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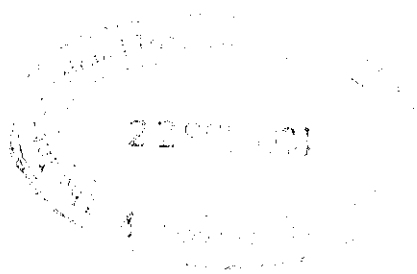
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Analytical

Farmer Management of Groundwater Irrigation in Asia

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*Selected Papers from a South Asian Regional Workshop on
Groundwater Farmer-Managed Irrigation Systems and
Sustainable Groundwater Management,
held in Dhaka, Bangladesh from 18 to 21 May 1992*



Editors: M. D. C. Abhayaratna, D. Vermillion, S. Johnson and C. Perry.

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INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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Abhayaratna, M.D.C.; Vermillion, D.; Johnson, S.; Perry, C. (eds.). 1994. Farmer management of groundwater irrigation in Asia: Selected papers from a South Asian Regional Workshop. Colombo, Sri Lanka: IIMI. ix, 205p.

/farmer-managed irrigation systems / groundwater management / conjunctive use / tubewell irrigation / sustainability / social aspects / economic aspects / aquifers / agricultural development / small-scale systems / case studies / surface irrigation / sprinkler irrigation / water users' associations / Asia / Bangladesh / China / India / Indonesia / Nepal / Philippines / Sri lanka /

DDC : 631.7

ISBN : 92-9090-309-0

Please direct inquiries and comments to:

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Cover photograph by John Colmey: Tubewell water entering a field canal during irrigation, Punjab, Pakistan.

Preface

WIDESPREAD GROUNDWATER IRRIGATION in Asia is relatively new. The rapid proliferation of groundwater irrigation systems in many areas of Asia, and especially South Asia, over the last three decades has mainly been at the initiative of farmers. Farmers have invested extensively in equipment, fuel and labor in order to have access to water when and where they need it. In order to have this control over water delivery they are often willing to pay several times more for lift irrigation water than for water from large canal systems. They conduct trial and error digging and drilling to locate favorable sites for lifting water.

The extraction, distribution and application of groundwater often involves complex challenges in social and agrarian relations. It involves economic tradeoffs between short- and long-term costs, risks and benefits. It often has management tradeoffs between local farmer objectives and broader sustainable use of aquifers. Environmental problems of waterlogging, salinity, decline in water quality and aquifer drawdown are advancing in many places where groundwater institutions and water laws are weak or non-existent. Governments seem unable to measure or regulate the use of groundwater for irrigation. It is becoming increasingly apparent that farmer organizations will also have to bear the main burden for achieving sustainable management of groundwater for irrigation, if it is to be achieved at all. Several members of the Farmer-Managed Irrigation Systems Network and Advisory Committee recognized the rising importance of groundwater irrigation in South Asia for meeting the needs of farmers and consumers for food and income. It was primarily because of their strong recommendations that the Workshop on Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management was held in Dhaka, Bangladesh in May 1992. We sincerely hope that this publication of selected papers from the Workshop will further the awareness among government officials, researchers and others about the challenges of farmer-managed groundwater irrigation—be they technical, economic, agricultural or institutional.

In the Workshop, the participants identified five priority areas of concern relative to sustainable management of groundwater irrigation by farmers. These are: (i) aquifer drawdown, (ii) FMIS groundwater support services, (iii) management problems under water-surplus conditions, (iv) management problems under water-deficit conditions, and (v) management problems in conjunctive use areas (i.e., joint surface water and groundwater irrigated lands). A synthesis of the topic discussion group conclusions and recommendations is provided in the *Overview* by Sakthivadivel, Parker and Manor. Papers which emphasize management issues at the level of the resource base are included in the section entitled, *Resource Development and Use*. Papers emphasizing system-level management are included in the section entitled, *System Management and Performance*.

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Acknowledgements

THE INTERNATIONAL IRRIGATION Management Institute (IIMI) wishes to acknowledge the contributions of all those who participated in the planning and implementation of the South Asian Regional Workshop on Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management, held in Dhaka, Bangladesh, from 18 to 21 May 1992.

We are grateful to all the dedicated professionals who prepared and presented papers, who participated in session discussions and field trips and who helped prepare topical recommendations on farmer-managed groundwater irrigation development and management in Asia. The sessions were lively and resulted in a very beneficial exchange of experiences and ideas. We thank all those who helped provide logistical arrangements, transport, food and lodging, workshop facilities and materials and secretarial support.

IIMI especially acknowledges the support and interest shown in this Workshop by the Bangladesh Agricultural Research Council, the Bangladesh Agricultural Development Corporation, the Bangladesh Rice Research Institute, the Ministry of Agriculture and the Bangladesh Agricultural University.

Finally, we thank the International Fund for Agricultural Development (IFAD) and the German Federal Ministry for Economic Cooperation (BMZ) for their generous financial support for producing this publication.

OVERVIEW

Overview of Workshop Activities, Issues and Recommendations

R. Sakthivadivel,¹ D. Parker² and S. Manor³

ARRANGEMENTS AND OBJECTIVES

THE FOUR-DAY South Asian Regional Workshop on Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management was held in Dhaka, Bangladesh from 18 to 21 May 1992. Fifty-seven participants from 10 countries including 5 International Irrigation Management Institute (IIMI) professional staff, attended the workshop. Five Indonesian participants who attended the workshop were taken on a one-week field trip after the workshop.

The objectives of the workshop were to: (i) provide a forum for professionals concerned with groundwater irrigation management in South Asia to exchange experiences and ideas, (ii) provide an opportunity for the professionals to jointly observe in the field in Bangladesh problems and challenges of groundwater irrigation management, and (iii) for a group of experts to jointly identify priorities and recommendations for research and development action on groundwater irrigation management in South Asia.

SUMMARY OF PROCEEDINGS

The first day's activities began with an inaugural session followed by presentations of syntheses of the papers that had been prepared. Discussion groups were then formed and assigned the task of identifying issues of particular concern for further exploration during the remainder of the workshop. These discussion groups were organized around the topics of:

- i) Aquifer and drawdown conditions.
- ii) FMIS groundwater support services.
- iii) FMIS sustainability under water surplus conditions.
- iv) FMIS sustainability under water-deficit conditions.
- v) FMIS sustainability within surface irrigation systems.

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The second and the third day were devoted to field visits to see the working of various types of farmer-managed irrigation systems (FMIS) under different management conditions in the northern part of Bangladesh. On the final day there were again small group discussions—this time set up to address and make recommendations about some of the areas of concern identified earlier. These three groups focused on technical considerations, institutional issues, and socioeconomic aspects, respectively.

SYNTHESIS OF ISSUES

The five discussion groups on the first day came up with a number of concerns for further exploration. These issues are listed below by discussion-group topic.

Aquifer and Drawdown Issues

There is an urgent need to collect and disseminate technical information on aquifer characteristics, groundwater quantity and quality, and drawdown conditions; on groundwater table variation in response to rainfall, surface water recharge and pumping; and on micro-level groundwater mapping and information system on groundwater availability and abstraction mechanisms. Organizational aspects of groundwater information collection and dissemination are also important.

Overdevelopment of groundwater and its utilization result in depressed water tables, interaction between shallow and deep aquifers, and imbalances between fresh and salt water interfaces. This leads to problems of inequity and lack of sustainability and increases cost of groundwater abstraction. Therefore, it is necessary to initiate careful monitoring of groundwater table fluctuations and introduce proper regulatory mechanisms for sinking and spacing of shallow tubewells (STWs) and deep tubewells (DTWs).

Valuable groundwater is often used inefficiently and at times wasted. Therefore, integration of efficient utilization of groundwater through better water management practices in conjunction with rainfall and surface water is necessary.

Selection of type of tubewells, their installation, operation and management are to be matched to meet the aquifer characteristics and drawdown conditions.

There is a need to enact proper groundwater regulatory mechanisms through a proper mix of technology and management for groundwater utilization so as to maintain groundwater at desired levels and prevent environmental degradation.

Solutions especially need to be found to problems associated with the following:

- i) The increasing costs of construction, replacement and operation and maintenance.
- ii) The deterioration of water quality.
- iii) The differential effects of water markets on the poor.

Research is needed on the impact of withdrawing state assistance for groundwater development and on how measures can be developed to improve the performance of groundwater development.

Groundwater Support Services Issues

There is a need to provide support services for groundwater FMIS in the following areas:

- i) Easily available credit for construction of wells, purchase of equipment and spare parts and operation and maintenance.
- ii) Price support, market information and marketing facilities and storage and transport facilities for their produce.
- iii) Subsidies for operation, maintenance and replacement.

For these support services to be effective it will be necessary to:

- i) Develop an institutional framework for group formation, partnership and legal framework for groundwater group.
- ii) Provide training for management support, recordkeeping, accounting and on-farm management.
- iii) Provide technical support services on information of groundwater resources available, selection criteria, on-farm water management; and well maintenance and mechanic support.
- iv) Provide spare parts during the recommended life span of the tubewell.
- v) Analyze and identify the impact of groundwater support services on the following:
 - a) technical performance of groundwater utilization in improving command area, pump operation efficiency, recovery of water charges, loan recovery and rates of return to investment;
 - b) macro-economic policies (protection versus free market, pricing policies including energy cost and subsidies for groundwater development);
 - c) management/organization style (ownership issue—individual versus group management and public versus private);
 - d) role of private sector; poverty alleviation through credit and water markets; role of STW/manually operated pumps.

Sustainability Issues of Groundwater FMIS in Water Surplus Areas

There is a need to improve economic efficiency and profitability of groundwater irrigation. Therefore, it is necessary to:

- i) Introduce macro-economic policies for profitable and efficient groundwater irrigation.
- ii) Provide groundwater development subsidies (increase output price, input subsidy, credit and insurance).
- iii) Balance surface water and groundwater development for their optimal utilization.
- iv) Encourage local manufacturing of groundwater development equipment.
- v) Ensure economic growth through better performance of water markets and improved access to water and credit markets for the poor.
- vi) Define and demarcate objectives of groundwater development in relation to growth, sustainability, equity, poverty alleviation and gender issues.

- vii) Discuss and identify the conditions under which drawdown issues assume importance in the short run and in the long run; there is a need to study agro-chemical pollution of groundwater and resource degradation.

Sustainability Issues of Groundwater FMIS in Water Deficit Areas

It is necessary for policy makers to recognize that priorities may be different between lift technologies under different groundwater environments and socioeconomic conditions. The level of resource management and institutional development necessary for different regions needs to be better understood in order to develop appropriate institutional objectives and management organizations relevant to farmers' interests. Through an improved information base governments need to better understand and plan for water conservation, improved recharge and conjunctive use. The social and economic implications of groundwater depletion need to be monitored by research or planning organizations. New mechanisms to improve the sustainability of resource management, including the study of the relative efficacy of water markets, regulation and control need to be identified.

There is a need for agencies and farmers to develop partner *not* client relationships, to strengthen the capacity of organizations (farmers, state agencies) to adapt and innovate for different groundwater conditions, to train farmers and tubewell operators, and to improve, reform or possibly privatize extension services (such as in Mexico) to make them more responsive to farmer interests. Groundwater irrigation activities should be integrated institutionally and sectorially (agriculture, energy and transport) for sustainable use of groundwater and other resources. Many countries in South Asia urgently need to collect and compile reliable information techniques for technology management, farmer needs and resource management, and to improve accessibility of the public to this information.

Sustainability Issues of Farmer-Managed Groundwater Irrigation Within Large-Scale Canal Irrigation Systems

Workshop participants agreed that more conjunctive management of surface water and groundwater resources was needed in many parts of South Asia. Groundwater irrigation within command areas of large-scale canal irrigation systems is now very prevalent in South Asia and has the potential, if uncontrolled, to lead to serious environmental problems such as waterlogging and salinization of water and soils. More sustainable conjunctive management of water will require the following actions:

- i) Development of methodologies and techniques for efficient resource management through conservation and utilization; select appropriate tubewell technology (deep versus shallow tubewells) for conjunctive use of groundwater with surface water; integrate groundwater activities with surface water utilization; treat groundwater as a common property resource through legal provisions and sanctions.
- ii) Assess the interaction between groundwater and surface water recharge in terms of groundwater abstraction and water quality, and suggest measures to control them.
- iii) Identify sources of pollution of surface water and groundwater and arrest deterioration of water quality.
- iv) Assess the linkages existing among groundwater user groups, surface water FMIS and public agencies, and suggest measures to improve their linkages and performance.

- v) Develop and field test a suitable organizational structure for conjunctive use of surface water and groundwater systems.
- vi) Stipulate proper regulatory and control mechanisms for water table control, and to prevent waterlogging and pollution.
- vii) Provide adequate training, cost-effective technology, adequate input services, market and credit facilities.

As an integral part of the FMIS Network Workshop on Groundwater FMIS and Sustainability of Groundwater, a field trip was organized to FMIS of groundwater at five locations in Rajshahi and Bogara districts. Of these, six were deep tubewells managed by various agencies of the Government of Bangladesh and one well was managed by a voluntary organization called Proshika. One well which was managed earlier by BARC is presently owned by a farmer.

Of all the problems, frequent mechanical failures and disruption in supply of electricity can be regarded as those which are beyond the organizational capability of FMIS. These problems have the potential to offset the planned distribution of water and thereby affect the uniformity in productivity levels (Well No.2). This can induce each member to withhold or delay payment, especially because of two attitudes: First, allowing those who are greatly benefitted pay, and second, the payment not being worth the facilities provided by the FMIS. Due to such attitudes FMIS will run short of funds to meet O&M costs and ultimately, fail to supply water in time and at equal quantum. This will force resourceful members to opt out of the FMIS (Well No.6).

A deeper analysis shows that all the problems identified arise from the inability of FMIS to: (i) expand its objectives beyond water supply for irrigation, (ii) identify alternative solutions to issues that plague them constantly, (iii) develop multi-tier leadership as an alternative, and (iv) strengthen support systems.

For almost all the FMIS that were visited, the objective is only to supply water even after many years of existence. With the extension of irrigation facilities there is a need to invest recurrently on inputs like animal power, seeds, pesticides, manure, labor and marketing. The poor opt for investment instead of paying operation and maintenance costs. In such cases, reduction of time and labor invested to procure inputs and a well-developed organizational mechanism for marketing can prevent distress sales and exploitation at the hands of middlemen. Probably the profits and savings from activities can help the poor in paying the operation and maintenance costs in time. Unfortunately, we tend to categorize these services as support systems and tend to play them down.

Problems that are universal to all FMIS are frequent mechanical failures. To overcome the lack of technicians, each FMIS can identify a few youngsters to undergo training in management of pump and other infrastructural facilities. The cost of training and payment can be borne by all the beneficiaries.

In situations where availability of spare parts is a big question, it is advisable to have a contract with a local supplier or a tool maker who can supply them. The other solution can be to identify those spares which are constantly required and to hold a stock of them. One of the best solutions is to store water in the form of ponds at various strategic places so as to meet contingencies.

It seems that on behalf of all the beneficiaries only the manager or the president carries out all the activities. In such situations, there is a greater chance of losing out the initial enthusiasm and dynamism of a leader, if he withdraws (Well No.6). Even in the absence of complementary objectives, subcommittees can be formed to look after distribution of water, procurement of spares, collection of irrigation fee, etc. Such subcommittees can expand the space for larger participation and the emergence of alternate leaders.

SYNTHESIS OF DISCUSSIONS AND RECOMMENDATIONS

The main technical issues were grouped by participants into the following categories: (i) groundwater resource assessment; (ii) groundwater exploration; (iii) water conservation and management; and (iv) environmental considerations in groundwater abstractions.

Under the existing methods of groundwater assessment and data collection, objectives and review of assessment and data collection are not well defined in most of the countries. Also, most of the data collection is at a macro level and is not readily usable at micro level by the farmers who need it most. Therefore, discussants recommended the following:

- i) The objectives of data collection and mapping groundwater resources and review mechanisms must be clearly defined.
- ii) Groundwater data and their assessment are not readily available at the micro-aquifer level (at the village level) for the farmers to use it. Attempts must be made to collect micro-aquifer data within the existing agro-ecological unit through cost-effective procedures and using the local knowledge of the farmers. Also, mechanisms must be developed to make it available to the farmers when they need it. Participatory research data collection should be promoted.
- iii) Existing data should be synthesized; attempts must be made to collect additional data to fill in gaps, to update the database and to analyze the data to bring them to a usable form and make them available to farmers, agencies and planners.
- iv) At present, many national governments rely upon foreign experts and assistance to develop requisite databases and to assess groundwater resources. It is necessary to develop local capability to undertake these assignments.

On the topic of groundwater exploitation, it was recommended that groundwater zoning be introduced into areas where only shallow tubewells can be used, areas where only deep tubewells can be allowed, and areas where both shallow and deep tubewells can be allowed, for groundwater extraction. Based on relevant environmental data and agro-ecological zones, appropriate groundwater extraction guidelines should be developed and disseminated, which are suited to the location through technology policy for groundwater extraction.

There was a lively discussion on the use of shallow and deep tubewells as extraction devices. Arguments were put forward for and against the use of deep tubewells. While discussing deep tubewells, two sets of issues were identified. The first set is with regard to existing deep tubewells. In Bangladesh itself there are more than 30,000 deep tubewells. The process and results of turnover and local management of these tubewells need to be looked into. Ultimately, most of these tubewells are likely to be owned by selected individual farmers who will be invariably well-to-do. The second set of issues is with regard to the installation of new deep tubewells. There was forceful argument to ban turbine pumps for installation of deep tubewells. It was also argued that in view of these large deep tubewells in water deficit areas such as hard rock areas, groundwater levels are receding fast, requiring innumerable shallow well owners either to deepen the wells or to abandon them. Therefore, there is an urgent need to regulate the use of deep tubewells in these areas too.

