Pricing for Groundwater Irrigation in the Hard Rock Areas of Deccan Plateau - Estimation of Willingness to Pay

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ABSTRACT

In this study we analyse the factors influencing the probability that farmers would choose to pay for electricity on pro-rata basis for pumping groundwater for irrigation. We also assess the rates they would be willing to pay if electricity supplies are assured. Finally we document farmers' reactions towards the basis of pricing electricity and draw implications for policy For the study, a random sample of 35 farmers was chosen in each of the "dark", "grey" and "white" talukas of Kolar district in Karnataka state. A total sample of 105 farmers was used to estimate the conditional probability that farmers would choose to pay on a pro-rata basis and their willingness to pay electricity charges.

Based on our sample, 43% of farmers prefer to pay for electricity on a pro-rata basis at a rate of roughly 18.48 paise per Kwh. The remaining 57% prefer to pay on a flat rate basis Willingness to pay declined with increases in the proportion of farm profits from perennials and vegetables. This suggests that measures which promote efficient water application technologies for perennial crops may be a feasible avenue for reducing the demand for groundwater and hence electricity.

It is crucial to recognise that while it is easy to grant subsidies and benefits, it is extremely difficult to regulate or withdraw them once they are introduced Hence, in areas where farmers are ready to pay on a pro-rata basis, electricity and groundwater metering could be introduced on a pilot basis. If this could be done, it would be desirable to draw the attention of farmers toward efficient use of water by subsidising shifts to less water intensive crops and efficient irrigation technologies. This would require investment in extension to convince farmers of the need for efficient use of scarce resources such as groundwater and electricity

INTRODUCTION

Groundwater extraction in hard rock areas is primarily through irrigation bore wells and traditional dug wells. Unlike traditional dug wells, electrical power to lift groundwater is a strong complement of borewell technology. Policies such as rural electrification, flat power tariffs, and the provision of irrigation well loans on soft terms have been implemented in order to increase groundwater irrigation These policies, combined with the degradation of other common property water resources such as irrigation tanks have increased the demand for

groundwater and led to an exponential growth in borewell investments.[23] Expansion in the number of irrigation pumpsets has generated its own problems

Electricity supplies in Karnataka state are the worst in the whole country with the exception of Bihar. Kolar district in the south-eastern section of Karnataka is a highly drought prone area. It contains the largest number of borewells in the State. Farmers in the district face problems due to. (1) high borewell failure probabilities[24] and, (2) irregular and inadequate electrical power supply As a result of these problems, farmers in the district are increasingly demanding improvements in power supply for their irrigation borewells. The first problem results in long term adjustments on the farm while the second problem forces farmers to make short term adjustments in the timing and amount of irrigation. In addition, poor electricity supplies force farmers to bear high costs for pump repairs, construction of surface storage structures and time and labour in farm management.

The state electricity boards (SEBs) at the macro level face an entirely different set of problems According to the National Council of Power Utilities, about 80% of the losses suffered by the SEBs are a result of policies to provide low (in some cases zero) power tariffs for irrigation wells[25] In Karnataka State, farmers have been required to pay for electricity to pump groundwater at a fixed rate based on pump horsepower (HP) since 1982. This situation further eased in April 1992, when even the flat rate was eliminated for pumpsets of up to 10 HP In Karnataka, about 98% of all the irrigation pumpsets are below 10 HP capacity. Thus, for most of the farmers the marginal cost of pumping is close to zero As Figure 1 indicates, the flat rate policy has virtually doubled the use of electrical power for irrigation in Karnataka.

