IRRIGATION MANAGEMENT NETWORK

Linden Vincent, ed

NEWS FROM THE FIELD: GROUNDWATER DEVELOPMENT AND LIFT IRRIGATION

News from Tunisia, Mali, Sub-Saharan Africa, Bangladesh and South India

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Comments received by the Editor may be used in future Newsletters or Papers

NEWS FROM THE FIELD

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Introduction

This paper on *News from the Field* is a new venture for the Irrigation Management Network. We plan to use it for the longer letters we receive, and for summaries of work undertaken which are sent to us by Network members.

This first set carries some of the responses to a paper highlighting information needs in groundwater development and pump technology for irrigation. This was circulated to IMN members who had indicated an interest in these topics on their Network registration forms. We are still processing the information received, but hope to publish more material, and a discussion of the paper circulated, in a forthcoming Newsletter. If you have any comments on these papers, please write to us.

STUDY ON RATIONALISING GROUNDWATER USE BY ELECTRIFICATION OF SHALLOW WELLS[1] - May 1990

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1. INTRODUCTION

Groundwater is being over-exploited both by electrification and by illegal digging of shallow wells. In light of this, the Ministry of Agriculture set up a study to review options for rationalising groundwater use. Controlled electrification seems to be the best means available, allowing precise monitoring and evaluation of water consumption.

2. PRESENT SITUATION OF GROUNDWATER RESERVES

The electrification of water-pumping in shallow wells by STEG (Electricity and Gas Department - Societe d' Electricite et du Gaz) has been placed under the authority of the Water Resources Administration (Direction Génerate des Ressources en Eau) in an attempt to reduce over-exploitation. Zoning has been introduced; in the prohibited areas electrification for pumping has been forbidden and in the 'safeguard' zones electrification is only permitted under certain conditions. Only in areas where groundwater reserves do not seem to be in imminent danger of over-exploitation is electrification proceeding without restriction.

Despite these protective measures, proliferation of electrified pumping has not been slowed. This situation prevails even in the prohibited areas where groundwater continues to be more and more dangerously over-exploited.

The strategy adopted to safeguard groundwater evidently requires revision, especially since it has been rejected both by farmers and by development and finance organisations. Farmers, who know the difficulties and handicaps created by diesel pumps and who are aware of how the electricity

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1 A 'shallow well' is no deeper than 25 m.

grid is developing in rural areas, constantly ask for their wells to be electrified.

It is already a fact that Tunisia's groundwater is over-exploited. This stems directly from increased withdrawals from electrified wells. The annual increase in the discharge of electrified wells is greater than that of wells equipped with diesel pumps. On average, electrified wells now discharge twice the average annual volume pumped by wells equipped with diesel pumps.

3. RESULTS AND INTERPRETATION OF STUDY

According to the results obtained from the study carried out in the provinces of Bizerte and Nabeul and after comparing real water consumption rates with theoretical plant needs, the following conclusions can be drawn:

- Water consumption rates tally with the theoretical level of crop needs for shallow wells which are equipped with diesel pumps;
- Whichever pumping equipment is used, electrical or diesel, water consumption rates on shallow wells are double those of deeper wells for the same irrigated area and cropping pattern;
- Holdings where shallow wells are electrified pump twice as much as those where the wells are equipped with diesel pumps (because electric pumps can be operated longer or more frequently);
- Large holdings (greater or equal to 4 hectares) use smaller amounts of water than in theory they need because farmers do not cultivate the full area under irrigation. Typically one family can irrigate 1 hectare depending on water availability, water wastage and intensity of land use. This can equally be the case of shallow wells with small pump yield. The following is an example: 972 metres'/hectare (m^3/ha) in summer for a surface of 4 hectares;
- On the other hand consumption is clearly increased for a small area. This can be explained since pumped discharge is greater than the theoretical design flow which will provide the water requirements of a small plot.

Real examples:

12.150 m^3/ha during the summer for a parcel of 0.4 hectares
11.097 m^3/ha during the summer for a flow of 5 litres/second (1/s) and a surface of 1 hectare.

In general, water consumption in winter exceeds plant water needs. Water wastage occurs during this time of year. *(However, some of this water may be important for leaching purposes. Editor)*

- Water consumption is correct regardless of holding size and flow rates, where water-saving systems are in use (those encountered include sprinklers and mobile tubing).

A certain caution should be exercised over these findings since they are drawn from a study of only 36 surface wells. They also need to be checked against the results of studies which will be sent in by all the Regional Agricultural Development Offices (CRDA - Commissariat Régional au Développement Agricole). These results, though, do seem valid, and even predictable. The main point to note is the tendency to over-exploitation by a shallow well or farm with certain characteristics. A well or farm with these characteristics could be identified and studied over the longer, term to see how extension advice can increase an owner's awareness of the various ways in which the resource may be exploited.

Certain practical proposals, based on these conclusions, are now presented, to reduce groundwater use while at the same time permitting electrification of shallow wells.

4. CRITERIA FOR EVALUATING GROUNDWATER OVER-EXPLOITATION

Agricultural production in the private sector is relatively well developed, primarily in those irrigation schemes where the rate of intensification is highest. From time to time, nevertheless, anomalies in water resources use are noted.

The illicit creation of shallow wells, electrification in prohibited areas or 'safeguard' areas or, quite simply, water consumption exceeding requirements (see study results), demonstrate how ignorant farmers are of basic technical ideas necessary for good management of water resources.

Once these basic ideas have been grasped at the popular level, they could help reduce groundwater depletion and saline water contamination. The aim is for farmers to pump only what they need for a given area of crops and reduce wastage. However, the danger is that these efficiency measures may encourage farmers to pump the same amount and irrigate a larger area proportional to waste water 'saved', which must be avoided.

The criteria which need to be defined to act on water consumption are:

- water needs in the private sector
- specifications of equipment to be installed
- corresponding energy needs.

It should be borne in mind that each shallow well represents a unique case and so generalising one piece of information or one result is problematic. The present study can only be a framework within which to place shallow wells which have similar characteristics. Therefore the characteristics of the irrigated parcel and of the shallow well must be known and indicated on the form requesting electrification. This must first be filled in by the person concerned, then by the Administration.

The parameters to be ascertained for a farm requesting electrification are:

- the number of the well
- the hydrogeological formation tapped
- the depth of the static and dynamic levels of the well
- the total surface area of the farm
- the crops to be irrigated

Then, with this information, the parameter limits to be calculated are:

- the theoretical water needs of the holding
- the maximum power of pump to be installed
- the maximum energy consumption for the year and for different periods of the year (winter, summer and peak times winter and summer).

5. PROPOSALS

Bearing in mind that energy conservation as well as water conservation is now of concern, an improved gravity irrigation system would be most appropriate for water distribution after pumping, especially since most of the underground reserves are relatively saline and require an extra quantity of water to flush out the salts.

By the same token, before any final decision is taken on electrification the possibility of equipping wells with renewable energy should be studied. Drip irrigation might be appropriate.

(a) The minimum tariff in Kwh as for improved gravity-fed systems should be applied up to maximum consumption levels. For any volume pumped which is greater than this, a penalty tariff will be applied. This will be the case if the infringement takes place for the whole winter, for the whole summer or for two consecutive months in the winter or the summer.

(b) Since total water use depends on the volume and duration of pumping,it is imperative to reduce pumping times, which should be carried out by STEG.