At the end, it was recommended that a three-phase approach be adopted which initially emphasizes shallow tubewells and groundwater management for stabilizing the drawdown level at an appropriate depth by regulating the use of shallow tubewells; second, to go for deep-set shallow tubewells and, finally, attempts may be made to go for deep tubewells where other methods of extraction have failed or are inefficient.

Under watershed conservation and management, it was recommended that the micro-aquifer should be the unit for groundwater conservation. It was suggested that a water balance study of the micro-aquifer be carried out to study the impact of surface water on groundwater and to design appropriate extraction mechanisms.

The key requirements in order to improve the efficiency of groundwater use and to manage the groundwater resources in a sustainable manner are as follows:

- i) Provide adequate technical extension services.
- ii) Establish a strong unit for maintenance of groundwater structures.
- iii) Provide adequate energy and energy distribution.
- iv) Diversify crops for efficient water use.
- v) Provide adequate credit facilities.
- vi) Carry out proper monitoring and evaluation.
- vii) Improve distribution systems and on-farm water management.
- viii) Carry out research on equity of distribution.

Under environmental considerations, it was recommended that in all irrigation systems, groundwater extraction and use should be controlled so as to minimize environmental problems, such as waterlogging and salinization, sea water intrusion, reduction in agricultural productivity, health hazards, groundwater deterioration due to pesticides and fertilizers, land subsidence, etc. It was also suggested that ecological balances need to be maintained for sustainability of groundwater irrigation systems.

Institutional and Organizational Considerations

Six functional issues were identified under this topic: (i) policy and legal aspects; (ii) planning; (iii) cost-sharing, resource mobilization and investment; (iv) creating appropriate groundwater infrastructure; (v) management of operation and maintenance; and (vi) agricultural production and marketing. Policy dialogues, workshops, pilot experiments and research were strategies suggested for developing appropriate institutional and organizational mechanisms.

Under policy and legal aspects, it was recommended that necessary institutions be developed and policies formulated with respect to integrating surface water and groundwater; and ensuring regulatory mechanisms, providing legal status to farmers' organizations (FOs), providing incentives, involving landless laborers and enacting strong legal provisions for considering groundwater as a common property resource.

Planning of groundwater resources needs assessment of potential and demand. A very strong participatory approach involving beneficiary farmers is recommended. Organizational strengthening of agencies, nongovernment-organizations (NGOs) and FOs is stressed. Coordination arrangements among agencies, NGOs and FOs is suggested.

Under supply and installation of extraction equipment, it was recommended that competition in adopting technology be permitted to allow involvement of private organizations in the above activities and to provide necessary training to FOs. There should be legal provision to ensure availability of spare parts for imported equipment.

Under management of operation and maintenance, it was recommended that both groundwater resource management and management of extraction technology be given due consideration. In addition, in those areas where surface water is available, conjunctive use and management are necessary. While beneficiaries are accountable for proper operation and management, agencies need to be made responsible for proper energy supply.

Under agricultural production, proper institutions are recommended for crop diversification, credit and marketing mechanisms. There is a need for inter-ministry collaboration between ministries dealing with groundwater, agriculture and other allied areas.

Socioeconomic Considerations

In order to make groundwater agriculture economically viable, groundwater extraction and utilization have to be effectively integrated into the larger national macro economy. In this endeavor, the group considered the following as important:

- i) Infrastructural facilities should be made available. Under infrastructural facilities, some of the areas recommended to be adequately developed were rural electrification, transportation and storage facilities, supply of equipment and spares, agro-processing industries, legal and administration framework of groundwater utilization and management and stabilization of exchange rates.
- ii) Pricing policies often need to be updated. Under pricing policy it was recommended to provide a selective subsidy for irrigation well equipment, appropriate pricing for surface water and groundwater, power, input and output pricing policies and reforms in credit policies.
- iii) Groundwater and surface water interaction need to be considered for optimal conjunctive use of surface water and groundwater.
- iv) Under institutional arrangements, it was recommended that water markets be promoted. However, institutions need to be created and strengthened to help regulate both sellers and buyers. Institutions for efficient conjunctive use and management need to be established.

The following recommendations emerged in the final plenary session:

- i) Groundwater should be considered as a common property resource. Groundwater and surface water must be integrated into a unified legal framework. All, including landless people, should have *inalienable* rights to water for drinking and religious purposes, followed by agricultural and industrial uses, in a hierarchical order. Groundwater should be considered a legally tradable commodity subject to regulation against over-exploitation. Groundwater use should be planned in conjunction with surface water.
- ii) Deep tubewells are costly and nearly universally controlled by large farmers. Appropriate institutional mechanisms should be in place before this technology is developed.
- iii) Banning of deep tubewells is not a possible solution. But their use should be regulated through viable local institutional arrangements.
- iv) Landless laborers should be given preference to manage tubewells in a sustainable manner.
- v) Some of the Aquifers extend over more than one nation (for example the Gangetic Aquifer). Regional efforts are necessary to assess groundwater potential and interconnectedness.
- vi) State policies toward groundwater management should target not only the individual pump owner but the network of wells that will interact now or in the future.
- vii) Well ownership may be individual, but communities in an area should be organized and be invested with the right of taking decisions on new individual investments in

wells in their area. Conservation technologies must be adopted by all well owners. Group purchase and distribution of power to well owners and enforcement of collection/loan repayment for credit provided to well owners are needed.

- viii) Aquifer characteristics, and recharge rates vary greatly within even small areas; therefore, state policies should be tailored to the nature of each ecological zone, (i.e., a groundwater resource endowment region). Blanket countrywide or statewide policies for areas of high ecological heterogeneity are likely to be inefficient and wasteful of state capital when direct subsidies are involved.
- ix) When the cost of pumping exceeds publicized and agreed-upon locally defined limits, all further official credit for extractive investments should be cut off. These include investments in well deepening, pump energizing, new well construction, etc.
- x) Choice of technology should be such that small groundwater groups are preferred over large groups when the resource base so permits. If shallow groundwater exists, then shallow tubewells are to be promoted rather than deep tubewells.

RESOURCE DEVELOPMENT AND USE

Hydrogeological Potentiality of Intensive Farmer-Managed Tubewell Irrigation Systems in Bangladesh: A Case Study

M.A. Sattar⁴ and K.A. Haq⁵

ABSTRACT

A FIELD STUDY was conducted in 10 farmer-managed deep and shallow tubewell irrigated areas of Barind Tract Groundwater Basin, Bogra, Bangladesh. This had the specific objectives of: (i) assessing the groundwater recharge in the study area, (ii) evaluating the fluctuation of groundwater table of aquifers and its response on rainfall and river water levels in the vicinity, (iii) evaluating the aquifer characteristics and properties, and (iv) recommending the safe utilization of tubewells based on discharge-drawdown relationship and well spacing for sustainable groundwater management in crop production.

The study indicated that the intensity of tubewells at present are 5 per square kilometer (km^2) with an average discharge capacity of about 56 liters per second (lps). The average irrigated acreage of all the tubewells was 0.83 hectare/lps under the rice crop which was much above the national average (0.40 ha/lps). During the 10 years from 1977 to 1986, the groundwater table was lowered indicating the highest lowering upto 7.87 meters (m) in the month of March. This was below the operation level of shallow tubewells. A multiple regression relationship with groundwater table (Y) as dependable variable, and rainfall (X1) and river stage (X2) as independent variables was accomplished. The study revealed that there is a significant direct relationship among rainfall, groundwater table fluctuation and stream flow. The lithological investigations indicated that 100 percent screenable materials were available from a depth of 12 m and beyond. The average transmissivity and storage coefficient values were 4,388 square meters per day (m^2/day) and 0.000587, respectively, which indicated that the study area has potential for tubewell utilization. A model for safe well spacing was developed between discharge versus spacing of wells. The findings indicated that for shallow wells with a discharge rate from 11 to 20 lps, the spacing was in the range of 122 to 250 m. However, for deep tubewells with discharge capacities of 47 to 54 lps the spacing was in the range of 300 to 390 m for safe and sustainable utilization of groundwater.

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INTRODUCTION

Groundwater in Bangladesh generally occurs under normal water table conditions, but in some areas, particularly in deeper aquifer, the water may be under semi-artisan or artisan conditions. The depth of the water table varies from zero to more than 15 m below the ground surface depending upon the location and season. Hydrogeologically, the upper fine sand and lower medium sand from one hydraulically interconnected aquifer was covered by a semi-permeable, semi-confining layer of silt and clay (Master Plan Organization [MPO] 1984). The static water level generally lies within the semi-confining layer. The deep tubewells (DTWs) and shallow tubewells (STWs), all extract water from a common aquifer, although from different but hydraulically connected layers.

Bangladesh can be divided into four major groundwater zones: (i) younger alluvium, (ii) complex geology, (iii) older alluvium, and (iv) coastal area (Jones 1972). Among the older alluvium, surface deposits in the area consist of fine grained older alluvium, chiefly the pleistocene Madhupur clay formation. The finer material is extended to great depths in some areas and therefore very little attempt has been made to develop large-capacity wells. Geophysical investigations indicate that there are some relatively good prospects of groundwater development in Bogra District and in the southern part of Tangail District.

Surface water is scarce in many parts of Bangladesh (mainly North and North West part of Bangladesh) during the irrigation season, so that groundwater has to be developed as an alternate and dependable source. But groundwater is also limited and there exists many constraints for its development. Therefore, it is essential to determine the quantity of groundwater that can be withdrawn safely for different uses. Groundwater withdrawal causes large decline in groundwater levels during the dry season in some typical areas where use has increased greatly in recent years (MPO 1984). The areas are Bogra, Rajshahi, Comilla, Dhaka and Mymensingh districts. Haq and Sattar's (1986) study at Bangladesh Rice Research Institute, Gazipur, indicated that the groundwater table during the dry season over a six-year period progressively declined and was close to 1.7 m per year. This yearly lowering of the groundwater table could be an indication that the annual rates of withdrawal from the groundwater basin has been greater than the yearly rates of recharge. The present study aims to find out the geohydrological potentiality of intensive deep and shallow tubewell farmer-managed irrigation systems for the safe utilization of groundwater.

The specific objectives of the study were as follows:

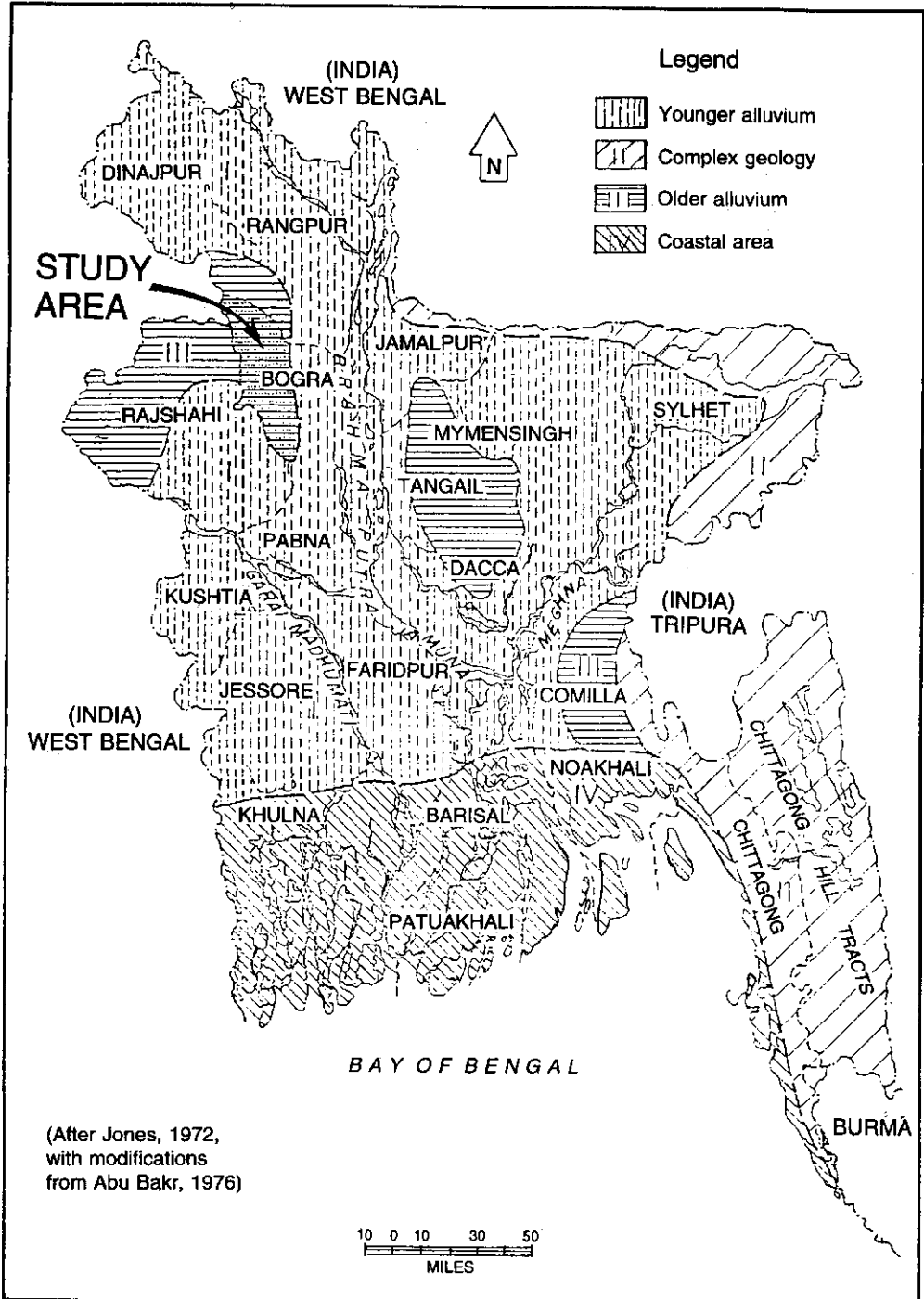
- i) To assess the groundwater recharge in the study area.
- ii) To evaluate the fluctuation of groundwater table of aquifer and its response on rainfall and river levels in the vicinity.
- iii) To find out the aquifer characteristics and properties.
- iv) To determine the safe utilization of tubewells for sustainable groundwater management.

MATERIALS AND METHODS

Selection of the Study Area

The study area has been selected based on the geohydrological zones of Bangladesh (Figure 1.1). It is mainly occupied by pleistocene deposits, i.e., Barind Tract of Bogra District (Morgan and

Figure 1.1. Approximate boundaries of groundwater areas.



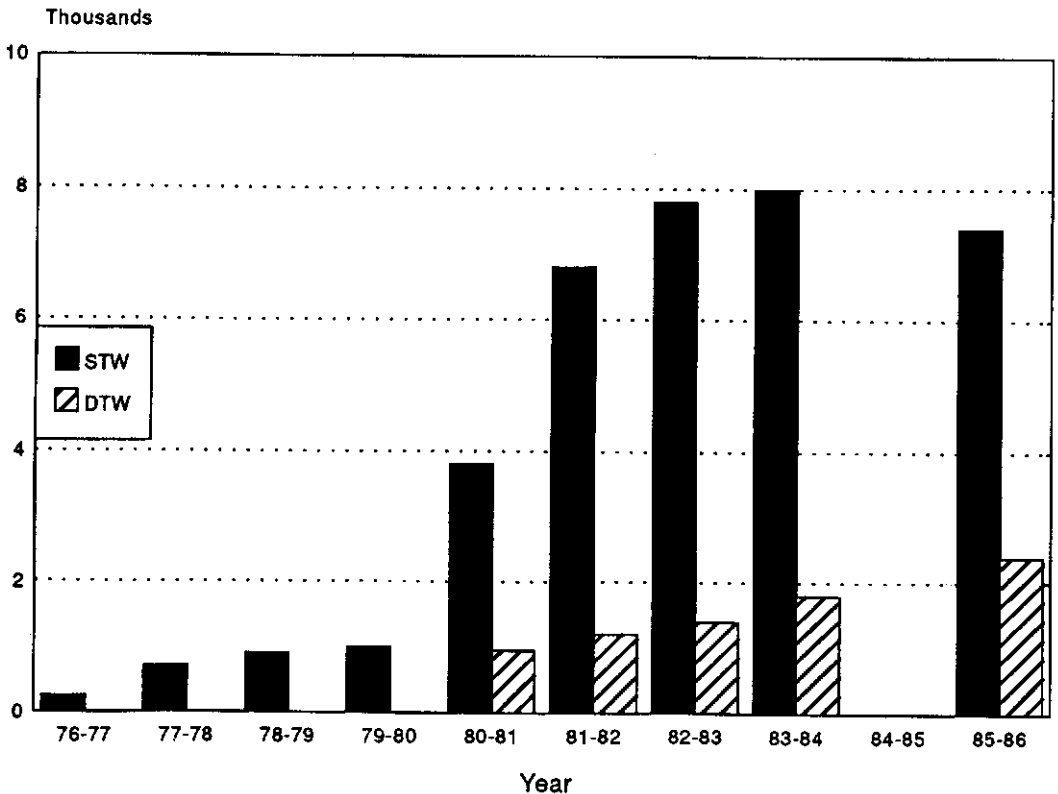
(After Jones, 1972,
with modifications
from Abu Bakr, 1976)

McIntire 1959). The Karatoa River flowing toward the south-west at the western margin of Kahlalu Upazilla has a great effect on the groundwater reserve. To fulfill the objectives of the study a pilot area has been selected in Kahlalu Upazilla covering 10.10 km², which has one of the most intensive DTWs and STWs in the Bogra District. The deep tubewell location map upazilla-wise, and the location of shallow wells within the study region were obtained from the Bangladesh Agricultural Development Corporation (BADC) local office. Annual increment of DTWs and STWs for greater Bogra District from 1976/77 to 1983/84 together with the 1985/86 tubewell status of present Bogra District are shown in Figure 1.2.