FOCUS OF THE STUDY

In this study we have attempted to analyse the factors influencing the willingness of farmers to pay for electrical power on a pro-rata basis Next we have analysed the rates at which they would be willing to pay if electrical power is provided in adequate quantities at the right time Finally we have documented farmers' reactions to alternative electricity pricing structures and have drawn implications for policy

STUDY AREA AND DATA BASE

In Karnataka state, demand for electricity is greater than supply which particularly affects farmers using groundwater from borewells Primary data for the study were collected from "dark", "grey" and "white" talukas of Bangalore and Kolar districts. Groundwater use in these districts is heavy and farmers frequently face problems due to inadequate and irregular power supply. A random sample of 35 farmers was chosen in each of the "dark", "grey" and "white"

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[23] For instance, the number of irrigation pump sets in Karnataka grew from 3 lakh sets in 1980-81 to 8 7 lakh sets in 1992-93

[24] N Nagaraj, 1993, Assessment of borewell failures in hard rock areas of Karnataka, PG Seminar report (unpublished), Dept of Agri Economics, UAS, Hebbal Bangalore

[25] N Vasant, Finances of State Electricity Boards, National Council of Power Utilities, Vol 5, No 4. 1987 pp 18-26

talukas. Borewell failure probabilities for each of the areas[26] in Kolar and Bangalore districts ranged from 0.55 to 0 65. There was no distinct difference between the three areas. In addition, cropping patterns and the problems faced by farmers regarding the supply of electricity were uniform in all study sites. Data from 105 farmers was pooled for this study in order to estimate the conditional probability that farmers would choose to pay on a pro-rata basis and the rate at which they would be willing to pay for electricity.

The crop pattern in the study area is dominated by commercial perennials and seasonal annuals. On average, about 40% of the gross irrigated area is occupied by perennials like mulberry (for sericulture), grapes and coconuts. Another 40% is devoted to vegetables (potato, tomato, onion, chilies and khol). The remaining 20% is occupied by food crops such as ragi, maize, popcorn and paddy. Vegetables are grown in rabi and summer, while food crops are grown in kharif Due to these factors, farmers use groundwater intensively. As mentioned earlier, irregular power supply is a rule rather than an exception in the study area in all the seasons and particularly in summer. For a farmer's committed cropping pattern, there is always a committed water demand.

Due to the problem of erratic and inadequate power supply, some of farmers have devised coping mechanisms. Most farmers have installed automatic starters which remove the necessity of pump monitoring. They have also constructed earthen storage structures for water storage so that pumping can occur whenever power is available This also enables them to utilise water from low-discharge wells.

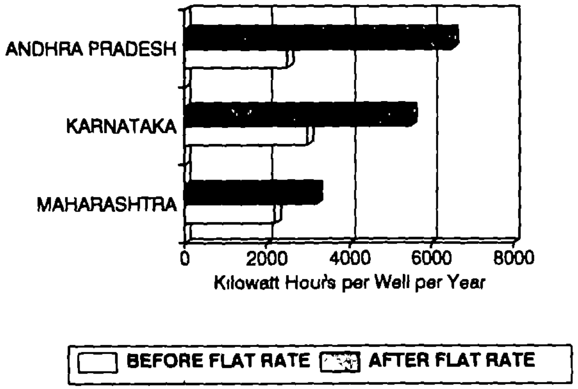
EMPIRICAL FRAMEWORK

In this study we hypothesise that the probability that farmers will choose to pay for electricity on a pro-rata basis decreases with: (1) the proportion of profits from perennial crops (PERIPROF); (2) the proportion of profits from vegetables (VEGPROF); (3) the kilowatt hours of electricity used per acre[27] (KWH); and (4) the proportion of area irrigated (IRRGAREA). The rationale behind the choice of these variables is provided below.

PERIPROF is the proportion of net return obtained from perennial crops to the gross profit. VEGPROF is the proportion of net return obtained from vegetable crops to the gross profit. The crops under both PERIPROF and VEGPROF are commercial crops and require large amounts of water.