(c) Piezometers ought to be installed as an extra precaution in critical zones where saline water contamination threatens a groundwater reserve and also where there are concentrations of shallow wells. These would enable effective monitoring of changing water levels and water quality, of both shallow and deeper aquifers.

6. CONCLUSION

The findings of this study on electrification ought to be put into effect at the regional level by water resources technicians from the CRDA, and by regional district level technicians from STEG. On one hand this would fix the maximum energy requirement in relation to the depth of the dynamic level of the groundwater reserve and on the other would fix the length and timing of electrical supplies corresponding to the pump yield from that reserve.

A copy of the table (or the graphs) of the maximum energy requirement for a given region ought to be handed over to each District in the region so that tariff scheduling bands based on energy consumption can be worked out.

A standardised form ought to be drawn up for each hydrogeological formation in each province. Each time a request for electrification was made, such a form would have to be filled out by:

(a) the farmer, who would note down all the specifications of the holding and the well;

(b) CRDA personnel, who would add the characteristics of the groundwater reserve and the maximum water requirements in power and energy per hectare.

STEG, for its part, in collaboration with the Administration, would prepare a proposal for new tariffs based on the degree to which power and energy are overused, and also a proposal for power supply timings.

A 'STEG information sheet' ought to be produced for each province and given to any farmer who wants well electrification so that the farmer is aware of procedures.

A case study is now underway to gauge the economic and financial effects of this electrification project, with a view to its being implemented as soon as is best. New laws are now being drawn up in line with this study to determine how electricity is to be used. It is also intended to create farmers' associations for managing the system and implementing the guidelines.

DEVELOPING VILLAGE LIFT IRRIGATION IN MALI

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GUAMINA is an NGO undertaking development actions in response to the needs identified by local people and making use of their full participation. Our actions are strongly focused on food self-sufficiency through small-scale irrigation schemes for rice and market gardening. At the moment GUAMINA is involved in four main irrigation scheme projects. In this paper we discuss the project in Boya, 60 km from Gao in the seventh region of Mali.

From the outset, though, it must be stated that rice or market garden irrigation schemes cannot be undertaken in isolation or they are bound to fail. Other components are necessary, such as small farmer organisation around the scheme and training in rehabilitation and management techniques (which consist of small farmer organisation, literacy training, natural resource management and environmental protection).

Earlier the Boya scheme was under flood recession agriculture. The rising of the River Niger, which flows near the village of Boya, inundated that part of the plain and the local people made use of this to grow rice. With the drought of recent years and the very low level of the rise in the river, the plains were no longer sufficiently inundated to guarantee a good rice harvest. This situation led the local people to develop the plain, seizing upon GUAMINA and another Canadian NGO for this work.

A preliminary study was conducted to discuss the development plan and how the work would be carried out. This was followed by the project document worked out on the basis of the preliminary study and with the full participation of the people concerned. The project outline is as follows:

1. GOAL AND OBJECTIVES

The project is aimed at increasing agricultural production by controlling and using efficiently the river waters in order to meet the needs of the people of Boya in relation to food self-sufficiency (development of a small-scale irrigation scheme, and traditional fields). For this the project must guarantee the development of infrastructure to increase the capacity of agricultural production:

- securing agricultural production by total water control;
- local consumption of foodstuffs;
- building up reserves;
- sale or exchange of supplies for other foodstuffs;
- training in management techniques of men and women involved in the irrigation scheme;
- training local people to be able successfully to take over the project when the NGOs withdraw.

2. PROJECT SUPPORT STRATEGY

GUAMINA's approach aims at involving as many people as possible in community development. The ground work with local people represents the first step in reaching this goal. Priorities are to be set out by the local people in relation to their needs. The project will proceed in this way in the village of Boya stressing, of course, the other necessary components.

3. PRESENT SITUATION ON THE BOYA PROJECT

(a) What has been learnt from the Project, at the level of small-scale irrigation?

Having been running for four years, the Boya Project is at the moment in its last year of funding. During these first four years much important work has been carried out, with development of a small-scale irrigation scheme covering 50 ha with individual parcels distributed according to criteria established by the local people themselves. This scheme extends over more than 50 ha with two motorpumps and a canal system which allows each user to irrigate their holding at their convenience.

The main thing learnt is that the scheme itself originates with the people, which means that the small farmers already had expertise in rice-growing techiques, in this case setting up the nursery beds, re-planting, respecting fertiliser quantitites, organisation of watering and of seedling densities. Also we can add awareness of the crop calendar, of the over-lapping of mineral

fertilisation as a function of the plant growing cycle and crop diversification on the scheme: sorghum IRAT-204 (or sorghum - Djebock variety, which is very well adapted to the area) and of Gorom-Gorom variety. The development of the scheme has been carried out with a lot of consultation and technical support from the two NGOs.

During high river levels the scheme received river water and motorpumps were used less. During the winter (the recession period of the river), however, the motorpumps were the only means available for irrigating the fields. This is why instead of double-cropping rice, the project adopted growing Djebock sorghum as the winter season crop. Market gardening should be added as well.

Traditional Fields

Rice growing in the bas-fonds (floodplains) is an activity which goes back generations in this area. The small farmers not only are totally expert in the different growing techniques but also have extensive knowledge of all the varieties cultivated locally. The need to conserve local strains must also be stressed. The disappearance of traditional varieties is a danger and a menace for this activity and might in the longer-term give rise to the disappearance of certain varieties if an adequate solution is not found. For the present, however, essentially three main varieties of local rice are grown in the region (Moberi, Tetere, Kossa), each made up of various strains maintained traditionally until the present.

In the traditional fields, growing is done as best as possible since the amount of flooding cannot be determined in advance.

Recently the river rise no longer allowed the traditional fields to be irrigated. The project therefore recommended supplementary irrigation, which is looking after the young shoots through using the motorpump until the river water arrives. At the times when the rise is small there will be recourse to the system of backup irrigation using motorpumps.

Also the project has introduced the system of planting carried out from a rice seedbed collectively maintained, in place of hand sowing in the traditional fields. This planting system will avoid the uncertainties of the floods which are often too strong or too weak.

(b) Problems met with:

- Inability to deal with the essential technical issues, in particular sticking to the crop calendar and the overlapping of mineral fertilisation as a function of the plant growing cycle;
- Lack of rest for the small farmers in the annual double-cropping;
- Overlapping of work times (irrigation scheme and traditional fields);
- Management of infrastructure, mainly the motorpump and irrigation network.

These different points are at present being dealt with in detail and adequate solutions are at present being recommended. These are to make investments profitable and to encourage take-over by the small farmers.

With a view to this, the project is in the process of putting the emphasis on:

- Training the small farmers and follow-up of the scheme;
- Awareness and extension of modern techniques;
- Improving the system of supplementary pumping for the traditional fields;
- Conservation of, and experimentation with, traditional strains with the intention of determining their potential and of improving cultivation methods.

(c) What has been learnt: In all, the project has:

- Carried out studies of development sites (50 ha);
- Set up infrastructure intended to consolidate the scheme and put the tools for working on the scheme at the disposal of the small farmers;
- Trained and introduced the small farmers to canal and masonry techniques;
- Achieved improved crop practices as much on the scheme as on the traditional fields;
- Diversified crops;
- Practised new techniques to produce seedlings in seedbeds of local strains used in the traditional fields;
- Achieved control and good water management from infrastructure created at the scheme level.