Farmer-Managed Irrigation System (FMIS)

Ten DTWs and STWs which are farmer-managed were selected for this study. The DTWs have been mainly implemented by the Bangladesh Agricultural Development Corporation (BADC) since 1977, and groups of farmers enjoy the use of the DTWs on a rental basis of taka (Tk) 3,500 (approximately US\$145) per year. However, by 1981 rental procedures were discontinued and DTWs were sold for Tk 70,000 (approximately US\$3,000) to the farmer groups. The procedures to procure deep tubewells begin with farmers who either organize themselves or are organized into user groups. Mandal (1982) provides examples in which the farmers themselves took the initiative to form a management committee to procure a deep tubewell and to manage the wells by themselves. The shallow tubewells are mainly procured and managed by the individual farmers.

Figure 1.2. Yearwise increment of STWs and DTWs in Bogra District, from 1976 to 1986.



Hydrogeological Information

The groundwater table was measured daily by using the electric probe method from seven production wells (DTWs) and eight installed observation wells for monitoring the groundwater table in the study area. Rainfall data and river water levels were collected from the local Bangladesh Water Development Board (BWDB) office for a period of 10 years from three gauging stations of major rivers; namely, Nagor, Karotoa and Katakhal, which are the main aquifer-connected rivers within the study basin. Eight available deepwell logs were analyzed on the basis of soil texture. These were plotted on positive and negative axes of aquifer as probability of occurrence of hydrogeology. The aquifer characteristics were determined through a pumping test using Jacob's method with the approaches of time-drawdown, distance-drawdown and recovery method. An attempt was made to find out the safe distance from DTW to STW by step drawdown test through the relationship between discharge (Q) versus radius of interference (R). Two deep tubewells and one shallow tubewell were selected for the test. The production wells were pumped at several successively higher pumping rates and drawdown for each rate was measured in each observation well. In each step, the radius of interference was determined from the drawdown curve. Each of the tubewell discharge was measured by horizontal scale (L-Scale) and their respective service area was recorded.

RESULTS AND DISCUSSION

Seasonal Fluctuation of Groundwater Table

Measurement of depth to water table in tubewells provides the record of change in the groundwater storage. Some records aid in determining the relationship of various facts such as the recharge of the groundwater reservoir. Weekly water table data were compiled for the analysis. The groundwater level starts rising from the latter part of May or June and it rises until the beginning of October. Ten-year secondary groundwater monitoring data have been used to show the behavior of the groundwater table (see Figure 1.3).

Rainfall Pattern

Annual rainfall of Bogra District from the year 1977 to 1986 indicates that 92 percent of the annual rainfall occurred from May to October and the rest from November to April. These rainfall variations directly affect groundwater recharge (see Figure 1.3).

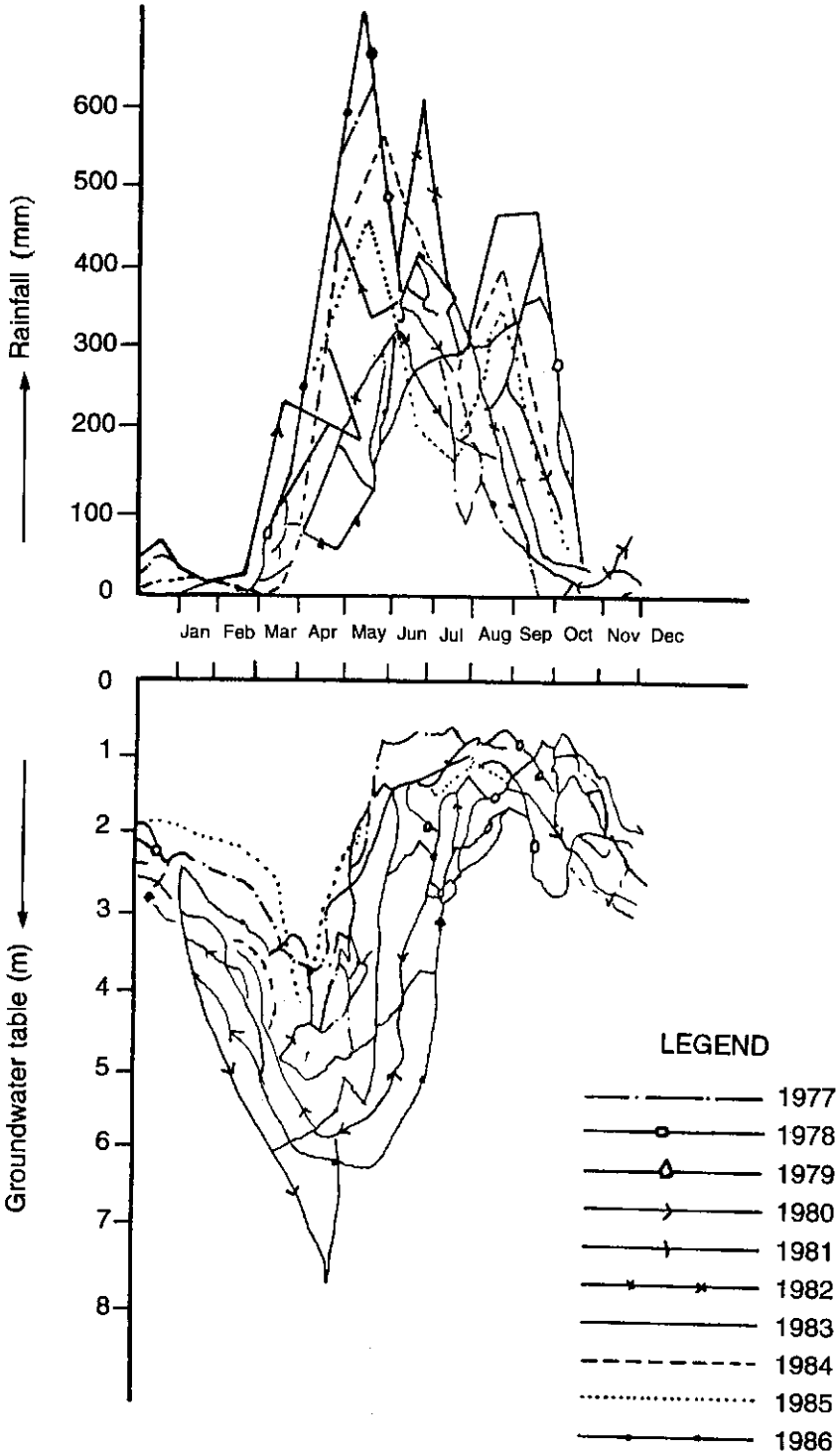
Assessment of Surface Water

The river water level data of Bogra District showed the maximum flow from June to October and the minimum in the month of April. The highest and lowest river water levels were 15.75 m and 11.21 m in the year 1984 and 1983, respectively (see Figure 1.4).

Relationship between Rainfall, River Level and Groundwater Table

An investigation was carried out to analyze the interrelationship between rainfall and groundwater table as well as river level data, within the few selected sites of the study area. The analysis was made on the basis of monthly records of rainfall, groundwater table and river level. A multiple

Figure 1.3. Fluctuation of groundwater table and the rainfall pattern, from 1977 to 1986.

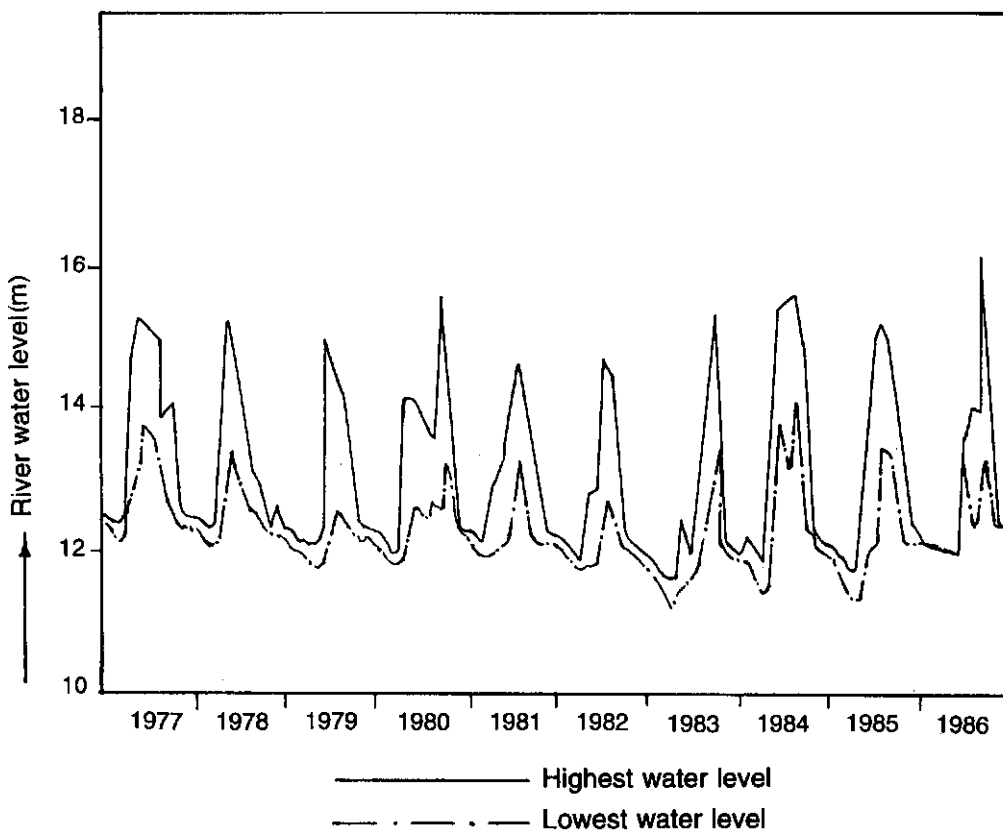


correlation analysis was made to establish the response of groundwater table (Y) to rainfall (X1) and river level (X2) and is given by the following equation:

$$Y = 12.5647 + 0.0399 X_1 + 0.7675 X_2 \quad (r^2 = 0.60^*)$$

The equation indicates a significant relationship between groundwater table, rainfall and river level, and shows that the rise in both groundwater table and surface water levels are influenced directly by rainfall. The river water level starts rising from the latter part of April upto the first part of August and it falls sharply at the end of the monsoon (September/October). The groundwater level, on the other hand, starts to rise from the latter part of April upto October and then declines until April of next year.

Figure 1.4. Hydrographs showing the highest and lowest water levels of Karatoa River, from 1977 to 1986.



Lithological Characteristics

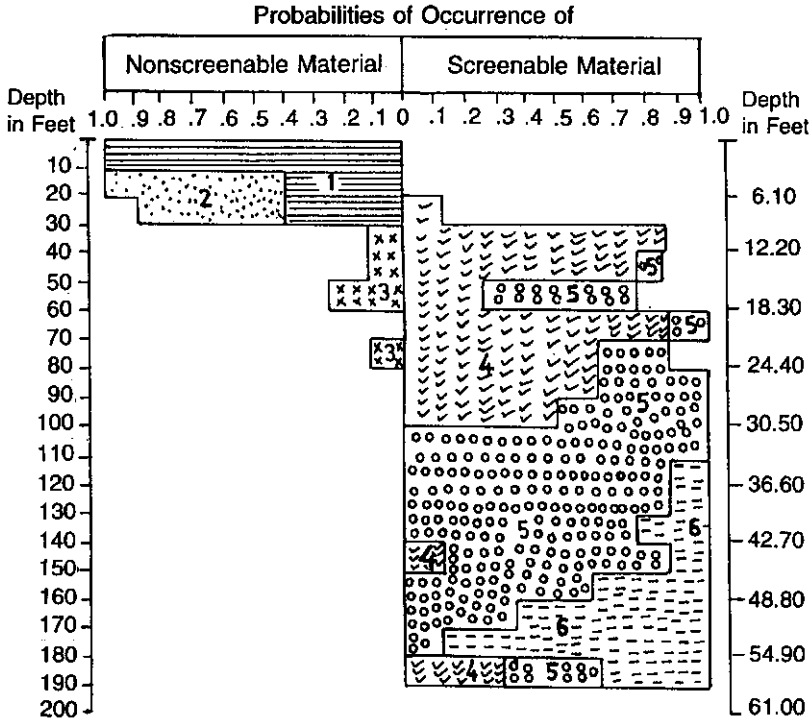
One test boring of 3.8 cm diameter was done upto a depth of 60 m to determine the continuity of aquifer depth on the study area. Samples were taken at every 1.5 m intervals to observe the lithology of subsurface formation. The stratigraphic views of lithological log of underground soil formation consists of clay, silt, very fine sand, fine sand, medium sand, coarse sand and gravel. From the lithological investigation it was found that the first screenable material begins from a depth of 12 m. The extent of this screenable material could not be identified since the bore log information beyond a depth of 60 m is not available. On the other hand, the BADC bore log analysis reveals that the first possible screenable aquifer can be expected with a 12 percent probability at a 9 m depth. Below a 9 m depth, the percent of nonscreenable material reduces sharply and varies from 12 to 15 percent (Figure 1.5). From 21 m upto a depth of 58 m, the probability of screenable material is 100 percent and suitable for installing both shallow and deep tubewells. The test boring indicated that 100 percent screenable material was available from a depth of 12 m and above, whereas, BADC boring logs indicated that 100 percent screenable material is obtainable from a depth of 21 m and beyond.

Determination of Aquifer Characteristics

The yield of a well depends on the characteristics of the aquifer formation such as transmissivity (T) and the storage coefficients (S) as well as the design and construction of the well. Transmissivity indicates how much water will move through the water bearing formation. Water storage coefficient is the volume of water that the aquifer releases from or takes into storage per unit surface area (Michael 1985). Transmissivity and storage coefficient are two important parameters for estimation of groundwater resources of an area. Johnson (1986) stated that transmissivity and storage coefficient are especially important because they define the hydraulic characteristics of the water bearing formation. If these two coefficients can be determined for a particular aquifer, predictions of great significance can usually be made.

The aquifer characteristics were determined through a pumping test using Jacob's method. Three types of analyses were performed, these are: (i) time drawdown, (ii) distance drawdown, and (iii) recovery methods. One deep tubewell was selected for the pump test. Five observation wells were installed radially in a straight line to record water response to pumping. The distance of the observation wells were from 10 m to 360 m. To estimate the aquifer properties (T&S), mathematical and graphical solutions for one set of data were made. Transmissivity values were 4,562 m²/day, 4,214 m²/day by time drawdown method (Figures 1.6a, 1.6b, and 1.6c). The storage values were 0.000648 and 0.000527 by time drawdown and distance drawdown methods, respectively. These values are much higher than the values obtained by Sir MacDonal and Partners (1977). The values indicate that the aquifer has good potential for groundwater development.

Figure 1.5. Probability of occurrence of hydrogeology interpretation (based on 8 wells).



CODE	LITHOLOGY
1	Clay, silty clay
2	Silt, silty and sandy clay
3	Very fine sand, very fine to fine sand
4	Fine sand, fine to medium sand
5	Medium sand, medium to coarse sand
6	Coarse sand, coarse sand with gravel

Figure 1.6a. Time drawdown analysis by Jacob's method.

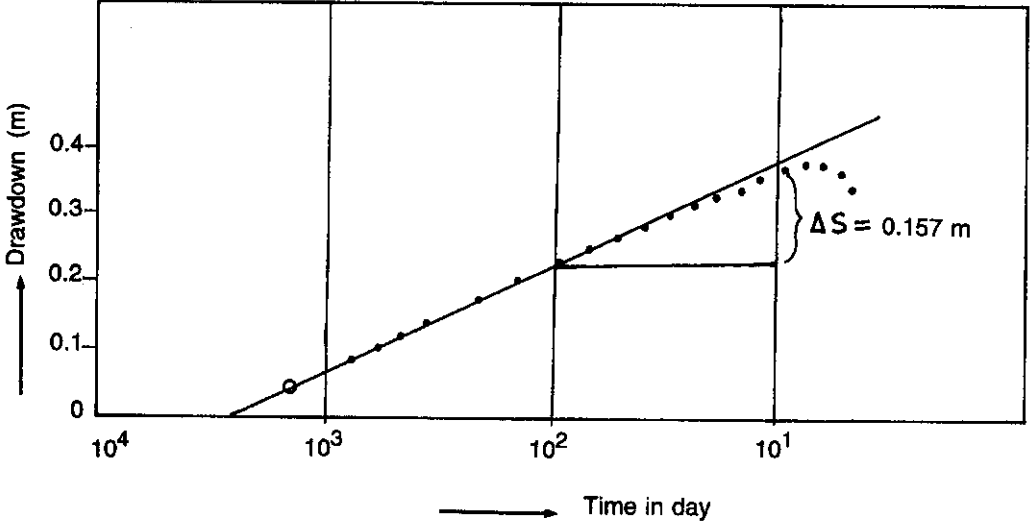


Figure 1.6b. Recovery solution for transmissivity.