Electricity Use before and After the Flat Rate.Policy in Deccan States

Fig-1



We hypothesise that as PERIPROF and VEGPROF increase, the proportion of groundwater used increases. This in turn increases the demand for electrical power Farmers who are highly dependent on groundwater pumping are less likely to be willing to pay for power on a pro-rata basis Similarly the farmers' preference towards pro-rata pricing is likely to fall with increases in the KWH used per acre. The more they use, the more likely they will be to prefer flat rate policies. The variable IRRGAREA should also have an inverse relationship with the farmers' preference towards a pro-rata basis of payment. In analysing the data, we have removed the scale effect in each explanatory variable to avoid multicollinearity problems

The probability P that farmers choose to pay on a pro-rata basis provides a sound basis on which pricing policies can be developed. The odds-ratio (= P/(1-P) indicates the ratio of the number of chances in favour of paying electricity charge on a pro-rata basis to one chance of preferring not to pay on a pro-rata basis (or one chance of preferring to pay on a flat-rate basis) The likelihood function of the logarithm of the odds (ratio) that farmers would choose to pay on a pro-rata basis is construed to depend upon the explanatory variables discussed earlier. The probability P that farmers pay on a pro-rata basis is estimated from the likelihood function of the logarithm of the odds (ratio) given by:

$$\text{Log}_e\ [(P/(1-P)] = A + B_1\ (\text{PERIPROF}) + B_2\ (\text{VEGPROF}) + B_3\ (\text{KWH}) + B_4\ (\text{IRRIGAREA}).$$

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[26] N Nagaraj, Op.cit.

[27] The total kilowatt hours of electricity consumed by irrigation well pumpset is computed as under A one HP pump run for one hour consumes 0 75 KWHs of power In the study area, the farmers on an average irrigated for 265 days in a year The $\text{KWH} = \frac{\text{(HP of pump)(0.75kwh)(No. of hours pumped)(265 days)}}{\text{(area irrigated)}}$

The conditional probability for the overall effect of all the explanatory variables is given by the estimated P (at the arithmetic mean level of variables).

Next, we have estimated the willingness to pay (WTP) of farmers towards electricity charges. The farmers were asked to indicate their WTP for a (unit or) kilowatt hour of electricity If a farmer mentions the pro-rata basis to price electricity, then the actual charge mentioned by that farmer was considered as WTP On the other hand, if a farmer mentions flat rate as the basis to price electricity, then that farmer's WTP is considered as zero, since the farmer's marginal factor cost is zero This WTP is the marginal willingness to pay (MWTP) since it measures the willingness to pay of each individual farmer The MWTP is estimated from the function

$$MWTP = A + C_1 (PERIPROF) + C_2 (VEGPROF) + C_3 (KWH) + C_4 (IRRGAREA).$$

As the MWTP includes both zero and non zero observations, the OLS does not provide efficient estimators of parameters for the explanatory variables. Hence TOBIT regression which uses MLE procedure has been used to find efficient estimates of MWTP. The total willingness to pay and the consumer surplus realised at the average level of use of electricity are also computed.

RESULTS

Roughly 43% of farmers in the sample choose to pay electricity charges on a pro-rata basis on the condition that the electricity supplies are timely and at correct voltages. Interestingly the MLE estimate of the probability that farmers prefer to pay on a pro-rata basis is also found to be 0.43 (Table 2).

The logit function correctly reflected farmers' preferences as indicated by the high percentage of right predictions. The probability that farmers choose to pay on a pro-rata basis declined significantly with increases in the proportion of profits from perennial crops and with increases in the proportion of profits from vegetables. The probability also declined with increases in the consumption of electricity per acre and increased with the proportion of irrigated area, but the coefficients were not significant.