GROUNDWATER DEVELOPMENT FOR SMALL SCALE IRRIGATION IN SUB-SAHARAN AFRICA: TECHNOLOGY FOR SMALL SCALE GROUNDWATER IRRIGATION IN NORTHERN NIGERIA[1]

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INTRODUCTION

In northern Nigeria dry season vegetable cultivation has been practised for generations in the *fadamas* or seasonally wet bottom lands (Carter et al, 1983). These fadamas range from localised depressions to major river flood plains. Water is lifted from perennial rivers, water holes and wells by the locally constructed counterpoised device known as the *shaduf*.

This is a labour intensive, low capital cost device which permits the irrigation of approximately 0.1 ha (Nwa, 1981). The main crops irrigated by the shaduf are tomatoes, onions and peppers. Even in the more extensive flood plain fadamas this sort of lift irrigation is largely restricted to the banks of perennial water courses and to the margins of natural water holes.

The technical intervention in recent years has been the introduction of simple technology for the construction of shallow boreholes, together with handpumps and motorpumps, as alternatives to the shaduf. This has increased the potential area of vegetable cultivation back across the flood plain, to cover virtually the whole of the fadama, or at least those areas where the water table is no deeper than about 3-4 m below ground surface.

The method of borehole construction used is described in detail by the present author in BSADP (1984). A 50 mm steel pipe is jetted into the fadama soil by pumping water or bentonite mud through it and using this fluid to return displaced soil to the surface. Usually a temporary casing of about 100 mm diameter is driven at the same time as jetting proceeds, so

[1] A longer paper on this topic was first presented to the Geological Society of the UK in 1988. Please contact the author if you could like a copy.

that permanent 75 mm diameter linings can be placed to the required depth. The lower part of the permanent lining is perforated (saw-cut) PVC. Finally the temporary casing is removed and if necessary gravel can be poured around the well screen. This procedure of well jetting can be used to construct irrigation tubewells up to 10-20 m deep in favourable ground conditions (Carter, 1985). Moreover, the technique is cheap (see below), rapid and able to be carried out by relatively unskilled personnel.

More often than not in Nigeria the preferred system of water abstraction from jetted boreholes is by petrol driven centrifugal pump operating by suction lift. Handpumps have been introduced, but the uptake has been less widespread than with motorpumps.

Cost of and returns to irrigation with this system are summarised below:

Table 1: Costs of and Returns to Lift Irrigation by Motorpump in Northern Nigeria (after Chapman in BSADP, 1984)

Costs (N/ha)	
Labour	215
Seeds	199
Equipment (pump and tubewell)	600
Fertiliser	42
Fuel	360
Marketing	192
Total	**1608**
Receipts (N/ha)	4883
Gross Margin (N/ha)	3275

Note: Average farm holding 0.66 ha (sample size 58).

The gross margin of more than N3000 (then approximately US$4800) which was possible under the new technology at that time, compares favourably with Chapman's figure of N2163 which was obtainable by non-pump users (shaduf irrigators or residual moisture farmers), (BSADP, 1984). However,

it should be noted that the Naira has been devalued by a factor of more than twenty since the date for which these figures apply. Fuel is still cheap, but imported equipment is affected.

At a seminar in Bauchi State in 1984 various encouragements and warnings were made in relation to future groundwater development of this type. Despite the attractiveness of the concept - and uptake of technology by farmers has been very rapid - a number of areas of concern were identified. These included:

(i) The effects of upstream developments (dams) on both traditional and introduced fadama agriculture;

(ii) The lack of data concerning borehole yields, drawdowns and recovery rates in the fadamas;

(iii) A lack of hard information on groundwater recharge, especially in fadamas affected by upstream developments;

(iv) The lack of any legislative control on groundwater abstraction.

Many of these aspects have been studied in the period since 1984, although much work remains to be done. The following sections relate to these concerns and to developments which have occurred in recent years.

1. CONFLICT WITH THE FORMAL SECTOR

Not surprisingly much of the land which is suitable for large scale formal irrigation schemes is that which either is being used or could be developed for small scale irrigation (SSI). So far most of Nigeria's larger irrigation schemes are based on surface water developments (dams in the head reaches of major rivers), and much cultivated and cultivable fadama land has been submerged under reservoirs. Often as much land has been flooded as is commanded by surface water reservoirs in the relatively subdued relief of the north of the country. In addition the combination of dam construction and poor rainfall in recent years has meant that annual floods in the middle and lower reaches of the major rivers have not reached the same magnitudes as formerly. Recharge to the fadamas may have therefore been reduced, with obvious effects on resource availability for SSI.

The reduction in oil revenues in the present decade has reduced the availability of funds for investment in highly capital intensive surface water developments and this has been to the advantage of SSI.

The recent merger once again of the Federal Ministry of Agriculture (which previously looked after small scale development) and the Ministry of Water Resources (which promoted the large formal schemes) at least give the opportunity for a more rational optimisation of combined small and large scale developments.

2. GROUNDWATER EXPLORATION IN THE FADAMAS

The use of electrical, and more recently electromagnetic techniques for groundwater exploration, is well established in the crystalline rock areas of many parts of Africa. In the hard igneous and metamorphic rocks of the Basement Complex groundwater has been located in the weathered zone above fresh rock or in hard rock fractures. With the advent of electromagnetic (EM) profiling the older resistivity profiling (constant separatio traversing) is less used, and now surface geophysical exploration generally consists of a combination of EM profiling and vertical electrical soundings (VES), (see for example, Beeson and Jones, 1988).

It is only recently that the same techniques have been applied in alluvial environments, but a considerable degree of success has been claimed for them there too (Temple-Hazell et al, 1988). The following observations are summarised from recent work of Temple-Hazell's Water Surveys Group in the northern Nigerian fadamas.

Significant aquifers suitable for SSI are to be found in the layered or lenticular sands and gravels of alluvial deposits in the often very extensive (up to 10-15 km wide) major river floodplains. To be compatible with the presently used drilling technology and pumping systems, aquifers with rest water levels no deeper than 4-6 m and in which drilling to 10-15 m depth is adequate, must be located.

The procedures used have included routine EM profiling together with vertical electrical soundings at selected type locations. Computer simulation for VES interpretation has been essential because of the difficulty of manual curve fitting. The greatest difficulty in quantifying thickness of sand and gravel aquifers occurs when they are overlain by highly conductive clay

deposits which may be up to 6 m thick. Even in sequences of sands, overlying clays or silts, in turn overlying highly resistive bedrock, there is significant ambiguity in interpretation of both EM and VES results. However, the major ambiguity is in the predicted thickness of the conductive layer, not the more interesting overlying sand layer.

In all cases geophysical exploration needs to be backed up by drilling, but the advantage of the shallow alluvial environments under consideration is that they can be readily penetrated by low cost techniques such as jetting, auguring or vibro-bailing.

3. GROUNDWATER RESOURCE EVALUATION

The only detailed evaluation of aquifer properties and well characteristics in the Nigerian fadamas appears to be that carried out by the Water Surveys Group (1986). This work included constant rate and step-drawdown texts on 30 shallow wells in the fadamas of the Gongola, Jama'are and Dingaiya Rivers of Bauchi State.

Sand and gravel aquifers varied in thickness from less than 2 m-16 m (mean 6.6 m, 30 sites). Transmissivity (T) ranged from 100 - 10200 m^2/d (mean 1600 m^2/d). Storage Coefficients (S) were consistently high, ranging between 0.005 and 0.29 (mean 0.11). In some of the constant rate tests evidence of barrier boundaries was found after only 12 h of continuous pumping. Well efficiencies varied from 13-86%.