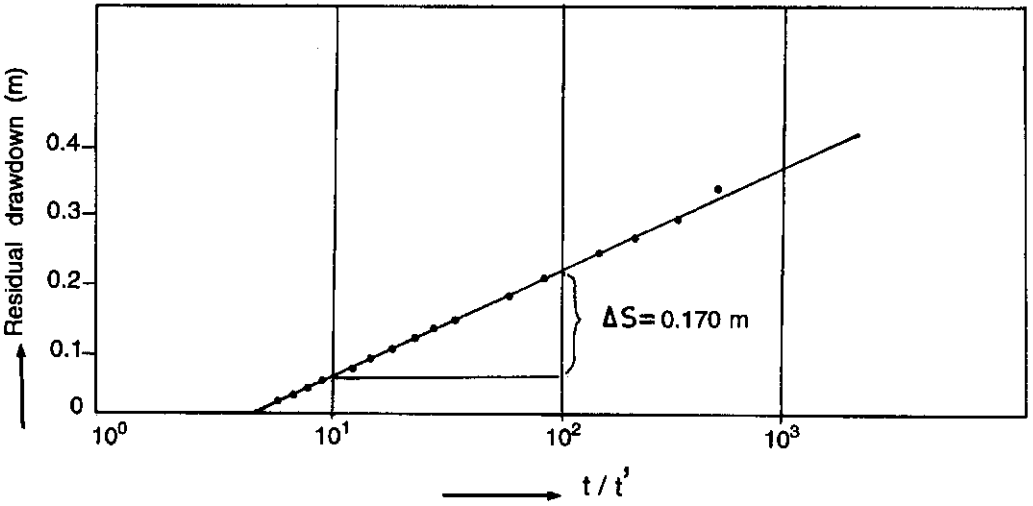
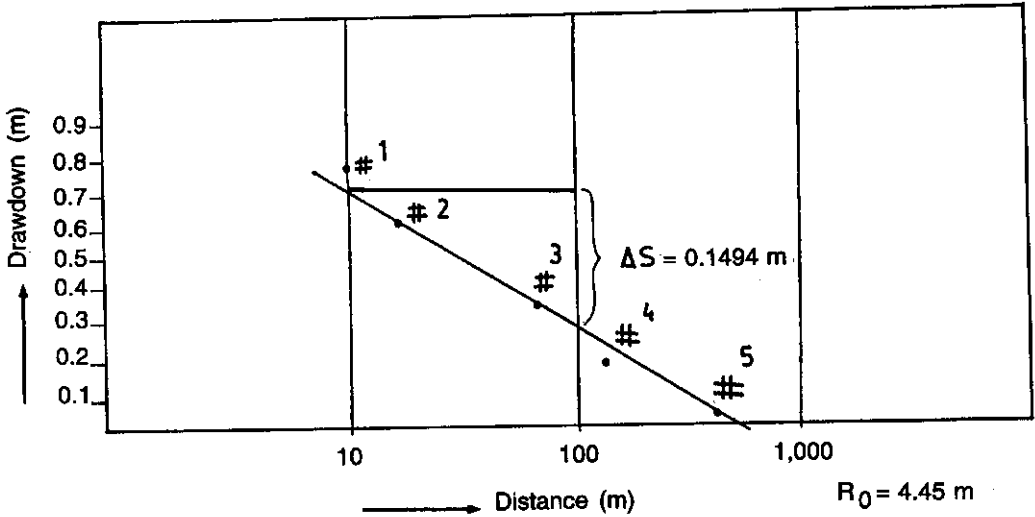


Figure 1.6c. Distance drawdown analysis by Jacob's method.



Model for Safe Well Spacing

A linear regression model was developed between discharge versus radius of interference. The model shows that there is a significant relationship between discharge and radius of interference. At the higher discharge rate the spacing of wells will also be higher as compared to the lower discharge rate (Table 1.1). A type curve has also been developed by plotting discharge (Q) versus radius of interference (R) on normal graph paper (Bangladesh Rice Research Institute [BRRI] 1989). From the type curve the spacing for any particular discharge rate can be estimated (Figure 1.7).

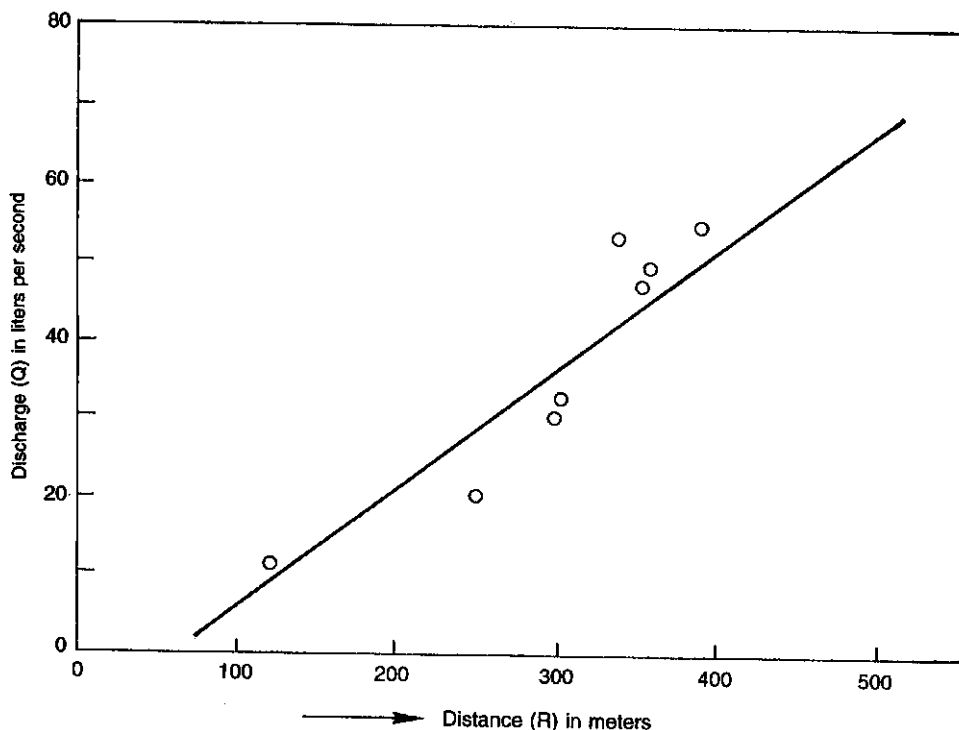
Table 1.1. Discharge versus spacing for deep and shallow tubewells at Kahalu Upazilla, Bogra.

Sl. number	Discharge (lps)	Spacing (m)
1	11 ^a	120
2	20 ^a	250
3	47 ^b	355
4	57 ^b	390
5	30 ^b	300
6	50 ^b	360
7	32 ^b	305
8	54 ^b	340

^a Indicates the discharge of shallow wells.

^b Indicates the discharge of deep wells.

Figure 1.7. A type curve of discharge versus distance for production wells.



Tubewell Performance and Utilization

The irrigated hectareage of the tubewell (area irrigated per unit time), discharge per unit time and the total amount of water applied are shown in Table 1.2. A maximum of 1.24 ha/lps was drawn from DTW No. 10 by operating the pump for 1,660 hrs, and a minimum of 0.56 ha/lps was drawn from DTW No. 5 by operating the pump for 1,583 hrs, during the dry season for rice cultivation. On average, irrigated hectareage of all tubewells was 0.83 ha/lps. Therefore, the tubewells under study were utilized upto their optimum level.

Advantages and Disadvantages of Intensive DTWs and STWs

The advantages of intensive DTWs and STWs are as follows: (i) can be used as a supplementary irrigation source during high water demand of the crop, (ii) allows to increase cropping intensity by alternative sources of water, (iii) permits an increase of the service area through a combination of deep and shallow wells even if the topography of the service area is not level, and (iv) enables more economic use of water by DTWs and STWs where the water table is near the ground surface.

The disadvantages are as follows: (i) low discharge of wells if there is interference of DTWs and STWs located in the same vicinity which increases the cost of operation, and (ii) high risk of crop production during the dry season, particularly under STWs if the water table goes below the operation level.

Table 1.2. Water utilization in selected deep tubewells at Kahalu Upazilla, Bogra.

Deep tubewell number	Location (village)	Total operating hours	Discharge of pump (lps)	Total area irrigated (ha)	Area irrigated per unit discharge (ha/lps)
1	Narhatta	1,390	74.00	44.20	0.60
2	Buril	1,316	42.00	35.51	0.85
3	Damai	1,350	39.10	29.15	0.75
4	Raushan Chapor	1,349	39.37	38.92	0.99
5	Katnaha	1,583	39.84	22.27	0.56
6	Kait	1,152	34.5	26.87	0.78
7	Vagdubra	1,500	40.55	28.34	0.70
8	Muril	1,620	38.50	40.49	1.05
9	Vishropur	1,620	41.42	30.36	0.73
10	Bokra	1,660	45.62	56.41	1.24

Note: Command area of shallow tubewells was not included.

SUMMARY AND CONCLUSION

The study area has an intensive development of tubewells for crop production. The intensity of tubewells per km² is 4 to 5 with discharge capacities ranging from 11 to 57 lps. The increasing number of DTWs and STWs may lower the groundwater table further in the study area from year to year, due to overdraft which was observed during the course of the study. There is a significant relationship between rainfall, groundwater table fluctuation and stream flow in the vicinity. The groundwater level started to rise after one month from the commencement of rains when the cumulative total of rainfall reached 15 cm. The study also indicated that the stream flow influences groundwater recharge favorably. The lithological investigation showed that the 100 percent screenable material lie 12 m from the ground surface and extend up to a 60 m depth. The aquifer characteristics such as transmissivity and storage coefficient were determined from pump test data. The results indicated that the aquifer has good potential for groundwater development. But the present trend of increasing the number of deep tubewells and shallow tubewells installed every year in the study area may lower the groundwater table below the operation level. This was indicated during the test of radius of interference between deep and shallow wells at full operation time. However, this issue can be solved technically from the findings of the study by using the distance drawdown and spacing relationships. Hence, a proper policy should be implemented in future for installation of wells in farmer-managed tubewell irrigation systems, with a view to attaining sustainability in groundwater management.

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Farmer-Managed Irrigation Systems and Sustainable Groundwater Management: An Endeavor of Proshika Target Groups⁶ to Ensure Sustainability of Groundwater Management

S.C. Sarker⁷

ABSTRACT

PROSHIKA MANOBIK UNNAYAN KENDRA, a nongovernment rural development organization in Bangladesh, initiated its irrigation program based on groundwater in 1980. The projects are being implemented by landless and marginal farmer groups. The major objectives of these projects are to establish rights on groundwater resources, to develop a sustainable alternative project management system in the irrigation sector, to create a bargaining situation between the landless and landlord farmers, to transfer ownership of the irrigation equipment to the target groups and to promote irrigation project management by women groups as a significant and prospective counterpart in groundwater development.

To achieve these objectives in particular, and to ensure the attainment of the goal of rural development in general, Proshika endeavors sustainable groundwater management through rural target groups. Attempts made to realize the objectives outlined above are diverse in nature. This paper focuses on some specific interventions by Proshika with reference to two case studies; i.e., (i) where beneficiaries have adopted management innovations successfully in Bastail—a village in Tangail District, and (ii) where the target group has failed to manage the tubewell in Baoni—a village in Gazipur District.

INTRODUCTION

Bangladesh is one of the least developed countries in the world. The estimated current population of the country is 108.8 million and it is expanding at a rate of 2.17 percent per year (Statistical Year Book 1991). The sex ratio of the population is 106 males per 100 females. The literacy rate is 24.8 percent for the population of 5 years and above. About 85 percent of the total population lives in the rural areas and 80 percent is engaged in agricultural professions. Basically, the

6 Landless and marginal peasants.

7 Irrigation Programme Coordinator, *Proshika Manobik Unnayan Kendra*, Dhaka, Bangladesh.

country's economy is predominantly agrarian, the cultivable land and the water resources are the principal assets of the country.

The total cultivable land in the country is 903,000 hectares (ha). There are three main rice crops cultivated in the country, which are aush, aman and boro. The boro rice is cultivated in the drought season, that is in between the period of aush and aman. These three rice crops cover an area of 222,189 ha and the crops other than rice cover 516,644 ha. The groundwater irrigation facilities were supplied by 22,510 deep tubewells, 81,511 shallow tubewells and 123,051 hand tubewells in 1990/1991, covering approximately a total area of 1,020,000 ha.

This paper attempts to present a synthesis of the experiences of both Proshika and of the groups of rural poor involved in groundwater irrigation management. It outlines the total mechanisms of the implementation processes including the management system through which the groups have been sustaining themselves over the last decade.

Proshika and its Experience

Proshika Manobik Unnayan Kendra is a National Nongovernment Organization in Bangladesh. Since 1976, it has been involved in organizing both the urban and rural poor for development through education, training and support services including credit. From 1989, a similar process has been initiated in the urban areas to provide development services to the urban poor. From its inception it has incorporated a sustainable development approach which is economically viable, ecologically sound, socially just and culturally appropriate.

Over time, Proshika's development activities have extended to 3,415 villages of 429 unions under 70 upazillas in 26 districts. Presently, the total number of groups are 23,252 of which 11,615 are male and 11,637 are female. It is notable that each group consists of 15 to 20 members.

Proshika's work priorities are defined by themes that refer to some of the topical concerns in rural development. And, the priorities cut across its programs, projects and activities in alternative development endeavors which can be grouped into several major areas. These are as follows: (i) organization of the rural poor, (ii) development education, (iii) employment and income generating activities, (iv) rural health infrastructure, (v) social forestry, (vi) ecological agriculture, (vii) Urban Poor Development Programme, and last, (viii) disaster management.

PROSHIKA'S ENDEAVORS TOWARD SUSTAINABLE GROUND-WATER MANAGEMENT BY THE RURAL TARGET GROUPS

Context

Groundwater Irrigation Project Management by the target groups as water selling enterprises, is an alternative development approach, because the members of the groups sell irrigation water to the fields of landlords under some agreed terms and conditions. But the tradition is, the landowners possess the equipment and use irrigation water to their agricultural land. In some cases the landowners sell water to other fields so that any losses from their own fields can be compensated by the additional income derived. The ultimate aim of the involved groups in groundwater irrigation management is to balance the social inequality between the rich and the poor.

Thus, Proshika Irrigation Programme forms a cycle of beneficiaries, starting with the landless who earn an income through the selling of irrigation water to the land owners, who in turn, are making a profit by raising the productivity of crops which again benefit the economy of the country.

CASE STUDIES

The following two case studies will help to illustrate the total implementation processes starting from initiating a proposal for a project up to its closing. These include group selection, farmers' motivation, credit support, training, technical assistance, share fixation and collection, marketing, etc. The first case study is one of success and the second is a story of mismanagement.

First Case Study

Bastail is a village of Mirzapur Upazilla in Tangail District, where a Bastail *Bhumihim Samity* (landless group) was formed 3 years back. The group consists of 30 members and they hold meetings twice a month. During the last three years they had been utilizing their own savings satisfactorily.

There was an old deep tubewell (DTW) installed in 1974 within the periphery of the residences of the group. The *Krishak* (landowners) Group could not operate the tubewell satisfactorily from the beginning as the manager was functioning individually, taking the full responsibility on his shoulder. He was facing credit, technical assistance and water charge collection problems without any consultation with the group. Three years after its commencement, the project ceased to operate. In 1985/1986, Bangladesh Agricultural Development Corporation (BADC) issued a circular allowing the sale of all the old deep tubewells to the formal/nonformal groups or individuals.

Depending on the above circular the landowning farmers requested the group to take the responsibility of the said deep tubewell project. The group then expressed its desire to Proshika of undertaking the maintenance of the abandoned DTW in their locality. The respective animator who organized the group and the Irrigation Technical Worker (Irrigation Engineer) discussed with the group members in a formal meeting the social, financial and technical advantages and disadvantages, obligations of the group members and the farmers toward the project, Proshika credit norms, etc. The group was hopeful and ensured their sincerity and confidence. They also conducted a group feasibility survey through indepth discussions to judge the uniformity of the group by class and by profession, age of the group members, amount of savings of the members and the performance of their own savings management, etc., and found the group to be feasible to operate the particular irrigation project. The Irrigation Technical Worker then conducted a technical feasibility survey along with the group leaders and the farmers, and found the command area of more than 45 ha to be most suitable.

Then, Proshika, the group, the ex-farmer's group and the Bangladesh Agricultural Development Corporation held a formal meeting where all four parties agreed to transfer the said DTW to the newly formed group on a cash sale basis. Subsequently, former group members and present farmers sat together for share fixation and agreed to fix up a crop share of 33 percent, and both parties concluded a sales agreement. The farmers could use irrigation water for five years with renewal of agreement every year. The group then purchased that DTW for taka (Tk) 52,800⁸ (US\$1,364) in cash. When all preparatory work was accomplished a seven-member management committee was formed by the group and the members were sent to receive training on irrigation project management in the local Area Development Center (field office). At the same time, an engine and pump operator and a water distributor were employed by the management committee and they were sent to receive training on engine and pump operation and water distribution at the

8 US\$1.00 = Tk 38.70.

Proshika Central Training Center, Koitta, Manikgonj. During the first year, the command area was restricted to 18 ha and an operational loan of Tk 50,000 (US\$1,292) was given to cover costs of fuel and oil, spare parts, wages, etc. After completing the first year of operation successfully, the group earned Tk 87,192 (US\$2,253). They sold rough rice to cover the total loan received from Proshika and whatever that was left was evenly distributed among the group members.

During this period the pump broke down three times and was repaired by the mechanics from BADC along with the Irrigation Technical Worker. For better implementation of the project, the group followed the procedures indicated below. The management committee was expected to hold weekly meetings to approve the expenditures already incurred and to give prior approval for forthcoming expenditures. The management committee had to present all the expenditures incurred during last four weeks and raise other relevant crucial management issues in the general group meeting for approval and rectification, respectively. The above systems were followed regularly for controlling operational expenditures, conflict minimizations amongst the groups and the farmers pertaining to irrigation water distribution, etc. During share collections, the group was subdivided into 4 or 5 sub-groups with management committee members as the team leaders. Each individual sub-group was responsible for the successful collection of shares and for making the accounts available to the group on a regular basis. This system committed them to a serious obligation which led to successful share collections. Another important factor is that the system helped the group to maintain group solidarity which paved the way for democratic leadership rotation among the group members. During the season, they sat twice along with the Proshika personnel for mid-term and final evaluations of their project. During the ongoing operational period, the Irrigation Technical Worker and other related Proshika field personnel provided close monitoring.

In this way, the group operated their irrigation project of 30 ha and earned Tk 119,200 (US\$3,080) in 1986/1987, of 25 ha and earned Tk 121,100 (US\$3,129) in 1987/1988, of 31 ha and earned Tk 124,033 (US\$3,205) in 1988/1989. The project got an electric connection in 1989 and the group immediately responded by decreasing the share rate from 33 percent to 25 percent, an action by which the group won the added confidence of the farmers. As a result, the command area increased to 33 ha in 1989/1990, and to 55 ha in 1990/1991, raising the earnings to Tk 206,032 (US\$5,324). This year too, the group has planned to irrigate 55 ha of land with an agreed crop share rate of 25 percent.