Thus, whenever farmers felt that they would be using more KWHs of electrical power, they preferred to pay the SEBs on a flat rate basis, and whenever they felt they would be using fewer KWHs of electricity, they preferred to pay on a pro-rata basis This is perfectly rational from their point of view

The average power consumption is around 17,000 units for those who preferred pro-rata tariff and around 18,000 units per year for those who preferred to pay on a flat rate basis (Table 2) The proportion of profits realised from the commercial perennial crops, vegetables and food crops did not differ much between the two groups of farmers The total area cultivated however was more for the group of farmers who chose to pay on a flat rate basis, which however does not offer any substantial explanation for their response

Considering the farmers' WTP towards electricity charges (Table 3), we find the estimate of MWTP to be about 18 paise per unit, if the electricity were supplied regularly and adequately. The MWTP declined significantly with increases in the proportion of profits from perennial crops and vegetables as hypothesised earlier. The MWTP declined with the quantity of KWHs used per acre and increased with the proportion of area irrigated However the coefficients were not significant for these variables

The results indicate that for every 1% increase in the proportion of profits realised from perennials, the MWTP declines by 7 paise per unit. Similarly for every 1% increase in the proportion of profits realised from vegetables, the MWTP declines by around 6 paise per unit. At a willingness to pay of around 18 paise per unit of electricity, we estimated the farmers' total willingness to pay as Rs 2982 for an average use of 6078 KWHs per acre. The total electricity bill would be Rs 1145, while the consumer surplus realised by farmers would be Rs. 1837 per acre. Hence the consumer surplus per acre at flat rate or zero marginal cost of power represents their total willingness to pay Rs. 2982 per acre.

Farmers' Reactions to Electricity Pricing Alternatives

As obtained from the logit analysis, the probability that farmers choose to pay on a pro-rata basis is 0 43 The farmers were asked the strategies they would adopt if electricity is priced on a pro-rata basis About 26% indicated that they would shift the crop pattern in favour of perennials such as mulberry, mango, coconut, eucalyptus, and seasonal crops like ragi and groundnut. About 30% indicated that they would reduce the area under irrigation while about 11% indicated that they would prefer to sell the water and abandon farming. About 16% commented that water yield from their wells fluctuates greatly and, given the high rate of borewell failure, they demanded that there should be no charge for electricity.

CONCLUSIONS AND IMPLICATIONS

The study estimated that around 43% of farmers would prefer to pay electricity on a pro-rata basis at around 18.48 paise per unit. Their willingness to pay clearly declined with increases in the proportion of profits realised from perennials and vegetables This calls for measures which promote efficient irrigation technologies at least for perennial crops

The domestic resource cost of production of electricity is around 1 rupee per unit. At present the entire cost of electricity is borne by the SEBs. At a recently held conference of power ministers, there was a recommendation that the State Governments should pay the SEBs at the rate of Rs. 0 5 per unit towards the supply of electricity to irrigation pumpsets. From this study, we find about 43% of farmers are willing to pay around Rs.0 18 per unit on a pro-rata basis, and the remaining 57% still prefer to pay on flat rate basis. It may not be difficult to draw the attention of farmers towards efficient use of water by charging on a pro-rata basis

and subsidising the adoption of efficiency measures such as shifts to less water intensive crops and alternative irrigation technologies. This would increase the total benefits both to society and farmers

This study would be more realistic if, on a pilot basis, electric meters could be installed on a sample of representative farms. Data could then be collected and analysed to confirm the preliminary results presented here.

Table 1. Probability that Farmers Choose to Pay on a Pro-rata Basis towards Electricity Charges

Explanatory variable	MLE estimates of logistic regression coefficient	t-value
PERIPROF	-2.9783	-1.75*
VEGPROF	-2 7007	-1.69*
KWH	-0.00002679	-0.46
IRRGAREA	0 5161	0.427
CONSTANT	2.1561	1.337

Likelihood ratio test = 3.57 with 4 degrees of freedom
Percentage of right predictions = 60
Conditional probability that farmers prefer to pay on pro-rata basis = 0 43

Note: * = significant at 5 per cent level

Table 2. Average Electricity Consumption among Farmers Who Prefer Pro-rata and Flat Rate Basis