On the basis of a number of assumptions (mean T and S values, 100% well efficiencies expected abstraction rates of 6.71/s and a typical pumping duration of 6 h) drawdowns were predicted ranging from 0.1-2.0 m. Beyond about 15 m from pumped wells drawdowns were observed to be negligible. In the major fadamas it was estimated that well spacings of 100 m would not cause undue interference, and such spacings would be appropriate in terms of crop water requirements and abstraction rates.

Recharge in the major fadamas studied was observed to be complete in periods varying from one or two days to a maximum of 25 days following the onset of river flow. Water tables rose by about 2 to over 4 m in this period. This observation confirms previous assumptions of complete and rapid recharge, but the effects of major dams (e.g. Tiga, Dadin Kowa and

Challawa) are already being felt in reduced or non-existent flooding and consequent reduced groundwater recharge in other river valleys.

4. DRILLING AND WELL CONSTRUCTION TECHNOLOGY

The main low-cost drilling method used in the northern Nigerian fadamas is still that described in the Introduction - well jetting or washboring. More recently introduced methods include the use of a vibro-bailer (a steel bailer hand-vibrated inside PVC casing, using steel auger extensions as drilling rod) and the placing of drive points. The latter are particularly suitable in thin, otherwise unproductive aquifers - at least when 'Johnson' type (high open area) points are used.

Well screens and casings are normally of 75 mm PVC, the former being hacksaw slotted (usually 1 mm slots, although this is often too large). Slots of 0.5 mm are usually more successful. Open areas can be as little as 4% with hacksaw slots, and still less than 10% with bench slotted PVC. Screen lengths of 5-10 m are needed to ensure entrance velocities are kept within the normally accepted limits.

Well development is generally carried out only by overpumping, whereas surging has been observed to give much improved performance.

Direct connection of pump suction to well casings is reported to give significantly better well performance than the usual practice of lowering the suction pipe well down inside the screen.

The most recent estimates of drilling costs (by jetting or vibro-bailer to complete 9 m deep, 75 mm diameter holes) are US$150-20Q per well (Water Surveys Group, 1986). These are based on 320 wells per year for a drilling crew.

It is likely that the efficiency of the well jetting technique can be significantly improved through design modifications. Current research at Silsoe College is concerned with the detailed relationship between nozzle size and angle, water pressure, volume and upward velocity, and hole diameter. These relationships are being investigated under laboratory conditions, and the objective is to optimise drilling performance, especially when well linings are sunk at the same time as drilling. The use of bentonite and other drilling muds is also being investigated.

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GROUNDWATER MARKETS IN RAYALASEEMA: A NOTE

V Ratna Reddy and B C Barah

This paper is based on extensive fieldwork conducted in Rayalaseema[1] region of Andhra Pradesh during 1986-88, in connection with the project on 'Economics of Water Sharing in Droughtprone Areas'[2], sponsored by ICAR.

The research was taken up in order to identify some of the villages where well irrigation is prominent and groundwater markets are prevalent, and the problems they face. Our visits to the villages involved meeting the village heads, farmers and visiting the wells to get first hand information on well irrigation and water sharing. A number of villages were identified in Chittoor and Cuddapah districts where groundwater markets are prevalent. However, in Anantpur it was difficult to find a village with these features as there was no water in the wells during 1986-87 consequent to severe drought conditions in the past three years. Apparently, groundwater markets are more conspicuous in non-drought years and regions. Finally, three villages were chosen for the study where fieldwork was conducted for two full years. The fieldwork was conducted by field investigators who stayed in the village throughout the survey period.

The present note draws on the experience and data obtained from these three villages during the two-year study period 1986-88.

PROFILE OF THE VILLAGES

The selected villages are Karakambadi and Kadirimangalam in Chittoor district and Kondapeta in Cuddapah district: their salient features are presented in Table 1. All the three villages are of moderate size, and are well connected by *Pucca* (surfaced) roads to the major towns/district head quarters, which are all located within 20 km. As far as the social composition of the villages are concerned, backward castes along with scheduled castes and tribes are dominant in Karakambadi village, whereas forward caste populations dominate the social structure in Kadirimangalam

1 The districts of Kurnool, Anantapur, Cuddapah and Chittoor.

2 Gokhale Institute of Politics and Economics, Pune, and Department of Economics, University of Hyderabad, Hyderabad.

(Kammas) and Kondapeta (Reddys). It has been noted here that the social structure of the villages seems to play a vital role in the development of groundwater resources. It was observed that institutional support for well irrigation is marginal in Karakambadi village when compared to other two villages. Farmers expressed their reluctance to utilise available loans in this village due to the problems faced. The specific problems are: (1) it takes much time and effort to go around the offices in order to get the sanctions, and (2) nearly 50% of the sanctioned money would go towards bribing the officials. However, there are 2-3 well-to-do farmers who acquired institutional loans. On the other hand, in the other two villages very few farmers have expressed these problems.

Table 1: Salient Features of the Three Villages

	Karakambadi*	Kadiri	Kondapeta
No of households	600	200	200
Total population (NOS)	4000	600	
Total area (acres)	1000	300	200
% of area irrigated	75	90	100
Major source of irrigation	well/ tank	well/ tank	well
No of wells	100	60	100
Major crops grown	paddy and groundnut	sugarcane paddy and groundnut	betlevine paddy and groundnut

* Karakambadi consists of 5 hamlets

Of the three villages, the two villages in Chittoor district belong to the same geo-climatic region with similar soil quality. The cultivated lands of these villages can be categorised into uplands and wetlands. Irrigated dry crops like groundnut are grown in uplands and irrigated crops like paddy and sugarcane are grown in wet lands with the help of tank as well as well irrigation. The cropping pattern of these villages is presented in Table 2. The cropping pattern in Karakambadi is dominated by groundnut, whereas it is dominated by sugarcane in Kadirimangalam, and groundnut and betlevine in Kondapeta. The difference in cropping pattern, despite similar agro-climate conditions in the first two villages may be attributed to the poor resource base, and economic conditions prevailing in the first village.

Table 2: Cropping Pattern in the Sample Villages (%)

Crop	% of area under crops in: Karakambadi	Kadirimangalam	Kondapeta
paddy	25	28	4
groundnut	66	26	53
sugarcane	5	46	-
betlevine	-	-	43
others	4	-	-
Total	**100**	**100**	**100**

As indicated earlier, the farmers in Karakambadi are not able to mobilise institutional finance to develop groundwater and cultivate more renumerative crops like sugarcane. On the other hand, the farmers in Kadirimangalam are well supported by the cooperative sugar-mill in its vicinity. It not only provides concessional finance for digging wells but also provides material inputs for sugarcane. Although the sugar cooperative is located within 20 km of Karakambadi, its operations have not extended to it so far. As a result only a few well-off farmers grown sugarcane in this village. The resource crunch in the first village is also reflected in the greater depth of the wells across the villages, which is a major constraint to growing water intensive crops like sugarcane. It can be observed from Table

3 that the depth of 66% of the wells is below 50 feet in Karakambadi, whereas in Kadirimangalam 42% of the wells fall into this category.