Second Case Study

Baoni is a village of Sreepur Upazilla in Gazipur District, where a *Jonodorodi Samity* (comprising 26 members) was organized in 1982. This group functioned with regular meetings, managing its own savings, and participating in the social activities. Similar to the first successful case discussed above, the group got the project and started operation with a command area of 16 ha in the year 1985/1986.

When the group's feasibility was examined, all the group members were found to be belonging to the same category in terms of class and profession with the exception of one member named Abdul Malek. Proshika advised the group to terminate the latter's membership from the group because he possessed 6 ha of land under the scheme, thus making the group heterogeneous in category. Accordingly, the group requested Malek to withdraw his membership from the group. But Abdul Malek had been rendering services voluntarily, staying outside the group during the season, and in this way he had made the group members become obliged to him. He utilized the absence of group members at meetings (as many of them very often had to go elsewhere in search of jobs) to his own advantage. Besides, he also created conflicts among the group members and the farmers without their knowledge, and subsequently, he himself mediated in resolving such conflicts. As a result, the group felt that Abdul Malek was indispensable to the group and to the

smooth functioning of their project. Accordingly the group convinced Proshika field personnel that Malek should be included in the group.

Abdul Malek diplomatically created frustration among the majority of the group members by convincing them that the project was a failure. As a result, many group members were alienated from the project. The main intention of Abdul Malek was to cultivate his land without paying a share and he was successful in doing so. On the whole, misappropriations and the blackmailing strategies of Abdul Malek disheartened the group members to a great extent. Ultimately the project had to be terminated after running for 4 years after reporting severe losses, though the general opinion of the group as well as the farmers is that the project did not incur losses. The group then took a decision to sell the DTW and pay the outstanding loan to Proshika.

SOME MAJOR FINDINGS OF THE ABOVE TWO CASE STUDIES

Conditions Necessary for Success of Project

First, the selected group must be free from heterogeneity (in terms of class and profession), and the leadership should follow a democratic process so that each group member can get the opportunity to exercise his responsibility. Second, the organization should pass through a reasonable span of time for strengthening the unity of the members and there should be enough evidence to show successful savings utilization. Third, project expenditures must be reviewed periodically and any problems should be solved immediately as they occur. Fourth, there should be no confusions regarding ownership of the project. Fifth, maximum participation must be ensured and the involved group members should not be kept unnecessarily busy all the time for official purposes. Sixth, the project benefits must be distributed evenly among the group members and impartial attention must be given to the interests of the group and the farmers. And finally, accountability and obligations toward the project are to be enhanced through an appropriate training process.

Promotion of Irrigation by the Rural Poor

Irrigation water is as important a resource as land for agricultural production. The mainstream government strategy for agricultural development is to support those who have land to acquire ownership of irrigation resources as well. This has led to further social and economic polarization and made the landlords "waterlords" as well, while making the conditions of the rural poor more vulnerable. This unbalanced resource endowment in favor of the rural elite has not led to better and efficient management of irrigation systems. In fact, there are countless examples of unsuccessful irrigation projects owing to factors such as small command areas, faulty and biased water management, corruption, etc. In order to address the issues of equity and better management, Proshika undertook a pioneering irrigation strategy through which the rural poor are assisted to acquire control and manage irrigation resources enabling them to contribute to increased productivity while enjoying a fair share of the benefits. This has led the rural poor to wield more social and economic power simultaneously improving the management of the water resources without Proshika credit.

Proshika has supported 744 groups with credit, training and extension services so that they can sell irrigation water to landowners. Around 80 percent of the projects are successful from an economic, social and managerial point of view. Out of those projects, 78 have become completely self-reliant requiring no further credit and training support from Proshika (Table 2.1). However, some technical assistance is provided and communication is still maintained by the field workers

for the further development of such projects. Table 2.1 also shows 13 shallow tubewells which were expanded from the income of the group members without Proshika credit.

Female Groups Involved in Groundwater Management

Participation in post-harvest technologies by the female laborers is commonly found in Bangladesh, while female participation in the crop production sector is rare. But Proshika has the following experience: It initiated an irrigation program by the landless female groups in 1987 at Madaripur. Subsequently, five projects were implemented in the districts of Manikgonj (upazillas: Saturia and Ghior); Tangail (upazillas: Mirzapur and Nagarpur); and Gazipur (upazilla: Kaliakoir); by female groups. Out of the five projects one ceased to exist for the following reasons:

Table 2.1. List of projects which have become completely sustainable.

District name	Area Development Centers (field offices)	Technologies		Time required in years for reaching sustainable stage		Expansion by group without Proshika credit	
		STW	DTW	STW	DTW	STW	DTW
	Name of upazilla						
Dhaka	Dhamrai	2	-	2	-	-	-
Madaripur	Madaripur	3	-	3	-	-	-
Do	Kalkini	1	-	2	-	1	-
Keshoregonj	Bhairab	2	-	2	-	-	-
Do	Kuliarchar	1	-	3	-	1	-
Manikgonj	Ghior	20	-	3	-	-	-
Do	Horirampur	2	-	2	-	1	-
Do	Singair	2	-	2	-	1	-
Do	Doulatpur	5	-	3	-	1	-
Tangail	Mirzapur	2	1	4	5	-	-
Do	Basail	2	-	2	-	-	-
Do	Sakhipur	2	-	3	-	-	-
Bogra	Sibgonj	5	-	4	-	2	-
Do	Gabtali	9	-	3	-	7	-
Sirajgonj	Serajgonj	8	-	3	-	-	-
Do	Roygonj	5	-	2	-	-	-
Faridpur	Bhanga	4	-	4	-	-	-
Gapalgonj	Muksudpur	1	-	2	-	-	-
B. Baria	B. Baria	1	-	1	-	-	-
		77	1	50	5	14	-

Notes: STW = Shallow tubewell. DTW = Deep tubewell.

- Traditional social problems, security and managerial problems.
- Misappropriations by the hired male group members in accounting and marketing, etc.

Yet, four irrigation schemes are still functioning after overcoming the above constraints. Proshika has learnt a lot from the failures of the above schemes. During the ongoing irrigation season, 14 irrigation schemes have been running with more participation by the female group members. They participate in engine and pump operation, water distribution and channel construction. Since DTW management is rather more complicated than shallow tubewell management, two DTW schemes are run jointly by the male and female groups. The management committees have been formed in such a way that the female groups can exercise more control over the project.

Further, in terms of sustainability of the projects, Proshika has observed that the female groups are doing better, because the female group members are found to be comparatively more sincere, careful and economically motivated than the male group members.

Group Members' Training as Engineers and Pump Mechanics

Mechanical knowledge for engine and pump servicing and overhauling is vital for the successful completion of an irrigation project. It also requires the dependable and sincere support of a mechanic. Proshika experienced that group-based mechanics function very effectively, particularly because they render their services to their individual group projects with an obligation. Since Proshika trained mechanics every year, a single group may have more than one mechanic who helps the irrigation group to get support immediately after any mechanical trouble.

Based on the above experience, Proshika started training projects in engineering and pump mechanism in 1981. Over the last decade Proshika has trained 270 group members as mechanics. Among them, 221 mechanics have been working very efficiently for the last few years and have been earning a significant income every year. The remaining 49 mechanics have abstained from work due to the following reasons: (i) lack of opportunity to exercise their skills, resulting in the discontinuation of work, and (ii) inability to sell technical skills on a competitive basis, a factor which is responsible for lower incomes. These situations diverted their attention elsewhere compelling them to go for jobs outside their own field.

There is a policy for participant selection. Accordingly, an interested group member who wants to be a mechanic, must be nominated by the group for training. Experience on irrigation water distribution and engine and pump operation are pre-conditions for such selection. Formal educational qualifications are not essentially required for the participants. However, the nominated group member must have commitment and enthusiasm for training. After completion of training, the group usually provides a loan to their member mechanic to purchase important tools and, if needed, Proshika also provides credit support through the group. Prior to the commencement of the season, all mechanics sit together to allocate the working areas and to fix up the seasonal charges, so that the irrigation groups may not face any mechanical problems. There is also a standing policy that the mechanic cannot claim charges for work in his own project. Besides, the new mechanic is not expected to engage in major overhauling activities. He will have to work at least for one season under an experienced mechanic. The policies which are discussed above are set forth just to fix up the accountability and obligations of a mechanic to his primary group.

The mechanic's activities are solely monitored by the irrigation technical workers. Training of the mechanics are often conducted by the trained mechanics of Proshika. Proshika hires them whenever their services are required as resource persons, and has been following this policy for a long period.

CONCLUSION

Proshika's endeavor of ensuring the sustainability of the groups engaged in groundwater management is a continuous process. It requires a dynamic and an appropriate policy on the project implementation process and Proshika accomplishes this with policy adjustments every year with the participation of the group members and the Proshika field-level workers. Proshika pays close attention to social, financial and technical aspects, so that the projects achieve a high rate of success. Perhaps the irrigation water selling concept by the rural poor may be a way of solving the complex problem of equity and productivity.

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Sustainability of Farmer-Managed Groundwater Irrigation Systems in Drought-Prone Areas: The Role of Socioeconomic Conditions

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ABSTRACT

IN INDIA, USING groundwater for agricultural purposes is one of the oldest forms of irrigation. Traditionally dugwells were the chief means of irrigation in drought-prone areas. Farmers evolved indigenous methods to lift water from shallow dugwells. Waterlifts were mostly drawn by bullocks and also by human beings, depending upon the depth of well and the area to be irrigated. Over the years economic compulsions and technological innovations seemed to have influenced to a great extent the spatial and temporal spread of groundwater irrigation. The increase in population has necessitated the optimum utilization of available groundwater. This has led to the construction of dug-cum-borewells and tubewells. Animal-drawn waterlifts were gradually replaced by diesel and electric pumpsets. Single-farm wells have become multi-farm wells, because of the division of property among brothers and other kinship members. The emergence of all these techno-economic changes in the ways and means of groundwater exploitation is believed to have posed a threat to the sustainable supply of water for agriculture. It is therefore attempted in this paper to highlight the understanding of groundwater management problems by the farmers and methods adopted by them to handle aquifer drawdown.

PROBLEM

Agricultural development in drought-prone areas is fraught with multiple risks emanating essentially from erratic and scanty rainfall. Farmers over the aeons have, however, searched out the environment for niches favorable to their own concept of welfare, and often, through centuries of long trial and error, have established farming systems with technologies (such as risk-spreading multiple cropping) suited to their needs (Dillon 1986). One such technology developed traditionally by the farmers to mitigate the adverse effects of inadequate and uncertain rainfall is groundwater harvesting for agricultural purposes. Since sophisticated technology to gauge groundwater potential in a given region was not available to farmers, their conventional wisdom and practical experience have been mainly responsible for the identification of appropriate sites for tapping groundwater. This has essentially led to the construction of shallow dugwells by

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individuals or by small groups of two or three farmers whose lands were geographically contiguous.

Farmers in drought-prone areas, having experienced uncertainties of rain-fed farming, tend to be cautious in using available water in wells judiciously to ensure a sustainable supply. This is because they can visualize the hardships if the drawdown goes beyond a level which they perceive as unsafe. Further, they are aware of the limitations of capital and technical knowhow required for deepening dugwells beyond a particular depth in a given region. Some of these factors play a crucial role in shaping up typology of wells in terms of depth, diameter, mode of water lifting and irrigation practices to be adopted, keeping in view the sustainability of the system in the long run.

In the wake of increasing population pressure and the consequent demand for more food production, the need for exploitation of groundwater has increased over time. This has necessitated technological innovations to be introduced to tap groundwater. Keeping this in view, the government has sponsored institutional credit programs to encourage dugwell irrigation. This seems to have led to an apparently paradoxical situation; for, on the one hand the technological revolution and institutional credit facilities enabled the construction of deep wells and on the other, it tended to jeopardize the traditionally established sustainability. Given this situation it is important to know how farmers manage groundwater systems keeping an altruistic view, namely, "live and let others live" in mind. What kind of strategies do they evolve to manage groundwater systems? How do they perceive drawdown conditions and plan for suitable farming systems? How do they share water scarcity? What kinds of interventions from the government are necessary to promote sustainability in groundwater exploitation? These are some of the questions that need to be examined to understand the dynamics of groundwater exploitation.

With a view to examining some of these issues a few farmer-managed groundwater schemes from I.V. Palli, a village in Anantapur District of Andhra Pradesh, India, have been selected. The issues and problems analyzed in this paper are essentially based on the experiences and views of farmers selected for this study; yet they are representative of the general conditions in the region.

The Study Region: Background

The study village is situated in an economically backward, semi-arid and frequently drought-prone region where annual rainfall ranges between 500-600 millimeters (mm), mainly during the southwest monsoon spread over June to September. Rainfall is not only low in the region but also highly uncertain. Therefore, shallow dugwells was the main source of irrigation. There are a few tanks located in the neighboring villages from which the village selected for the study does not get any direct benefit by way of surface irrigation. But it is benefitted indirectly as the tanks contribute to the recharge of groundwater aquifers which in turn enables a rise in water level in the wells. Since rainfall is low in the area the chances of tanks getting filled frequently are less. It was reported by the local people that the cyclonic storms in the Bay of Bengal, the frequency of whose occurrence is as uncertain as rainfall itself, are some times a blessing in disguise for this area; for, it ensures adequate rainfall enabling innumerable tanks in the region to receive full storage. Farmer experience indicates that if the tanks are filled to full capacity in one year there will be no scarcity of water in the wells at least for two years even if rainfall is low. During such years they go for water-intensive crops without much problem. It indicates farmers' ability to judge drawdown possibilities based on monsoon conditions in a given period of time.

Red soils with rocky formations are predominant in the region. This is one of the characteristic features of the soil profile in the Deccan Plateau, where the hard rock area forms about 90 percent of the geographical area (Dhawan 1986). This could perhaps explain the little scope left for the introduction of the tubewell technology. Hard rock bottom does not permit deep dugwells. However, during the last two decades the number of dugwells has increased, the externalities of

which would be examined elsewhere. Rice was the chief crop under dugwell irrigation. Aquifer drawdown in successive years seemed to have effected substantial changes in cropping pattern under well irrigation. Farmers have been using the cropping pattern as one of the important means to ensure a sustainable supply when groundwater becomes scarce.

Groundwater Systems (Dugwells) Selected for Study: Salient Features

The groundwater systems selected for this study are traditionally built shallow dugwells, which are mostly a century old. The details are presented in Table 3.1.

Table 3.1. Salient features of farmer-managed groundwater systems selected for the study.

System number	Depth of well (in feet)		Whether converted into dug-cum-borewell	If yes, depth of bore (in feet)	Area irrigated (command area in acres)
	At the time of first construction	Present			
1	20	30	Yes	100	11.5
2	22	26	Yes	120	5.3
3	18	22	Yes	60	4.6
4	12	24	Yes	80	8.2
5	12	24	Yes	90	8.0
6	26	26	No	-	5.7

Note: 1 foot = 0.30 meter.
1 acre = 0.40 hectare.

The present owners of the six systems, the details of which are presented in Table 3.1, are second- and third-generation people. Therefore, none of them are able to say the year in which the well was constructed. Almost all the wells were deepened two to three times depending upon the drawdown status of aquifers over years. Further, it was reported that desilting of the wells once in five years or so, depending upon the water level in the wells, is undertaken to keep the aquifers active without allowing any clogging. This practice was perhaps followed to ensure sustainability. During the last 20 to 30 years a number of new wells have come up in the area. This has affected water availability in the old wells. All the farmers, therefore, were forced to construct borewells. The dugwells under reference have been converted into dug-cum-borewells, for the dugwell technology, as mentioned earlier, does not permit deepening of well beyond a certain depth. Further, hard rock strata in almost all the wells seems to be the major constraint to deepening the wells. Even so, some farmers (in Systems 1 and 2) did attempt to deepen wells through the blasting of the hard rock bottom, but without favorable results. Some of these natural constraints have been responsible for integrating modern tubewell technology with the traditional dugwell technology to ensure an adequate supply of groundwater. Therefore, dugwells have been converted into dug-cum-borewells.

Another interesting feature is that the number of beneficiaries per well has increased over the years making them common property because, single/twin-farm systems have been converted

into multi-farm systems. This change tends to influence water use and management strategies which might affect the sustainability. Table 3.2 gives the details.

Table 3.2. Number of beneficiaries per system, their relationship, and type and number of waterlifts.

System number	Number of beneficiaries		Relationship	Type and number of waterlifts per system	
	At the time of construction	At present		At the time of construction (Moht)	At Present (electric pump)
1	1	7	Kinship	2	3
2	2	4	Non-kinship	1	2
3	1	2	Kinship	1	1
4	2	4	Non-kinship	2	1
5	3	8	Non-kinship	2	2
6	1	4	Kinship	2	-

Note: Moht = A system used to lift water from shallow dugwells.

It can be observed from Table 3.2 that the number of beneficiaries (owners) has changed over time. This shows that the groundwater systems, started with single ownership, assume common property nature in the course of time. This happens essentially due to two reasons: (i) patrilineal right to inherit property leads to division of land among brothers and hence becomes common property; and (ii) the sale of land by the original owners to others outside the kinship circle. It is interesting to note that out of the six systems under reference, three systems (50 percent) have owners who do not belong to the same kinship. This shows the prevalence of a cooperative culture for exploiting groundwater, may be in a small way. It appears that this kind of cooperation emerged out of economic compulsions. For instance, small farmers with tiny holdings find it uneconomical to have an independent well (Reddy 1988). Further, raising funds independently to construct a well may be a difficult proposition. Therefore, two or three farmers whose parcels of land are geographically contiguous used to come together and construct a well and share the costs and also water on a pro-rata basis of the land they own. In such cases land will be owned individually and the irrigation well becomes common property. The individual rights to use water in proportion to their land are registered and guaranteed under law. Any attempt to prevent members from using their individual share of water could be challenged in a court of law.