Details	Pro-rata basis	Flat rate basis
1 Proportion of farmers WTP	0.43	0.57
2. Electrical power consumption per farm per year (kilowatt hours)	17,353	18,283
3. Profit (Rs. per farm)	26,590	29,270
4. Proportion of profits from perennial crops	0.43	0 455
5. Proportion of profits from vegetable crops	0 42	0.44
6. Proportion of profits from food crops	0.15	0.11
7. Irrigated area (acres)	3.53	3.47
8. Total cultivated area (acres)	9.59	11.48

Table 3. Willingness to Pay by Farmers to Pay on a Pro-rata Basis towards Electricity Charges

Explanatory variable	MLE estimates of Tobit regression coefficient	t-value
PERIPROF	-0.7372	-1.60**
VEGPROF	-0 5917	-1 39*
KWH	-0 000009711	-0.59
IRRGAREA	0.20517	0.59
CONSTANT	0.52	1.18

MWTP at mean values of explanatory variables	Rs 0.1848
Total willingness to pay at mean value of KWH	Rs. 2982 0 per acre
Total electricity bill per acre at rate of Rs. 0.1848 per unit	Rs 1145 0per acre
Consumer surplus at mean KWH and mean MWTP	
Average electricity consumption per acre (kilo watt hours)	Rs.1837 0 per acre
	6078.0

Note: ** = significant at 10 per cent level, * = significant at 15 percent level

End Notes

1. For instance, the number of irrigation pumpsets in Karnataka grew from 3 lakh sets in 1980-81 to 8 7 lakh sets in 1992-93

2 Nagraj, N. (1993). Assessment of Borewell Failures in Hard Rock Areas of Karnataka PG Seminar Report. Hebbal, Bangalore. Dept. of Agri Economics, UAS. (Unpublished).

3. Vasant, N (1987)· "Finaces of State Electricity Boards". National Council of Power Utilities. Vol 5, No 4, pp. 18-26.

4. Nagraj, N. op.cit.

5 The total kilowatt hours of electricity consumed by irrigation well pumpset is computed as follows: A one HP pump running for one hour consumes 0.75KWH of power. In the study area, the farmwes on an average irrigated for 265 days in a year

$$KWH=\frac{(\text{HP of pump})(0\ 75\text{kwh})(\text{No of hours pumped})265\text{ days})}{(\text{area irrigated})}$$

VIKSAT ACTIVITIES

MISSION

"VIKSAT aims, through interaction of Government and Non Government Organisations and People's Institutions, for strengthening of people's institutions with active participation of both men and women from all sectors of the community for equitable, gender sensitive and sustainable development and management of natural resources"

ACTIVITIES

VIKSAT's two major programme areas are Joint Forest Management (JFM) and Participatory Groundwater Management. VIKSAT works directly with the village communities in its field projects in Bhiloda taluka of Sabarkantha district and Kheralu taluka of Mehsana district

The role of VIKSAT in the field programmes is to facilitate emergence of community organisations, build their technical and organisational capacities through training, enable their increased access to government schemes and funds and assist them in implementing management activities. The focus is to expand the scope of participatory natural resources management both in magnitude and quality

VIKSAT also performs the role of a resource centre VIKSAT provides support to other NGOs, government organisations and community organisations working in the state through newsletter and publications for information dissemination, training for capacity building and process documentation for sharing experiences

VIKSAT is publishing a bimonthly newsletter "Vasundhara" in Gujarati for wider dissemination of knowledge about issues, concepts, practices and experiences in natural resources management VIKSAT has recently initiated a network of people's institutions and NGOs working in the forestry sector in the state with a view to strengthen people's institutions

VIKSAT is the Regional Resource Agency, appointed by the Ministry of Environment and Forests, for facilitating the National Environment Awareness Campaign (NEAC) in the state of Gujarat since 1988

VIKSAT was set up in the year 1977 as an activity of Nehru Foundation for Development (NFD), a registered charitable trust founded by Dr Vikram Sarabhai VIKSAT's activities are governed by a council of management consisting of eminent personalities in the field of Natural Resources Management