Table 3: Depth of Wells Across Village

Depth of Well (in feet)	% of wells in: Karakambadi	Kadirimangalam	Kondapeta
below 50	66	42	7
51 to 150	28	55	38
above 150	6	3	55

In contrast, the picture in Kondapeta is quite different from the other two villages. Kondapeta is situated on the branches of river Penna. Though it comes under K C Canal, command water never reaches as it is situated in the tailend of the canal. However, because of its location on the branches of river it has rich groundwater resources when compared to the other two villages in Chittoor district. Kondapeta is traditionally a betlevine growing village. This village is buzzing with betlevine operations throughout the year. The high profitability of the crop has resulted in cash flows throughout the year and the village is conspicuously affluent as a result. In this village, groundnut and other crops are grown in the lands which are not suitable for betlevine cultivation. The wells in this village are mostly greater than 150 feet deep (see Table 3). Although the high water requirement of betlevine, as reflected in the depth-to-watertable, the groundwater is still reliable.

GROUNDWATER MARKETING

From our discussions with old farmers, it appears that groundwater marketing is as old as well irrigation in these villages. Well irrigation is not a new phenomenon in this region. Most of the wells in the sample villages are inherited from generations and hence old. In most cases the present owners do not know the age of their well, though a number of farms are going for new wells, especially in Kadirimangalam in recent years. The only changes that have taken place in recent times are energisation and deepening of wells. The depth of the old wells has almost doubled during the last 10-20 years indicating the depletion of water table consequent to energisation of wells. Except in Karakambadi, many of the wells in the other two villages are either bore-wells or in-well bores. In Kondapeta, a number of farmers have borewells on the river bed to facilitate uninterrupted water supply during summer. On the other hand, the very low adoption rates of rig technology in Karakambadi village can be attributed to capital constraints which are the consequence of their social and economic backwardness. Further, in this village only about 50% of wells have power connections and the rest use diesel pump sets. Whereas in the other two villages almost all the wells are equipped with electric motors. In the two villages in Chittoor district the horse power (HP) of the motors range from 3-5 HP, and in a few cases it is 7 HP, whereas in Kondapeta of Cuddapah district the HP ranges from 7-15 HP.

Selling and buying of water is a common phenomenon in these villages - at least for one season in normal years in the two villages of Chittoor district, while it is a round the year activity in Kondapeta of Cuddapah district. The magnitude of groundwater marketing in these villages is demonstrated in Table 4. It can be seen that more than 70% of the sample irrigated households are involved in groundwater marketing in one form or another. In order to understand various activities of groundwater marketing, we have grouped irrigated households into four categories, i.e. pure owners, joint owners, sellers and buyers. Pure owners are not involved in any kind of groundwater marketing activity. Joint owners are those who own the well or motor in partnership with one or more persons and sharing the water from the well. Joint ownership is observed in different forms. For instance, farmers become joint owners of the well by inheritance (through division of joint families). In this case farmers may have a jointly-owned motor, or separate motors. In some cases a well owner may join with a non-well owner to establish a motor on the well. In this case the well owner would be given preference in lifting the water. The other forms of groundwater marketing activities include water sellers and buyers. Water sellers are usually big farmers, while the buyers belong to the small farm size group who cannot afford to invest on a well. It can be observed from the table that marketing of groundwater takes place on a large-scale in all the villages. Even after taking out pure and joint owners, between 40-50% of the sample households in the villages are directly involved in water marketing.

Table 4: Distribution of Farmers by Groundwater Marketing Activities

Village	Pure owners	Joint owners	Sellers	Buyers	Total
Karakambadi	24 (30)	21 (26)	18 (22)	18 (22)	81 (100)
Kadirimangalam	26 (28)	18 (19)	20 (21)	30 (32)	94 (100)
Kondapeta	16 (19)	27 (32)	15 (17)	27 (32)	85 (100)
Total	**66 (25)**	**66 (25)**	**53 (20)**	**76 (30)**	**261**

* figures in brackets are % to the respective totals.

Water rates are charged on the basis of number of hours and horse power of the motor in all the villages and for all the crops, except in betlevine. For betlevine in Kondapeta a flat rate of Rs 20[3] per irrigation per acre is charged. This may be due to the high water demand of the crops which needs 4-6 irrigations per month throughout the year. Usually water buyers enter into an oral agreement with the sellers before they plant betlevine. In the case of other crops the charges are Rs I/hour per one HP motor. Kind payments, especially in the case of paddy, are also prevalent, usually 4 bags (76 kg each) of paddy are given as water charges for irrigating one acre of paddy. Though these rates are uniform for all the villages, the share of water charges in gross income of the crop vary from village to village depending on the yield rates as well as intensity of irrigation required.

3 In 1991, 20 rupees = $US 1.

As the buying and selling activities take place at an informal level and by oral consent, we have not observed any problems between buyers and sellers. It is generally understood that sellers will provide water to a buyer only after fulfilling their own requirements. In the case of multiple buyers, the distribution of water, i.e. who gets the water first from the sellers well, is on the basis of 'first come, first served'. That is, the person who approaches the seller first will get priority in the regular distribution of the water and he will be the last person in the event of seller withdrawing water supply due to paucity of water. In fact, in some cases where the well yield is high the distribution system goes as far as 1 km and the distribution systems, either field channels or pipe line, are laid by the buyer at his own cost.

GROUNDWATER DEVELOPMENT: SOME ISSUES

The experience of these three villages provide us three different developmental scenarios and helps us to raise some issues in groundwater development. Of these three villages, Karakambadi, a traditionally poor and backward village and Kondapeta, a traditionally rich village, stand at extreme poles. In Kondapeta private capital, accumulated over generations, dominates groundwater development. As such it does not face any problems, either economic or ecological, of groundwater exploitation as it follows the pattern established over years, and it is very unlikely that they would deviate from this pattern. It appears that the groundwater potential and the cropping pattern, though highly water intensive, are perfectly matched for the time being in this village.

On the other hand, Karakambadi suffers from capital constraints and negligence at official level which may be attributed to their lower social as well as economic status. Though these farmers are aware of the benefits of sugarcane crop and the available rig technology, which would facilitate growing the crop, only a handful of them grow sugarcane. These are some of the big farmers of the village who can afford to go in for deeper wells with rig technology.

The experience of Kadirimangalam is more interesting and revealing. This village is in transitory stage of development. It is a typical model of many such villages in various fragile resource zones of the country which are suffering from the reckless policies of the government. The establishment of a cooperative sugar-mill in this region in the early 1980s helped farmers

to enjoy the benefits of this highly remunerative crop. Prior to this sugar factory their cropping pattern was dominated by paddy and groundnut. It was hardly ten years after they started growing sugarcane and enjoying the profits before they felt the pinch of depleting groundwater resources. Most of the farmers have either drilled bore-wells or in-well bores which are financed by the cooperative sugar factory. In recent years most of the wells are unable to supply the water for sugarcane. As a consequence of deepening of wells, some of the existing dug wells have gone dry and water selling for sugarcane has almost stopped. In fact, in 1986-87 on some plots sugarcane crop had withered away due to lack of water. This, in'turn, prompted the farmers to go in for more and more deepening of wells and powerful motors, the latest being the submersible motors which cost around Rs 25 - 30,000. But this does not seem to be helping much. On the contrary, farmers are losing heavily. In fact, it was reported that in the summer of 1987-88 about Rs 10 million was spent in this village alone on new borewells with only 50% success rate (the cost of one well with submersible motor will be between Rs 50,000[4] - 75,000). It was also reported that some farmers got salt water when they drilled even deeper. After this the frustrated farmers started blaming the government for poor advice regarding the location of the wells. If the situation continues, the farmers may have to shift their cropping pattern, though they are not thinking of that option now.