Practical Problems Faced by Farmers

The depletion of the groundwater table year after year, caused partly by the additional wells in the study area and mostly by less precipitation, made farmers realize the importance of modern technology. While attempting to adopt modern technology, namely, tubewell technology, the farmers seem to have faced many problems. The most important problem, as reported by many, was the selection of an appropriate site for a tubewell. They used their practical wisdom and also sought the help of local water diviners in selecting an appropriate site. Both the methods are not scientific and therefore, striking a potential aquifer is a chance factor. For instance, the farmers

of System 1 (Table 3.1), wanted to drill a deep bore in the hard rock to augment the water supply in the well. Even after drilling to a depth of about 80 feet (24 m) the hard rock stratum continued to a further depth and they got disappointed. However, a second attempt was made to identify another site with the help of a water diviner to drill another bore, a few feet away from the first one, to a depth of about 100 feet (30 m). This time also it was not possible to clear the hard rock strata and thus the farmers abandoned all hope of striking deep aquifer and tried to manage with the available water. In both instances the investment had gone waste. Had appropriate technology been available to strike potential aquifers the wasteful expenditure incurred by the farmers could have been avoided. The demonstration effect of such failures tends to leave an adverse impact on other farmers willing to adopt modern technology. Though finance is another major constraint for deepening wells, farmers are able to overcome it if there is a guarantee of getting plentiful water.

In the case of the other four systems under reference (Systems 2 to 5) the situation is different. They also had the same problem of identifying the right site to install bore. But by trial and error methods they could successfully strike active aquifers. Especially the Systems 4 and 5 have copious supplies of water after groundwater systems were transformed from traditional to modern technology to ensure a sustainable supply of groundwater.

Technological Progress and its Impact on Sustainability

The transformation of groundwater irrigation from low-cost traditional dugwell systems to cost-intensive modern tubewell technology, and the changing ownership pattern seem to have influenced farmer attitude toward water use and management. Practical wisdom and field experiences of the beneficiaries over a period of time have enabled them to assess the availability of water in the wells depending upon the temporal and spatial intensity of rainfall in the region. Accordingly they plan cropping patterns. For instance, it was reported that when rainfall is good where tanks and ponds in the area get filled in a particular year, farmers are sure that groundwater aquifers get recharged and water in the wells will be plentiful. In such years water intensive crops like rice are grown on a large scale. If the rainfall intensity is less semi-dry crops are cultivated, so that water scarcity does not occur. Majority of the farmers are aware of the fact that excessive drawdown in successive years leads to drying up of the aquifer. Therefore, cropping pattern is used as an effective measure to ensure a sustainable supply of water. This has been the age-old practice in the study region with the result that, in none of the wells under study, as reported by the beneficiaries, have the water levels gone below critical levels, of about 2 feet (0.61 m). Even if the water occasionally depletes to the bed level of the well, farmers manage in such a way that it reaches a sustainable safe level, as perceived by them, by practicing utmost economy in water use for the crops. These practices are more true in the case of single-owner systems, though the systems with more than one owner also adopt such measures.

Besides the introduction of tubewell technology and extension of institutional credit, the supply of electricity on subsidized rates appears to have changed the outlook of farmers toward sustainability. It may be recounted here that traditionally *Moht*¹⁰ was the chief devise used to lift water. This was replaced by diesel pumps in the study region in the late sixties. Later, when the villages were provided with electricity in the late seventies, diesel pumps were replaced by electric pumps. It is interesting to note that as long as *Moht* was the chief means of lifting water from wells there seemed to have never been a scarcity of water. This was because, farmers were

10 *Moht* is a system used to lift water from shallow dugwells. A long and thick rope and a big leather bucket are used and it is operated through animal labor (bullocks or buffaloes). In local parlance it is called *Kapila*.

extremely cautious in using water; for, it was a laborious job involving both manual and animal labor. The introduction of diesel pump technology has made farmers relatively more liberal as far as on-farm water use is concerned. However, the high cost of diesel oil had a built-in check on over-use of water. But, the introduction of electric pump technology, particularly the introduction of fixed tariff (demetering), based on horse-power (hp), seems to have consolidated the sense of liberalism among farmers which has left its own impact on the sustainable use of water from wells. Since power tariff is based on hp irrespective of the quantity of electricity used, farmers tend to use more pumping hours than actually required resulting in the wasteful use of water, which was not the case under Moht irrigation. This practice seems to have led to drawdown in all the wells under reference, necessitating their deepening more than once.

Further, technological progress in groundwater lifting (diesel and electric pumps) while bringing attitudinal changes among farmers in water use has also encouraged the proliferation of single-farm dugwells in the study region, contributing to the fast depletion of groundwater. Before the advent of pump irrigation, dugwell irrigation was practiced predominantly in the farms adjacent to the village. Farmers generally avoid dugwell irrigation in the farms away from the village as it requires transportation of water lifting equipment, namely, long and thick rope, a big leather bucket and also animals (either bullocks or in some cases buffaloes) daily from the village to the farm. Families with a single male member cannot afford this; because it requires at least 3 male persons (adults) to operate Moht for lifting water from wells (two persons to lift water with the help of two pairs of bullocks and one person to water crops on the field). Therefore, families with at least 2 to 3 male members used to venture to go for dugwells, that too in the farms close to the village.

With the introduction of pumpsets (diesel and electric) the scenario of groundwater systems has changed in the study region. Dugwells were constructed even in farms away from the village. The competition to use groundwater has increased. This has resulted in the depletion of the water table and created water scarcity in some of the older systems where plentiful water was available.

For instance, in System 1 (see Table 3.1), as reported by the present owner cultivators, water seems to have never been a problem. It was irrigating about 11 acres (4.5 ha) of land with 300 percent crop intensity (one semi-dry crop followed by two rice crops a year). The well was known for the plentiful supply of water in the region. Ten years ago, when a neighboring farmer had constructed a dugwell just about 100 meters away from this system the availability of water in the older well had drastically come down. Further, when the new dugwell was converted into dug-cum-borewell, the aquifer drawdown seems to have gone beyond the reach of the older well with the result that the older well has dried up completely in spite of the best efforts by the farmers to deepen the well. Unable to strike any other aquifer farmers of the older well have now switched over to rain-fed farming. While this is only an illustrative example of the externalities of new technology contributing to the over-mining of aquifers and thus endangering the sustainability of groundwater systems in the region, many farmers have fallen into a perpetual debt trap by resorting to dugwell irrigation without understanding the limitations of groundwater availability. It is in this context that the role of the government becomes important in regulating groundwater. Approximate norms to maintain spacing between wells need to be stipulated and farmers should be educated about the limitations and disadvantages of indiscriminate mining of groundwater aquifers.

Water Distribution: Methods and Practices

It is obvious that single-owner systems do not have problems of sharing water. The management strategies adopted to regulate drawdown and ensure a sustainable supply of water for irrigation were, as mentioned already, essentially linked with the cropping pattern and its intensity (high water-intensive crops followed by higher intensity of cropping when water is plentiful). But it

would be interesting to note how water is shared between the farmers when a system takes the form of common property in the course of time for reasons explained above. As seen from Table 3.1. the systems under reference are small in scale in terms of area irrigated and also number of participants. Before we discuss water sharing methods adopted by the group-owned and -managed systems, let us look at the status of water lifting devices in the groundwater systems under reference (see Table 3.2).

Traditionally, Moht was the chief source of water lifting from dugwells. If a system is owned by two persons they used to provide for two Mohts, so that each partner can use them independently or some times interchangeably depending upon the location of farm plots. As long as water supply in the well is abundant unrestricted use is allowed to partners, though legally, water right is linked to area owned by a farmer under a given well. In times of scarcity, strict measures are adopted to share available water equally between partners by fixing rosters based on time sharing if watering is to be completed in a single day; and if watering is spread over a week or a mutually agreed period the roster will be based on sharing days. In either case the share is linked to area owned or any other norms of entitlement. In olden days, since it was difficult to share the time in terms of hours, farmers followed the movement of the sun. For instance, if there are two partners, one is allowed to use water up to sun-rise and the other from sun-rise to sun-set. The order will be reversed in the next day or for the next watering, so that the advantages or disadvantages, if any, are shared equally. If there are more than two partners, the rostering would be up to sun-rise, sun-rise to noon and noon to sun-set. This roster goes on changing. In case water is very scarce where the entire area cannot be irrigated in a single day, they resort to a roster where each partner uses a full day. This again is based on a pro-rata basis of each partner's entitlement for water in a given well. These rosters also change according to cropping pattern. If it is for rice the roster is invariably based on time sharing in a day, for rice needs watering every day. If it is for semi-dry crops the roster is based on sharing of days in a week or in a stipulated period of a roster. This kind of strict rotation has a built-in check on excess use of water. It also ensures economy and efficiency in water use which in turn contributes to sustainability.

With the advent of pump technology, Moht has become redundant. It can be noted from Table 3.2 that the increase in number of pumpsets is not commensurate with the increase in number of partners in each system. This shows that one pump is shared by two or three farmers. As reported by the farmers, to have a pumpset independently for each tiny plot is not economically viable and also many cannot afford it. Therefore, they are in a sense compelled to think of collectivism. Since each one of them understands local dynamics well it is easy to arrive at mutually agreeable terms and conditions in operation, use and maintenance of a collectively owned pumpset. Water sharing from the common source has, however, remained more or less on the same lines as it used to be under Moht irrigation days.

Water use methods and land preparation for irrigated farming have changed after the introduction of pumpsets. For instance, it was reported that farmers were very particular about uniform leveling of land while the Moht System was in operation, to enable smooth and quick spread of water with minimum wastage. Under pump irrigation they seemed to be not very particular about this aspect. They do not bother much even if it takes more energy, time and water. The liberal attitude developed by the farmers toward water use has led to drawdown conditions necessitating periodic deepening of wells, where some are successful in striking potential aquifers and some not. While nature plays its own role in recharging the groundwater aquifers, man has greater responsibility to maintain the balance by resorting to judicious use of groundwater. Unplanned growth of wells has resulted in the depletion of groundwater level, the externalities of which, have affected many resource-poor farmers adversely. For example, they have had to abandon the shallow wells and be out of irrigated farming. In effect, area under irrigation has not increased commensurate with the increase in wells. It shows that additional area claimed to have been brought under irrigation by the new wells is not an addition in real terms. The gain of new

entrants is the loss of old ones or the gain of resourceful farmers is the loss of resource-poor farmers. This raises the question of equity, the answer for which, may be difficult to find under the existing socioeconomic conditions.

Tragedy of the Commons

Many of the groundwater systems, as seen above, acquire common property nature over time. Though the groundwater systems have had established norms and practices to share water without affecting sustainability, it is well known that common properties, whether it is land, water, forest or any other resource, are fraught with several crises associated with their operation, maintenance and use by the members, leading some times to temporary or may be permanent disuse. This phenomenon is generally known as "tragedy of the commons" (Hardin 1968). It was reported that the majority of the systems under reference were the victims of the tragedy of the commons at one time or the other. Many farmers take it as a natural process that might some times last for two to three years. Established social authority and the rural ethos help in finding solutions for such problems.

While it may be true that the tragedy of the commons relating to a system's operation and use of water is taken care of by the existing social ethos of a village, certain other problems are some times left uncared for, which affect the sustainable supply of groundwater. For instance, System 6 in this study is totally abandoned due to conflicts among partners. This would have been resolved, as stated by the local farmers, if it were only a local problem of conflict resolution. It is a different issue and more pertinent one in the context of sustainable groundwater recharge. There is a long bund diverting a rivulet just upstream of the well under reference. A few years ago because of heavy rains the bund got breached and the rivulet now flows straight into the well. This has caused silting up of the well. Though several other farmers are also affected by the breach they do not show much interest in its reconstruction. Before the breach took place the bund was enabling water storage in a fairly big pond which was in a sense a percolation tank to recharge groundwater. Because of this breach, the water supply in System 1 and also in other wells adjacent to the pond belonging to farmers of a nearby village have been greatly affected. Since the cost of reconstruction is high and many farmers are otherwise occupied, it is left unattended to with the result that the water supply is affected in some wells and some other wells in the downstream are abandoned. In all, about 15 to 20 acres (6 to 8 ha) of hitherto irrigated land has gone out of irrigation. In spite of the attempts made, by some of the affected farmers to date it has not been repaired. If the breached bund is restored to facilitate water storage as it used to be before breaching, a minimum of six wells will be benefitted by it, and about 40 acres (16 ha) of land gets assured irrigation.

While this is a single micro-level example of how the tragedy of the commons affect groundwater levels, a serious view of the ramifications of such tragedies at the macro level is necessary. It is in such matters that the government's intervention becomes more important. The government should not only take up such repairs but must also educate farmers on preserving traditional ponds and tanks which are the main sources of percolation in drought-prone areas.

It is often recommended that the government should stipulate stringent measures to ensure equity and sustainability in groundwater exploitation. One should appreciate the limitations to regulate groundwater through appropriate spacing between wells (Dhawan 1990). In a democratic policy where a major proportion of land is owned by private individuals, it is not possible to regulate spacing between wells. The indirect means such as not providing institutional finance, electricity for pumpsets and so on would not be effective checks, for, many farmers can raise their own funds or borrow from private money lenders to construct wells. Similarly, diesel pumps can substitute electric pumps if electricity is not supplied. Therefore, the only option open for the government is to educate farmers about the ways and means to regulate groundwater use,

encourage community wells to extend groundwater irrigation for small and marginal farmers and promote watershed management to recharge groundwater aquifer.

Resumé

The discussion so far brings out certain interesting findings. Traditionally, dugwell irrigation was popular in drought-prone areas. When dugwell technology was the prerogative of a few farmers whose lands were located nearer to the village, plentiful water was available even in the shallow dugwells. When the number of dugwells increased over time the necessity to strike deep aquifers arose. The limitations of deepening dugwells beyond a particular depth have made farmers look out for an alternative technology to tap groundwater. The emergence of tubewell technology enabled a few rich farmers to convert traditional dugwells into dug-cum-borewells. The negative externalities of modern technology on traditional dugwell irrigation were many. Farmers in the traditional systems were careful and judicious in using groundwater. They used to maintain a minimum depth of water in wells to keep aquifers active. A judicious combination of crop mix suitable to water levels in wells has been used as one of the means to sustain water supply. The emergence of tubewell and pump technology has encouraged the liberal use of water resulting in wastage. This has necessitated deepening of wells at regular intervals, which has increased the cost of irrigation. Though farmers have evolved strategies to manage groundwater by appropriate methods of irrigation and sharing of water, the tragedy of the commons strikes often resulting in temporary or some times permanent disuse of irrigation systems. Thus, the government should take an initiative to construct percolation tanks and encourage watershed management to ensure sustainable recharge of groundwater aquifers.

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India groundwater development / data collection

Parameters of Doubt: Prospects for Groundwater Assessment to Help Farmers in Hard Rock Areas of South India

Linden Vincent¹¹

INTRODUCTION

THIS PAPER EXAMINES the policy dilemmas in increasing farmer participation in both the management of groundwater-based irrigation technology, and also in groundwater resource management, and to see how the farmers' role in both can be better integrated. The paper looks first at the conceptual issues in developing frameworks to study groundwater irrigation management needs. It then looks at the issues and opportunities for improved groundwater management by farmers in the hard rock areas of South India, and the data initiatives this will require. "Hard rock" is a general term used to describe the metamorphic and volcanic rocks found across Central and Southern India, to distinguish them from the sedimentary formations also found in these regions (in which water yields are usually higher), and the alluvial deposits of the flood plains.

In India, extensive groundwater development is a relatively recent phenomenon associated with development and dissemination of lift technologies, and the power sources to operate them. Groundwater development and the organizations in charge of it, are embedded in an institutional framework designed to stimulate agriculture production and transform agrarian structures through new technologies, and not to manage groundwater resources in an equitable and stable way. More effective management of groundwater resources thus requires a major institutional shift which gives greater importance to development and support of water rights and negotiation over abstractions, and gives farmers clear benefits from the technology installed. This shift will be difficult because the technical innovation program has been very successful in some areas and advantageous to existing organizations. Nevertheless, in the hard rock areas, the technology delivery system has been poor, with poor selection and installation of well casings, pumps and motors. The technology available is not always relevant to the agrarian structure of small farms, nor to the groundwater hydrology of low yields with a high variability across the year.

Current attempts at groundwater management through controls on the siting of new wells, and increasingly sophisticated hydrological modeling, are ineffective for equitable and sustainable use. Sustainable use is more likely to be achieved by controls or incentives that restrict the quantities of water mobilized, and programs that provide more easily accessible information and forums for negotiation. Controls or incentives to prevent usage of certain types of pumps and motors might also be more relevant.

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MANAGEMENT ISSUES AND ORGANIZATIONS IN GROUND-WATER FARMER-MANAGED IRRIGATION SYSTEMS (FMIS)

The dilemmas in promoting greater farmer management in groundwater irrigation can be illustrated through some standard frameworks for irrigation management. Management tasks and resulting activities are influenced by the following:

- i) Availability of water under existing technologies.
- ii) Competition for available water resources.
- iii) Capital, labor and skills needed for water acquisition.
- iv) Operational complexity in water distribution, both in regular conditions and under periodic scarcity.

Where a clear social mandate for irrigation management exists, the resulting institutions reflect three other social controls as follows:

- i) The objectives of investors in irrigation technology.
- ii) The property rights that control access to the benefits of this technology and its management organizations.
- iii) The legal and jural structures that enforce these property rights.

Research on indigenous surface water FMIS has usually found organizations for irrigation management carefully nested within an overall framework to minimize conflicts and maximize benefits from irrigation, with structures for technology management and resource management quite congruent. This is not the case in groundwater management in many countries, where there is no clear institutional focus on either groundwater irrigation management or groundwater resource management, and where groundwater development is implemented through a range of technology and credit organizations. The problems of poor definition between controlling institutions and performance of management tasks occurs with gravity schemes as well as groundwater, and many initiatives to increase farmer participation have been constrained by lack of broader change in controlling institutions. However, the problems have been severe for groundwater in the water-scarce regions of India. The technology focus of the prevailing groundwater institutions has resulted in poor installation of technology, that will be very expensive to correct and provide very little chance of increased water yields to levels desired by farmers. Thus there are major constraints to encouraging farmers into greater management responsibilities. The uncertain property rights, and lack of respected legal and jural systems encourage competition and direct appropriation rather than collaboration. There are no indigenous management institutions and principles on which to build.