Thus, natural resource planning needs more judicious planning and understanding of basic problems. Hasty and politically motivated decisions, like establishing sugar factories in low rainfall and water scarcity regions, prove detrimental rather than beneficial to the farming community in the long run. An appreciation of farmers' awareness and understanding of their resource structure is vital, and their involvement in the planning level would help in arriving at more appropriate policies. In this context, community participation of village community in solving their problems through institution of self-correcting mechanisms may be a viable proposition (Shah, 1990). But here the problem is that village communities at present are ill-equipped to organise themselves in order to solve their problems and hence, there is need for an outside organisation which can motivate and help the farmers in this regard.

As far as the problem of depletion of groundwater table in Kadirimangalam village is concerned two plausible solutions, at this juncture, can ameliorate

4 In 1986, US$ 1 = 1 Rs.

the conditions. One is that groundwater recharging mechanisms like percolation tanks would enhance the availability of water (supply side adjustment). Another is shifting the cropping pattern towards less water intensive crops (demand side adjustment). It may be noted here, that contrary to the popular belief, there are crops like mulberry, grapes, citrus, etc, which are as renumerative as sugarcane and have lower water requirements, but they have marketing and/or processing requirements (Vincent, 1989)[5]. Moreover, some of these crops are suitably adopted to the conditions of these regions. Therefore, more concerted efforts are required on the part extension service department in order to educate farmers on various alternatives available for them within the given resource constraints. And, the role of non-governmental organisations (NGOs) in this regard would be vital.

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5 *These crops also have high cultivation costs, and thus can only be grown by farmers with available capital, and the tenure security to produce tree crops. With good water supply, groundnuts, vegetables and fodder can be profitable (although at a lower level than fruit crops or sugarcane): they have lower cultivation costs and are less demanding on operational budgets. With unreliable irrigation, net returns are low on most crops, and farmers will not risk extensive use of inputs. Editor.*

GROUNDWATER DEVELOPMENT AND DEPLETION: PROSPECTS AND PROBLEMS IN A POCKET AREA OF BANGLADESH[1]

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Bangladesh is mostly underlain by unconsolidated to poorly consolidated thick sediments. In addition, the tropical monsoon climate characterised by high temperature, heavy rainfall and often excessive humidity is very favourable for extensive development of groundwater resources in the country. Groundwater, a renewable natural resource, is observed in Bangladesh to be in dynamic equilibrium consistent with the extraction by natural and artificial means and recharge from rainfall, flood waters and surface water bodies. Different techniques and concepts for the development of groundwater are being practised without detailed investigation of the resources and its overall management policy. For example, the groundwater development programme using deep tubewells (DTWs) started in the country in late sixties. But tubewells were installed initially almost without evaluating the hydrogeologic characteristics and development potentialities of the local aquifers. There are important factors in determining the amount and cost of groundwater that can be developed and in forecasting the consequences of development.

The groundwater development programme in Bangladesh has been suffering due to various reasons, of which insufficient hydrogeological data, poor and widely variable estimates of potential recharge and improper matching of well numbers and types to the identified groundwater resources are all very important. Although many authors have called for better planning (Rust, 1983; Haque, 1984; Radosevich 1983), little attention has been given to the after-effects of heavy groundwater withdrawal and consequently many alarming situations have been anticipated (Khan, 1988). Often individual events are extrapolated without scientific foundation. For example, reactions began when in Bogra, Jamalpur, Pabna and Chittagong (four

1 A full version of this paper, complete with hydrological data, is available from the authors.

districts of the country) groundwater level failed to return to the previous year's level at the end of recharge period (Bhuiyan, 1983). In Joydebpur (an *upazila)* region, the groundwater levels dropped 15 m below suction pump capacity during dry season and it was estimated that the groundwater table might go 50 m below the pump capacity at the end of this century (Anik, 1984). At the same time, due to depletion of groundwater level the moisture content in the top layer of the soil diminished causing the land to become dry and sandy. If this trend continued without control, then certain parts of the country, especially the northern part could become deserts in the long run (Anik, 1984). Heavy pumping of groundwater in the northern part of Bangladesh exhausted soil moisture within the upper shallow aquifer affecting agricultural crops, many fruit and deep, rooted trees and thus upsetting the natural econological balance (Khan, 1988).

However, many researchers did not agree with these predictions. It was observed that the highest and lowest static groundwater level at some locations in the northwestern part of Bangladesh (Rajshahi Barind area) came nearer the ground surface during 1987 after installing many deep and shallow tubewells, than during 1965-66 when there were no tubewells (Asaduzzaman, 1987). Asaduzzaman also reported that all types of trees and vegetation that grew in the area before installation of tubewells are still growing and no ecological imbalance have been observed.

We have completed a study of the Muktagacha upazila in Mymensingh, using test drillings and pumping tests. We studied monthly data on static water levels in 18 representative deep tubewells over eight years (1983-1990). We also estimated present requirements of groundwater based on total agricultural and domestic activities, made a field survey of existing vegetation in the dry season and interviewed experienced local inhabitants.

The aquifer in question is a single unit, layered with a mixture of fine, medium and coarse sands and sometimes with layers of gravels at the base. The aquifer was of the semi-confined/leaky type and possessed a good potential for development by 56 1/s (litres per second) to 85 1/s capacities deep tubewells. The thick clay layer above the aquifer limited the volume of storage in the upper part that restricted operation of suction lift pumps. The quality of groundwater in the aquifer was within the safe limit for irrigation purposes.

GROUNDWATER POTENTIAL

The overall development of the resources must be based on safe-yield which is actually the useable portion of the total dynamic component of the groundwater available within the zone of water table fluctuation. This component in the study area was essentially the result of the annual rainfall, seepage from surface water bodies and return flow from irrigated fields. The hydrologic safe-yield of the aquifer under study was estimated to be 621 millimetres (194.62 million cubic meters, MCM) for the dry season irrigation period with an allowable fluctuation of static water level of 12.42 meters. In fact, this safe-yield could be significantly increased by creating more recharge facilities through extending irrigation command area by abstracting more groundwater during dry season. The calculated safe-yield would allow water level fluctuation above mean sea level and would not create any possibility of saline water intrusion from coastal areas.

CURRENT UTILISATION STATUS OF GROUNDWATER AND EXTRACTION RATES

The utilisation of groundwater in the study area were being done by deep tubewells, shallow tubewells and hand tubewells. At present, 370 deep tubewells of capacities carrying from 56 1/s to 85 1/s, 50 shallow tubewells of capacities ranging from 14 1/s to 28 1/s and a large number of hand tubewells are operating over the groundwater basin. The amount lost from storage increased from 104.58 MCM in 1983 to 142.88 MCM in 1989, due to increasing extraction by continuous installation of new deep tubewells.

The effect of current rate of extraction was mainly focused on the position of static water level. The static water level started rising during March/April in response to monsoon rainfall, and started falling during September/October of the same year with recession of rainfall. The water table dropped very rapidly when irrigation wells started extracting groundwater. During the year the maximum and minimum depth of static water level from the ground surface in 18 locations were recorded to be 14.29 meters and 1.00 meters, respectively. The dry season water level dropped below suction lift capacity of suction mode pumps eliminating the possibilities of operation of these pumps. The lowest water level progressively declined from year to year due to increased extraction from storage by installing additional deep tubewells every year. However, the lowest values of static water level at the aforesaid locations indicated a fully recharged aquifer *at the end* of the rainy season except in 1989 (because of the severe drought in the same year). The long-term static water level trend also showed that whatever depletion of groundwater level occurred in dry season due to abstraction was completely recharged during the wet season indicating no mining of underground water. The results of this study clearly indicated that the groundwater reserve of the study area was in a stable equilibrium condition for the last 8 years (1983-1990) although a continuous annual withdrawal at an accelerated rate was made. Furthermore, almost in every year, the depleted aquifer was completely recharged from rainfall before the end of rainy season and a part of recharge opportunity time remained unused causing rejection of recharge.

AGRO-ECOLOGICAL EFFECT OF GROUNDWATER EXTRACTION

Attempts were made to evaluate the impact of heavy pumping on the agro-ecology of the study area. The large scale irrigation applied in high yielding variety (HYV) rice and other crops increased atmospheric water vapour and may have reduced temperature and increased the possibility of rainfall. Though static water level dropped beyond the extraction capacity of the roots of many fruit and other trees during the dry months of February to April, there remained sufficient soil moisture within the rootzone of these trees during the rest of the months of the year. The only problem encountered was the non-functioning of hand tubewells during the dry months which made stopped availability of potable water for drinking as well as household purposes. The deep tubewells served the purpose of hand tubewells during this period. The rural-based well-experienced people did not see any harmful effect on the growth of any type of vegetation including large trees, because of groundwater extraction. In some cases they were encouraged to grow some necessary vegetation through having facilities for continuous supply of water during dry months.

We know that the techniques of groundwater evaluation are relatively subjective, and that questions may be asked about the accuracy and reliability of our initial results. We suggest the evaluation studies should be continued for reassessment and refinement until a database is available which is suitable for long-term planning.

The main impact of current levels of development (which are still below the full aquifer potential) has been on shallow watertable conditions in the dry season, and it appears that local people have been able to adapt to these.

However, on-going monitoring is required. We know we are actually still pumping within the safe regional limits of the aquifer, but we must ensure that development stays within this limit.

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GROUNDWATER DEVELOPMENT AND MANAGEMENT IN THE CRITICAL AREAS OF ANDHRA PRADESH, KARNATAKA AND TAMIL NADU STATES OF SOUTH INDIA

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INTRODUCTION

Liberal energisation of wells, subsidised power tariff for agriculture pumpsets and easy availability of institutional credit have contributed to a surge in groundwater development in Andra Pradesh, Karnataka and Tamil Nadu states of south India during the last three decades. The number of wells increased from 1,510,000 in the year 1960, to 2,860,000 in 1985 (Karnataka state registered a more impressive growth rate of 9.8% per annum). In the above period, the area irrigated by wells increased by more than two times.

Though rapid increase in groundwater irrigation was recorded in most parts of the country, the adverse effects of over development are more conspicuous in the three southern states because of the predominance of low rainfall hard rock areas which cannot sustain large scale development.

High initial cost, execution delays, inter-state disputes and environmental problems are a few limiting factors in expanding irrigation through major and medium projects. Poor management is eroding fast the vast potential of more than 100,000 irrigation tanks created through the ages. Given the above limitations, further increase in irrigation potential can be achieved only by maintaining the pace of groundwater development. The recommendation of the Working Group on Minor Irrigation for Formulation of the VIII Five Year Plan, proposing an investment of Rs 12 billion[1] for constructing 525,000 wells in the three states during 1990-95, confirms this view. However, development has to be on scientific lines. Otherwise, such ambitious targets will have devastating effects on the groundwater regime,

[1] In 1991, 20 rupees = $US 1.

1. PROBLEM AREAS

The critical groundwater ares in the southern states suffer from a number of problems related to estimation of potential and development and management of groundwater. Among them are the following:

Estimation of Potential The State Ground Water Departments (SGWDs) are responsible for estimating groundwater balance and classifying the blocks (group of villages) as 'white' (under-exploited), 'grey' (close to fully exploited) and 'dark' (fully exploited) areas.

Estimation of groundwater potential reveals that more than 90% of the blocks are under-exploited (white), whereas the ground realities are different. Over exploited conditions, reflected by alarming decline of water levels, are existing in many areas, including in a few white blocks.

Development of Critical Areas It is a paradox that demand for wells is more in dark and grey areas as compared to white areas because, the aquifer capabilities in a developed area are proven and the farmers are tuned to the advantages of well irrigation. Though institutional credit is not available for wells in the dark blocks, construction of new wells is going on unabated, resulting in alarming decline of water levels. Investments in such areas merely inflate the number of wells, with hardly commensurate increases in irrigated area.

Well Design in Critical Areas Design of wells in the hard rock areas, particularly in the critical areas, has undergone a vast change during the last decade. The traditional large diameter, shallow open wells were initially converted to dug-cum-bore wells, and later to bore wells (and then to still-deeper bore wells). Consequently, thousands of dug wells have gone dry and had to be abandoned along with their centrifugal pumpsets. However, the chase of groundwater through deeper and deeper bores cannot go on forever, because the productive fracture zone in the hard rocks is limited, which is already exceeded in the critical areas by bore wells.

Tradition-bound farmers insist of constructing large dug wells, at times 3 to 4 times larger than the optimum size, not realising that the recuperation capacity of wells is independent of the size[2]. Unproductive expenditure due to fall in water levels, reduces the useful life of a bore well to a mere 3 to 4 years. With thousands of bore wells constructed each year in the critical areas, the wasteful expenditure due to faulty well siting, over designing and reduced life is astronomical.

It is essential to arrest the declining trend of water levels. Improving recharge by desilting irrigation tanks and constructing new percolation tanks besides other soil conservation methods are a few important steps in this direction. In addition, drastic reduction in groundwater draft by shifting the crop pattern in favour of widely spaced crops which could be irrigated through drip system is necessary.

Inequitable Distribution In critical areas, due to lack of institutional credit, only those who could mobilise private resources could construct wells. Denying institutional credit in a dark block, however, justified, has deprived the poor farmers of the vital input of credit and forced them to continue with subsistence rainfed farming or purchase of water at exorbitant prices. Cultivating large ares of horticultural crops and irrigating them through community drip irrigation appears to be the solution for improving equity under well irrigation, particularly in the critical groundwater areas.

Electrification of Agriculture Pumpsets Farmers in the critical areas of Tamil Nadu construct bore wells because of deep water level conditions which do not favour dug wells. These farmers are forced to operate the bore wells with inefficient compressor pumps and incur heavy operational costs because of the enormous delays (up to 8 years) in receiving electric connections.

With the introduction of a flat tariff for agriculture pumpsets (in Tamil Nadu state, power consumption of electric pumpsets up to 5 HP is free), farmers are resorting to indiscriminate and almost incessant pumping, which has played havoc with the slender groundwater resources of the critical areas. As a result, even villages depending solely on groundwater for drinking are seriously affected.

2 Many farmers construct these large diameter wells to provide a 'reservoir' for pumping, since in hardrocks.the low transmissivities means water will be drawn down while pumping. These wells may take a day or more to recharge.

Government Sponsored Schemes - Subsidy Government of India and the State Governments have sponsored several schemes for groundwater exploitation and its efficient use. Under these schemes, selection of areas for implementation and the subsidy rates have to be determined more scientifically. For example, under the schemes for installing drip system, the subsidy rate does not vary between Thanjavur district which has abundant groundwater and Kolar and Coimbatore districts, known for scarce groundwater.