As activities develop to increase the farmers' role in groundwater irrigation management, it is important to understand the constraints that the existing technology focus has left in converting farmers and groundwater development organizations more toward farmer management. Are farmers being encouraged to determine objectives for new institutions, and to get involved in their operation, or are they merely being encouraged to perform certain management tasks?

This framework can certainly be used to identify many ways in which groundwater resources will require different management structures as compared to surface FMIS. It also facilitates the discussion of problems faced by a "system" of well users across one aquifer, as well as the more conventional concept of a community benefitting from a single source. However, it also highlights the importance of hydrological information to groundwater irrigation management, as well as information on technology costs in capital and labor. For groundwater irrigators, collaboration

and sharing of information on water availability is often very important in consolidating farmer interaction. There is less stimulus from mobilizing communal supply of labor and funds than is found in surface FMIS.

There will also be quite important differences in management needs between different groundwater areas. In the hard rock aquifers of South India, where water resources are generally poor, water yields are heavily dependent on annual recharge, and show a fair degree of fluctuation in their water levels and well yields across the year. In these areas, public borewells are rare as there are few yield advantages to borewell development. Such communal borewells and dugwell developments that exist have often been developed for welfare reasons, and may be sited in locations where water resources are poor. It is open (hand-dug) wells which dominate over most of the hard rock areas, often operating only for one household.

THE PROPERTY REGIMES OF GROUNDWATER RESOURCES IN INDIA

Understanding the bias of institutions controlling groundwater development helps in identifying many of the current confusions over groundwater rights, and the inadequacy of legal and jural systems to protect them. As the current groundwater institutions are focused on technology dissemination, the property regimes on rights of access to benefits tend to follow the interests of the controllers of these institutions. It is not surprising then, that most of the controls are directed at benefitting and protecting the holders of private property.

The main dissemination has been to private farmers (usually with land as collateral) who can repay a loan with interest. Banks and private industrial companies have been leading actors in technology dissemination, despite the appearance of control by various state agencies. Thus, although siting restrictions were one of the earliest controls investigated by Indian authorities to reduce overdevelopment, the banking institutions have no incentives to support such restrictions to private farmers.

Even though there are public borewells mobilizing water initially within a "state property regime," increasingly, ownership and use is vested in a local association or corporation with rights directly comparable to private ownership. Although groundwater is often referred to as an "open access" resource, the controlling influence is private property as a means to acquiring and installing technology. Thus groundwater resources are best identified as a private property regime where there are no restrictions on the externalities caused in the use of that resource by the owner. This certainly helps in understanding the resistance to changes in legal and jural structures to provide better groundwater management.

The dilemma for groundwater development (as with surface water) has not so much been about the right to develop an abstraction point but about the volume of water that can be taken from that site. However, whereas surface water is highly visible and catchment principles can fairly easily be understood by communities and superintending institutions, this is not the case for groundwater, which is largely invisible and unpredictable. The hard rock aquifers are particularly poorly understood by both farmers and superintending authorities.

Where the incentives to mobilize irrigation technology are largely subsistence based, and the technology commanded within village resources, irrigation management has *de facto* been directed at sustainability (although it may not be cited as a specific management objective). Rights to extractions are seen more as group access within common property regimes, with cooperation between groups encouraged, rather than enforced, by a superintending agency that itself gains direct benefits from the subsistence economy and from fostering collaboration. Indeed the

dependence of the "supra-group" on the system it legislates upon encourages its relative impartiality and determination to avoid disputes.

Where the incentives are production of a surplus, profit or returns to capital invested, as is true for much groundwater investment, and the technology need not (or cannot) be developed on a community base, then the incentives to collaborate over equitable property rights and legal institutions become profoundly different.

Incentives to improve (or even initiate) groundwater resource management systems are limited in India for several reasons. First, existing controls are weak, and naturally, powerful vested interests are often able to circumvent them. Superintending groundwater organizations have no legislative function. They gain little from working with local groups, and much from the continued distribution of technology. The organizations involved in groundwater development are diverse, and interests are not concurrent. Many groundwater organizations are now starved of funds, and are increasingly involved with urban water supplies and pollution problems.

Most seriously, however, data are not available as information that can be easily understood, and can be agreed by farmers and superintending institutions as a basis for action. Much effort has gone into diffusing or inducing technical change. Rather less has gone into helping farmers determine what technology they need and can pay for from irrigated crops. Almost no effort has gone into systems to disseminate information and support negotiation.

Although the key credit and technology agencies have known the problem of competition between wells and over-pumping, little action has been taken to define further controls. This is partly because it is difficult to construct pump technology with very strong controls on flow, unlike surface water. The technology itself is "lumpy," and actual volumes abstracted depend on efficiencies, on pumping time, and even energy supply, not simply the structure itself.

Although principles like riparian rights and prior appropriation have been used to determine access rights for surface water, these are very difficult to apply in groundwater, especially in India where pump technology has changed so rapidly. The direction of groundwater flow is too poorly understood to be able to use the principle of riparian rights. If a farmer wishes to claim prior appropriation rights, should this be done on a volume per year, or a sum per month? Should it be done in relation to the existence of a well or the time of ownership of particular technology? It is not surprising that beleaguered local authorities take refuge in spacing rules, as they are the only guidelines for which procedures exist, even though they are recognized as unreliable and are flouted with impunity.

Control of volumetric extraction has been avoided because it is so difficult to set up technology to do this. However, the dominant institutions have also had little concern for the smaller farmers who are most commonly the first affected by declining resources, since they have often tried to avoid assisting these farmers (indeed, prevailing trends in agricultural modernization may support their disappearance). Their key supporters in the development agencies and local officials have few powers to preserve the opportunities of small farmers once groundwater resources become oversubscribed.

Following these dilemmas logically, it could soon become necessary to distinguish rights to install technology at a site, and rights to extract certain volumes from that site, as opposed to rights to use the water after it has been mobilized by lift technologies, and set up legal and jural systems that can control powerful private interests. However, since the hydrological calculations are almost impossible, and the legal controls unlikely, then it is the rates of abstraction that require controlling. This can be done directly, or through removing subsidies and financial incentives on pump technology and the goods it produces.

Increasing the sustainability of groundwater use by restricting site access to technology is not a helpful strategy; it disadvantages groups which need government help in acquiring capital and skills for the technology. Moves to greater sustainability are more effectively initiated by helping farmers to understand the potential of the groundwater resources in their neighborhood, and

developing forums where the rights of use can be discussed and agreements negotiated. Helping farmers to understand the adequacy of groundwater for preferred cropping schedules, and the consequences of over-pumping and inefficient use, is also critical.

DATA COLLECTION FOR GROUNDWATER DEVELOPMENT AND MANAGEMENT

The wealth of organizations involved in groundwater development in India suggests that there should also be a wealth of information. There is indeed a wealth of figures, but the majority is derived from highly empirical calculations, and is still based on relatively crude groundwater analyses, with limited studies on key aquifer parameters for modeling recharge and flow. These comments are in no way meant to criticize Indian field workers, who perform the tasks set to a very high standard. The problems are in the techniques they are required to use and the data they are able to collect. First, this reflects the heavy orientation of data collection toward the needs of technology dissemination. Second, it reflects the limited options of many groundwater agencies, which often do not have sophisticated drilling equipment, and whose available rigs are heavily in demand for practical drilling rather than research purposes. Usually research agencies do the specialized reconnaissance and pumping tests. This is expensive, slow, and the information often does not return to the local staff.

As a result many of the techniques used to estimate aquifer behavior and water yields are now widely criticized. They make heavy use of data which are easily accessible—such as climate and water levels—but make very little use of conventional aquifer parameters. The figures in use for aquifer parameters like transmissivity and storativity have often been derived through quite inventive (but unconventional) procedures.

Most of the hydrological data for groundwater management come from the following sources:

- i) Procedures in the “norms for assessment” which are used to estimate the potential number of well developments in an area, for credit funding purposes.
- ii) Procedures to help field staff and farmers select small agricultural pumpsets and well diameters, usually in relation to “design flows” for particular cropping patterns.
- iii) Hydrological data from the drilling of borewells, often furnished by contractors.
- iv) Data from remote sensing.
- v) Geophysical logging data for the siting of wells.

The known weaknesses of calculation procedures (i) and (ii), and the difficulties of obtaining more accurate estimates of parameters through conventional pumping tests, are some of the reasons why remote sensing and geophysical logging are increasing in popularity with groundwater data organizations. These techniques allow the compilation of maps and local groundwater profiles which permit local staff to respond more quickly to administrators and the public. Maps can be compiled relatively easily from satellite data and existing hydrological data, and local hydrological conditions are “ground truthed” by studies from available pumping data rather than specialized tests. The measurement known as the “specific capacity” of a well¹² has

12 Liters per second that can be pumped per meter of water level drawdown in a well; not to be confused with the aquifer parameter known as “specific yield.”

been uniquely important in the mapping of Indian groundwater resources, and the techniques for its calculation have helped determine many of the current "spacing norms" on well development. However, the technique is only in existence because of the pressures to disseminate pumps, and the lack of options for more sophisticated and detailed measurements.

While some additional data collection will be needed for improved planning, the real issue is to raise public debate and understanding, and put pressure on the production of useable results, both from existing and new data. Extensive collection of new data will not necessarily overcome these data gaps, nor will such work necessarily return to the public domain where it can be accessed by farmers and local administrators. Thus, although the weaknesses of existing techniques are known, it may be more relevant to do some serious overhaul and study on existing data bases, especially as this would help to explain some of the mistakes that have been made in borewell installations and pump recommendations. Such studies would also bring new understanding into circulation quite quickly, whereas extensive development of new pumping tests will be expensive and time consuming.

Local staff are the best people for such work, as they know the local areas, the foibles of local equipment and something of the history of pumping tests and calculations performed by their colleagues. Centralizing information for more complicated modeling may produce some additional information on resource availability, but it will not provide information easily understandable by farmers and local government officials, nor to the local geohydrologists who have to face the farmers. Ironically, information in regional centers is sometimes more easily accessed by powerful interests, whereas the direction of flow of information is much more open in local offices.

While farmers do want to know if there are options for their region to develop more groundwater, they really want to know about the security of their existing well investments, and their likelihood of attaining adequate water yields to cover their costs from crop production. Data mobilization initiatives to support farmers are likely to have a different organizational framework between tubewells and dugwells, with differing impact on broader FMIS initiatives in improving performance and cost recovery, and turning over projects to farmers.

For public borewells, the quality of information on groundwater yields and its variability has strong implications for initiatives to improve performance. However, the participation procedures in design and implementation now widely practiced in surface FMIS may be difficult to use in the hard rock areas, because of the extent of technical problems and shortfall of water required. The current systems of drilling and logging, often provided by contractors, means that little reliable information is available to estimate the number of beneficiaries from a well and the pumping regimes which will be possible. The actual areas that can be served may often fail to encompass entire communities.

Time lapses of two years or more may take place before the well is energized, leaving villagers uncertain of developments. Subsequent additional pumping tests to estimate equipment needs are common. As engineers still use quite crude estimates of "design flows" for various crops, their guidelines to farmers on crop options are still weak. They can rarely predict the variability in water yields across the year which is almost invariably present in sedimentary and metamorphic rocks in South India. Most seriously, there are often problems in the installation of well-casing and pumps, reducing yields and creating operational difficulties. However, in improving procedures of technology delivery, additional thought must be given to manpower and transport for dissemination, as existing resources are overstretched in many state agencies. Any social organizers and trainers to promote groundwater FMIS face more technical challenges in reforming groundwater delivery than with gravity schemes.

The large community of farmers dependent on individual dugwells and borewells equally face some special data needs, and need new initiatives to provide this data. In South India, field officers in data collection organizations are a more appropriate base for advisory services.

However, there has to be much more effective liaison between these field officers and rural development officials, as well as farmers. Farmers want to know where to locate a well, the type of wells and in-well bores it is worth developing, the likelihood of finding good quality water, and the right kind of pumps to install. This can improve their dialogue with contractors and bank officials. They do not need detailed guidelines, but ideas on the problems likely when excavating wells and installing and operating pumps. They need to know what information is available from public agencies, what can come from contractors, and what they can simply get from other farmers. They also need help and advice on the likely water regime across the year, on the effects of heavy pumping both on their own well sites and on their neighbors, and perhaps a study initiative to promote exchange of information.

It is also necessary to examine the pumps and motors available on the market, to see if these exacerbate overpumping on small holdings, and are really suited to prevailing hydrology. The range of capacities of pumps and motors is quite limited, and in the past has been strongly influenced by the state agro-industry corporations who manufactured and distributed pumps in some states, and also by credit and subsidy policies which were based on certain types of pumps and motors.

Equally, more relevant information should flow regularly to local administrators involved with approving and assisting groundwater development. This includes information on the pattern and extent of well development and pump usage, and the effects of subsidized electricity consumption. Unfortunately, such information is unlikely to be exchanged if farmers think their developments will be seen as illegal and stopped (or taxed), and some thought has to be given on how to make information flow better between different groups.

What is really necessary, however, is a framework of controls or incentives for groundwater management that is both understood and seen as equitable, both by different kinds of farmers and well owners, and between different water users. This requires recognition that not only are current controls unworkable and based on dubious assumptions, but they are actually inappropriate to improved groundwater management. Institutional objectives must change in order to achieve sustainable groundwater use. Allowing farmers to participate in prioritizing institutional objectives for groundwater development as well as in the design of structures to undertake management tasks will be the first step in the right direction.

Groundwater and Electricity Co-Management: Generating New Options

Marcus Moench¹³

ABSTRACT

GROUNDWATER OVERDEVELOPMENT IS a problem throughout Northern Gujarat. In India, horse-power (hp) based electricity charges encourage inefficient water and energy use in overdeveloped areas. Pumping accounts for 30 percent of electricity consumption in Gujarat and underlies the state's power crisis.

The social conditions necessary for farmers to manage groundwater overdevelopment are difficult to meet. User group and resource boundaries are poorly defined, information is not available, private well ownership complicates free rider control, and large heterogeneous groups utilize aquifers. Government regulatory attempts have not been successful. Institutional structures which address groundwater problems need to be created at the required scale to meet the necessary social conditions, and rectify pumping incentives.

Cooperatives have been proposed as a response to the state's electricity crisis. Electricity to village-level organizations should be metered. They can then meter membership consumption. Since pumping is often the primary end use, unit charges should create incentives for electricity and water conservation at organization and end-use levels. As a result, the organizations could provide an appropriate nucleus for water management activities. Defining management entities using the electrical system could address many of the free rider, user group, and information issues complicating emergence of farmer-based groundwater management systems.

INTRODUCTION

This paper presents an overview of groundwater problems in Gujarat (India), their linkage with energy supply issues, and potential management alternatives. The paper argues that new institutional approaches are required to address emerging groundwater problems. Electricity and water co-management is presented as one possibility. The paper is organized linearly. Groundwater problems are identified first and then linked with power supply and pricing patterns. Specific power supply problems are discussed subsequently. Attention is then re-directed to existing management alternatives and the social factors influencing user groups' ability to manage groundwater. Following these proposals creation of electricity cooperatives are described and

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their potential utility for groundwater management is examined. Conclusions are drawn in the last section.

Groundwater Overdevelopment

Groundwater resources are overdeveloped in many hard rock and arid sections of India. Isolated problem areas such as Mahasana District in Gujarat are well known (see Figure 5.1). The extent of overdevelopment is, however, poorly documented and potentially greater than what the estimates suggest.

Groundwater maps prepared by the Central Ground Water Board (CGWB) for the period April 1979 to May 1987, show drops of more than 2 meters (m) throughout most of Gujarat excluding canal command areas. In large areas the decline was more than 4 m and water levels in the unconfined aquifers were more than 20 m in depth. Water quality in most areas with shallow water tables was poor with TDS more than 1,000 milligrams per liter (mg/l) (often more than 3,000 mg/l), and bicarbonate more than 500 parts per million (ppm). Although May 1987 was a drought period, the decline is long term in extensive areas. For example, depth of the water table declined from 4-16 m in May 1978 to 8-28 m in May 1990 in Ahmedabad, Sabarkatha, Mahasana, and Banaskatha districts (High Level Committee 1991).

Official groundwater availability estimates (the primary guide for development finance) paint an optimistic picture. According to these estimates only 31 percent of utilizable recharge to unconfined aquifers was extracted in 1986 and a further 3.2 million hectares (ha) could be sustainably irrigated from groundwater (Government of Gujarat 1986). Extraction exceeded recharge in only 5 out of 182 Taluks and was greater than 65 percent of recharge in a further 14. These estimates are unreliable (Moench 1991a,b; Dhawan 1991). CGWB and the Gujarat Water Resources Development Corporation (GWRDC) scientists note that extraction estimates are based on old well census statistics, poorly known crop water duties, and well yield-irrigated area assumptions.¹⁴ Recharge estimates are based on Taluk (not hydrologic) boundaries, water table fluctuations, assumed infiltration levels, and specific yield estimates (Government of India 1984; Narasimhan 1990; Moench 1991a,b). Senior scientists indicate that they are as uncertain as the extraction figures.¹⁵

Official estimates suggest that groundwater in confined aquifers is approaching full development throughout North Gujarat. Extraction exceeds 70 percent of recharge in Ahmedabad, Gandhinagar, Sabarkatha, Mahasana and Surendranagar districts and is 40 percent in Banaskatha (see Table 5.1). Of the remaining five districts having significant resources in confined aquifers, three are high rainfall and irrigation is rare in the remaining two.

Officially estimated levels of groundwater development in unconfined aquifers are at odds with observed water table declines and high levels of development in deeper aquifers. The extent of overdevelopment is unknown, and it appears to be widespread. The current focus on development must evolve into a management focus.