After demarcating the critical groundwater areas, schemes for conservation of water could be implemented in such areas more aggressively, if necessary by providing much higher doses of subsidy. The present policy of spreading the subsidy uniformly for all areas will not achieve the desired results.

3. WATER USER ASSOCIATIONS

The drop in water levels in the critical areas is bound to be more rapid in future due to lower aquifer transmissibility as a result of reduced saturated thickness. Serious attempts, therefore, have to be made to arrest the declining trends. Groundwater legislation, though effective, could not be considered seriously in view of the difficulties involved in implementation. The ultimate solution probably lies in the collective management of water resources by farmers themselves. Water User Associations at village/micro watershed level have to be organised to decide the future development of groundwater and also improved management of the available meagre resources.

4. ISSUES FOR FUTURE STUDIES

Estimation of Potential Study a couple of blocks/watersheds in detail to compare the potential for wells as estimated form the groundwater assessment carried out by the State Ground Water Directorates and on the basis of field conditions. Such comparison will give a clue to a realistic estimate of the feasible number of wells which will form the basis for more purposeful planning.

Design of Wells Study the well design adopted by the farmers and examine their suitability to the hydrogeological conditions.

Decline of Groundwater Levels Is the declining trend of water levels in critical areas due to erratic and inadequate rainfall or over development? Study the effect of large scale groundwater extraction through bore wells on the existing open wells and shallow bore wells.

Bore Well Failures Study the high rate of failure (reported to be about 60% in critical areas) of the bore wells are the construction stage. What is the life of bore wells in critical areas due to declining water levels and how does it affect the viability of the investments on wells and pumpsets?

Technical Advice to Farmers Study the existing institutional arrangements for tendering advice to farmers on site selection and well (and pump) design - suggest improvements.

Energy Tariff Study the impact of subsidised, flat energy tariff on the extraction of groundwater, particularly in bore well areas. Also the advantages of metered tariff over flat tariff. Which class of farmers is actually benefitted by flat tariff and at whose cost?

Inequitable Distribution How do poor farmers cope with the need of drilling deeper and deeper bores due to declining water levels? Is groundwater in critical areas the monopoly of the more affluent who could drill deeper?

Development of Critical Areas What is the impact of denying institutional credit for wells in critical areas? Which section of farmers is affected most by this policy? How far this policy has helped to retard the growth of wells and arrest the decline of water levels? What is the relevance to groundwater legislation to Indian rural conditions.

Protection of Critical Areas - Water User Associations What is the awareness of farmers and administrators in critical areas to the impending danger of declining water levels? Are the farmers in a mood to organise themselves and face the challenge? What could be the role of NGOs in this direction? What is the scope in the critical areas for shift in the cropping pattern in favour of widely spaced horticulture crops which could be irrigated through drip system? How far can marginal farmers could be benefitted by community drip irrigtion system, installed on a common well?

A PROPOSED ACTION PROGRAMME TO MAINTAIN GROUNDWATER LEVELS AND ACHIEVE SUSTAINABLE AGRICULTURE IN TAMIL NADU

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Groundwater is extracted through 1.6 m wells to irrigate about 1.2 MHa in Tamil Nadu, which is almost 40% of the total irrigated area. The depth of open wells vary from 10-15 m in some pockets and near the river bank to 50-70 m in districts like Coimbatore. Bores inside the open well have gone to a depth of another 50-70 m in various places. Groundwater bores have gone up to 100-150 m. The groundwater table has depleted from 10 m to 50 m in the last 40-50 years. The area of irrigation by each well has reduced from 1.5 ha to less than 1 ha in the last 20-30 years.

The assessment of groundwater potential is estimated by many agencies/scientists and the figures given are anybody's guess. It varies from 1.4 MHm to 2.56 MHm.

The last data given by the Directorate of Ground Water has indicated that the total groundwater draft is about 50% and there is scope for constructing another 1.2 MHm wells in Tamil Nadu. However, if you visit the various districts and analyse the groundwater potential, it is observed that most of the wells in all the districts have reduced water supply and thousands of wells have been abandoned. This alarming situation is not only found in Coimbatore, which is traditionally known for its groundwater shortage, but also in Madurai and Chidambaranar and Ramanad Districts.

The Government records say that the extraction of groundwater in Pasumpon District is 1% to 24% in various blocks and about 80,000 more wells could be constructed in the District. But the picture in the field is completely different. Though the district obtained good rains during January 1990, the situation is alarming. In many *taluks*, the water table has dropped to 20-30 m from ground surface and large numbers of irrigation wells have deep bore wells inside to a depth of 60-70 m, and side bore for a distance of 50-70 m.

Further, hundreds of wells in Chidambaranar district (Sathankulam block), Madurai District (Chinnamanoor and Andipatty blocks), and thousands of wells in Coimbatore district (Karamadai, Sulur, Madukkarai, Avinashi blocks) have been abandoned. The depletion of groundwater totals is very alarming all over Tamil Nadu. Therefore, there is an urgent need to look into this aspect very seriously and take some urgent action. Otherwise, even drinking water may not be available in another 5-10 years if the trend continues.

There are many controls in regulating/construction of wells in the State. Banks give loans if the spacing of 200 m is maintained. The electricity is given only for about 8-16 hours daily in most of the areas. Energisation is not that easy and it takes at least 4-6 years. In spite of these restrictions and constraints, many new wells are constructed every year, not only by the individual farmers but also by the Government. The net result is not only lowering the water table and reduced water supply but abandoning of these wells. Though the public as well as Government are aware of the situation, no concrete action is taken for want of proper perspective and will.

As early as 1977, the Tamil Nadu Government brought the groundwater control and regulation bill in the assembly. However, subsequently, it was dropped as there was a strong lobby opposing it. Government of India is advising all the State Governments (including Tamil Nadu) to enact groundwater laws, but nothing could be done so far. Even today, the farmers are able to pump water from these deep wells, thanks to the free (nominal) electricity charge (Rs 50 HP/year) levied by the Government. This again has accelerated the process of depletion of water table and wasting of ground water by many farmers.

Under these circumstances what is to be done is the question. The following action plan is suggested:

- The situation is very serious and all (farmers, public and government) should know the consequences;
- Critical analysis of the rainfall of the area/water shed;
- Assessing the groundwater potential realistically;
- Need for groundwater regulation and control at least in some basins/watersheds to start with;

- Need to diversify crops and cropping patterns based on the available water (tapped);
- Maintaining groundwater level at a determined/particular depth for sustainable agriculture;
- Introduce crops which will use less water, but give more profit per unit quantity of water;
- Adopt drip and sprinkler systems;
- Water should not be conveyed through open/earthen channels on any account, but use pipes with control structures;
- Recharge the groundwater by providing suitable structures.

Government should not invest money for deepening wells or to go for deep bore wells for getting water during the summer. Instead that money may be used to conserve the water during the rainy seasons and encourage economical utilisation of water. The farmers in one village (lyyampudur in Gobi taluk) have spent nearly 10,000,000 rupees for drilling borewells up to 500 ft depth (250 wells) and installing compressors, but without success. This trend is there in Mettupalayam, Avanashi, Pallam taluks of Coimbatore district, and many other districts including Ramanathapuram which is supposed to be a backward district. If this trend is allowed to continue, the fate of the Tamil Nadu is very gloomy. If the people and Government do not view this trend seriously, immediately, the future generation will blame all of us. Hence, an action plan should be worked out and implemented before 2000 AD, otherwise all are doomed.

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