14 S. C. Sharma (GWRDC); K. C. B. Raju (CGWB) and others.

15 Discussions with Dr. K. C. B. Raju and T. N. Narasimhan.

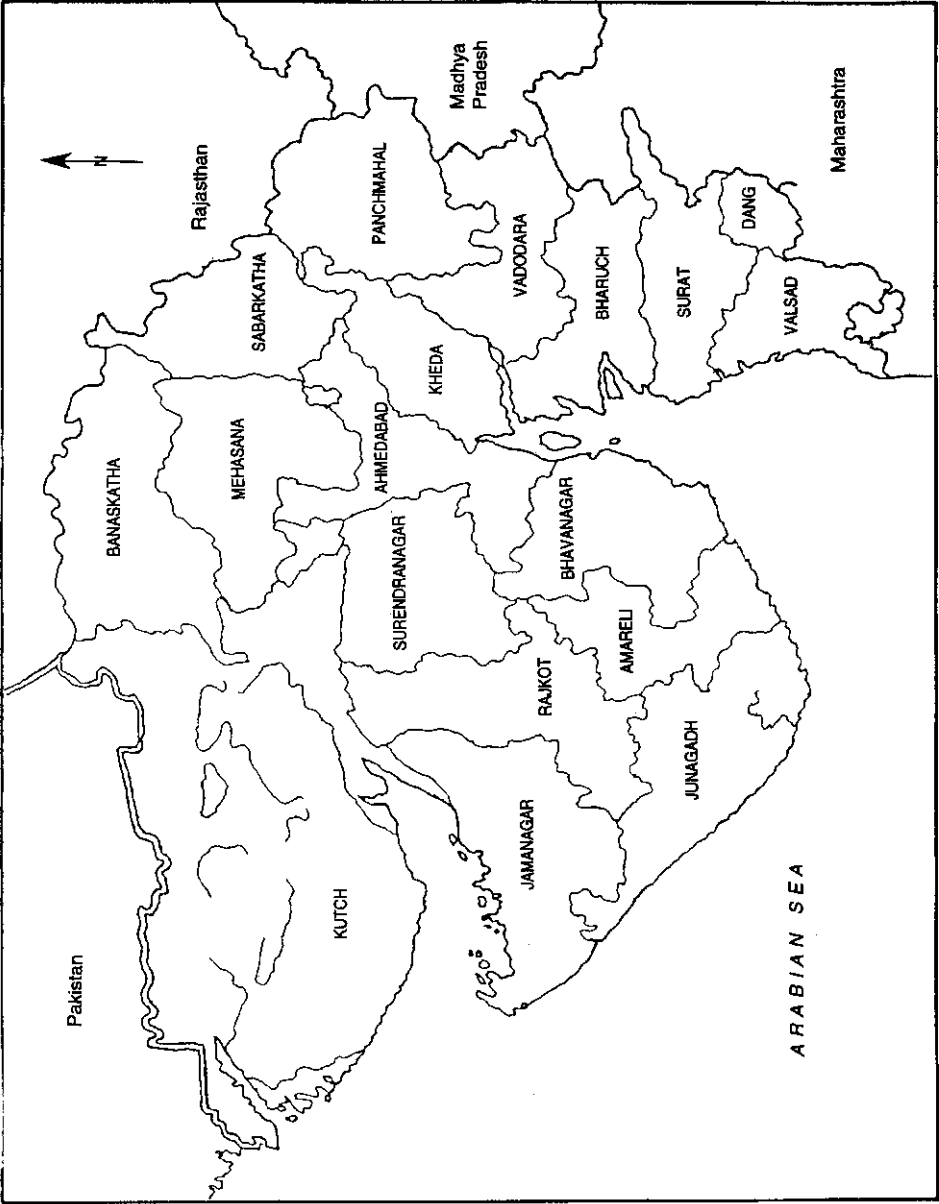


Figure 5.1. Districts of Gujarat State, India.

Water-Electricity Linkages

Estimates for 1990/1991 suggest that agriculture accounts for roughly 32 percent of all electricity consumption in Gujarat.¹⁶ Gujarat State Electricity Board (GSEB) officials state that 30 percent of total power production now goes for pumping.¹⁷ These percentages are much higher than the official 18.4 percent agricultural consumption figure reported for Gujarat in 1986/1987 (Dadlani 1990).

Table 5.1. Estimated development of aquifers and water table decline by district.

District	Estimated development (%)		Water table decline (m)		
	Unconfined	Confined	79-87	78-90	78-90
Ahmedabad	23	97	2-4	4-8	to 20
Gandhinagar	30	97	2-4	4-8	to 20
Banaskatha	33	40	2-4	4-8	to 20
Sabarkatha	43	97	0-4	4-8	to 30
Surendranagar	37	72	0-4	na	na
Mahasana	66	88	2-4	4-8	to 40

Sources: Column 1 and 2, Government of Gujarat 1986.

Column 3, Central Ground Water Board.

Column 4 and 5, High Level Committee 1991.

Note: na = Not available.

Agricultural pumpset efficiency is very low. Surveys by the Institute of Cooperative Management indicate typical efficiencies of 13-27 percent in farmers' pumping systems (S.M. Patel 1991). Efficiencies of more than 50 percent could be achieved with readily available and affordable technologies. Electricity for pumping is, however, priced at an annual rate according to pump horsepower. According to GSEB officials, current charges equal 0.15 Rupees/kilowatt-hour (Rs/kwh) (US\$0.0054/kwh) while generation costs are 1.18 Rs/kwh (US\$0.0421/kwh).¹⁸ Given the pricing structure and subsidies, farmers have little incentive to invest in pump or water use efficiency.

In Gujarat, unlike the rest of India, official figures suggest that the number of diesel pumps is double the number of electrical ones (CGWB 1991: Tables 34, 35). Pump numbers give a misleading picture of the importance of electricity in pumping. Virtually all pumping from confined aquifers use electricity to run submersible pumps. In addition, farmers prefer electricity for pumping because of its low cost. Diesel pumping costs have been estimated at a Rs 1.9/kwh equivalent (US\$0.068/kwh), much higher than the Rs 0.15/kwh (US\$0.0054/kwh) which farmers

16 Discussions with World Bank officials.

17 C. S. Chatper, GSEB Headquarters 1992.

18 A. H. Dhebar, GSEB Office, Sabrimati 1991.

pay for electricity.¹⁹ Many farmers have both types of pumps and use diesel only as a backup when electricity is unavailable. As a result, where sufficient connections are available, electricity is the primary motive power for pumping.

Power sources influence water management practices. Due to insufficient generation capacity utilities power shedding has become a general practice. Electricity is often rotated so that farmers receive it at night. In response, they leave pumps switched on so that irrigation starts whenever power comes. Uncertain power availability and night rotations make careful irrigation management difficult. Farmers tend to apply as much water as possible when they can. Diesel powered irrigation is, in contrast, carefully managed. According to farmers, the cost of diesel can account for 90 percent of crop profits. Most of those using diesel claim to apply water as carefully as possible.

The cost of power also influences water sale rates. Field work in Mahasana District indicates that farmers having electric pumps generally charge 1 rupee per hour per horsepower (Rs/hr/hp) during the dry season. This is often halved in the monsoon to maximize profits relative to fixed electricity charges. Since most costs of electrical pumping are fixed, maximizing water sales maximizes profits. In contrast, diesel pump owners charge seasonally uniform water rates.

On the whole, the cost of pumping appears to influence farmers' water use and pricing decisions. Flat-rate electricity charges encourage extraction and create disincentives for efficient use. Unit prices do the reverse.

Power Problems

A variety of problems affect the rural electricity system. Voltage fluctuation is common and often causes pump damage. Rural lines are overloaded and the GSEB is often only able to provide connections 4 to 5 years after applications are received. In rural areas, about 9 percent of the total power generated is lost to theft and collections are a major problem.²⁰ The GSEB shifted from metered rates to annual charges due, in part, to theft and collection losses.

The above problems have led to near financial collapse of the GSEB. As a result, the organization is now "actively considering" the involvement of private companies or cooperative agencies in generation, transmission, and distribution.²¹ Metering and rate increases are also contemplated. Given the diesel pumping costs, ability to pay is not a major issue for many farmers. How to enforce metering and collection is the main issue facing the GSEB.

Groundwater Management Questions

Groundwater management responses to depletion must address efficiency incentives. As long as strong incentives for inefficiency remain, little basis exists for management. Power subsidies mask water costs and constrain the evolution of a management system. Since (excluding well investments) it costs no more to pump from deeper levels, individuals have little incentive to conserve or participate in management.

Even with incentives for efficiency, the evolution of effective management systems would be difficult. In many cases, management will make little difference to well water levels unless it functions at an aquifer scale. Aquifer characteristics are often difficult to determine and vary

19 Discussions with World Bank officials.

20 C. S. Chatter, GSEB Headquarters 1992.

21 Personal communication, GSEB officials in Baroda.

greatly between areas. Where groundwater availability and movement are topographically defined, "village" management systems may make a significant impact. In the large aquifer systems that characterize many geologic environments, management must cover extensive areas to address depletion.

Groundwater Management Alternatives

Regulation is the primary groundwater management approach being considered in India. The central government circulated a model bill to the states in 1970 (Dave 1983). Only Gujarat has passed legislation and that has yet to be enforced. Gujarat's Act allocates power to license tubewell construction, regulates groundwater use and prevents waste (Sinha and Sharma 1987). Acts proposed in other states, create "authorities" staffed by individuals from state organizations (Moench 1991 a,b). These authorities are given regulatory powers within notified areas. Enforcement is through fines, search and seizure of provisions, and (in some cases) electricity denial. None of the Acts allow for the inclusion of local representatives in the management structure or devolution of authority to local groups.

Regulation is unlikely to be successful. In Mahasana, for example, declining water tables led to the closure of groundwater development financing in 1976 (Ghosh and Phadtare 1990a: p. 319). New wells are also regulated via limiting electricity connections. Neither financial nor electricity limitations have proven effective. Private financing is available and illegal electricity connections can be obtained. Drilling companies in Mahasana estimate that over 2,000 wells are drilled in the district each year.

Existing regulations have probably limited groundwater access for those who cannot afford private financing or do not have the influence to obtain illegal connections. They have done little to slow the use of groundwater by the wealthy. Since most wells are privately owned, regulations are difficult to enforce. They also have strong equity implications. Depending solely on regulation for groundwater management is not feasible.

The primary alternatives to regulation are indirect management through economic levers or development of local institutions capable of evolving socially feasible management systems.

Energy pricing is the main economic lever which influences pumping directly. Numerous discussions with farmers suggest that they will be unwilling to pay higher rates unless voltage and supply timing issues can be remedied. Theft will also remain a problem. In addition, differentiating between the needs of management areas through electricity pricing will be difficult. Depletion necessitates prices which encourage conservation. Where waterlogging is present, prices should encourage higher pumping rates. Politically it would be very difficult to charge high unit electricity rates where water is scarce and low annual rates where it is plentiful. Finally, it is far from clear how much impact an approach based solely on economics would have. In the Western United States, energy prices are a factor in farmers' willingness to invest in water conservation but play a minor role in crop choice, and therefore, the overall water use decision (Moench 1991c).

Local institutions tend to require certain conditions to establish effective management systems. Management often occurs when: (i) user group and resource boundaries are clearly defined, (ii) resource use and condition information is available, (iii) free riders can be controlled and management decisions enforced, and (iv) broad support exists for management (Moench 1986). These conditions become difficult to meet as group size and heterogeneity grow. In a study of 93 groundwater management groups, Nagabrahmam (1989) found average sizes from 3 to 21 members. Several groups identified small size as a factor in their success. Group homogeneity (economic and caste) also influences community well management success (Ballabh and Shah 1989).

The above considerations suggest that farmer-based groundwater management institutions will face significant difficulties in addressing depletion problems. Aquifer boundaries are often poorly known making resource and user group boundaries unclear. Condition information is difficult to obtain since local water levels may indicate little about the overall water balance. As a result, it may be difficult to establish broad support for management. Free rider control is also likely to be difficult. Wells are generally private and user rights strongly entrenched. How user groups could enforce extraction limitations is open to question. Finally, management scale is likely to be a major issue. Unless resource use patterns can be managed at an aquifer scale, depletion problems will be impossible to address. Physically appropriate management areas will often contain large, heterogeneous, user group populations.

In isolation, none of the management alternatives identified above can address emerging depletion problems. These problems threaten the viability of many communities. Institutions must be evolved to meet social requirements for management, to address the physical resource problems, and to rectify water use incentives.

ELECTRICITY: GROUNDWATER CO-MANAGEMENT OPTIONS

Electricity Cooperative Proposal

The formation of cooperatives has recently been proposed as an answer to electricity supply problems by the National Dairy Development Board (NDDB).²² This proposal, widely supported in Gujarat, faced opposition from the Central Energy Authority.²³ The idea is being revived following recent encouragement of private participation in the power sector. It should be noted that electricity cooperatives, although new to India, are common elsewhere. They are, for example, one of the main sources of rural electricity in the United States of America.

The NDDB proposal, developed for Kheda District, envisioned electricity supply through a nested series of cooperative organizations. Village cooperatives would buy electricity from an "Apex Rural Electricity Cooperative Society." The Apex Society would have society unions at substations and a peak generation organization. This structure should provide regional representation for villages. Local societies would: (i) maintain low voltage supply lines; (ii) distribute electricity; (iii) keep connected load within line capacity; and (iv) collect dues. The Apex Society would have one meter at each village and charge unit rates. Village societies could meter members, impose flat tariffs, or follow other pricing systems.

The primary incentive for farmers to form electricity cooperatives would be improving the quality and timing of power supplies. In Kheda District from 1981 to 1987, rural electricity supply during the nonmonsoon period averaged 15-16 hours/day and was less than 9 hours/day in some months (Tata 1991). Voltage fluctuations also necessitate frequent pump repairs. Problems with power availability, quality, and access to connections are constant complaints of farmers. High quality power supply to cooperatives would be essential.

The GSEB is interested in rural electricity cooperatives for financial reasons. Low electricity charges, theft, and nonpayment of dues in agricultural sector underlie the GSEB's precarious

22 This section is based on Tata (1991) and interviews with Mr. Sen and Dr. Kurian at NDDB on March 4 1992.

23 Dr. Kurian, personal communication.

financial position.²⁴ Without some new institutional structure, metering and electricity rate increases may not be possible. Selling bulk power to user groups would greatly reduce the number of meters requiring monitoring. Since local groups would have primary responsibility for collecting electricity charges, theft and nonpayment problems should also be reduced.

Local distribution organizations could provide avenues for increasing efficiencies. Metering supplies to village groups and, if done, to individuals should create incentives for efficient use. Furthermore, line capacity limits possible connected load. Readily available pump improvements can reduce connected load by about 50 percent (S.M. Patel 1991). Local organizations could, thus, increase connections through pump rectification. They could invest directly or grant connections if individuals rectified other's pumps.

Groundwater Management Linkages

Electricity cooperatives could provide a flexible means of rectifying ground water use incentives and a potentially appropriate institutional structure for management.

Electricity distribution by user groups could enable rate manipulation in response to groundwater conditions. User groups would have the freedom to experiment with different rate structures. Unit rates or increasing block pricing would establish, respectively, uniform and rising marginal costs for water and could be used to create differing incentives for conservation in shortage areas. Where waterlogging is present, uniform annual charges would establish declining average costs and encourage extraction. Efficiency arguments advanced in the preceding section for electricity would also apply to water. Irrigation service is the "real" end use of pump energy. Individual or institutional investments in water conservation could reduce energy consumption and connected load required. They could be used to reduce power costs or increase connections.

Establishment of farmer-based institutions for electricity distribution could create options for managing groundwater through pumping economics. It is important to recognize, however, that encouraging water use efficiency is unlikely to solve depletion or other complex management problems. Rectifying the incentive structure may be a necessary precondition for the establishment of management systems but it is probably not a sufficient one.

Management Institutions

Farmer-based electricity distribution organizations could form an appropriate institutional nucleus for groundwater management. Local institutions should have incentives to ensure water use efficiency and, thus, become involved in water management. Incentives to initiate management could also exist where groundwater problems are a major local concern or threatened the institution's viability.

Managing groundwater through electricity distribution organizations could have advantages over institutions created specifically for that purpose. First, access to electricity is a much more tangible and immediate benefit to individual users than managing a nebulous "groundwater resource." Second, user group boundaries are clearly defined (those having connections), information on use patterns is readily available (metering), and there are avenues for free rider control (connections). These factors address some of the management limitations suggested by experiences with other common property resources.

24 Discussions with GSEB officials in Baroda.

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Utilization of Groundwater Resources in North-Western Sri Lanka: Some Issues Pertaining to Sustainable Development

M.D.C. Abhayaratna²⁵

ABSTRACT

DURING THE LAST few years there has been an increasing emphasis on the development of the groundwater resources in the intermediate and dry zones of Sri Lanka. Construction of shallow dugwells are subsidized by two implementing agencies of the government through the Agrowells Program to promote year-round cropping. Nevertheless, the Program has not proceeded by proper hydrological surveys. At the very inception the Program suffered a number of setbacks specially with reference to group wells. On the whole the subsidy covers only a fraction of the cost of constructing a well and poorer farmers are automatically excluded from the Program as they have no means of meeting the balance expenditure. Over-estimation of the potential of the agrowells, exposure of the farmers to the Program without proper training in the methods of irrigation and pump maintenance, inadequate attention given to agronomic aspects of groundwater utilization, negligence of the institution building for the post-construction phase and the failure to mobilize active farmer participation are major constraints to the sustainable development of the groundwater resources. It is imperative that the strategies followed at present should change toward achieving sustainability for the future.

INTRODUCTION

Expansion of irrigated agriculture in Sri Lanka during the recent past is closely associated with the increase of major irrigation schemes and the rehabilitated village tanks. Despite the significant rise in the irrigated area, the total extent covered by all surface gravity irrigation systems do not still exceed 25 percent of the cultivated area of the country. However, there are vast stretches of land with favorable soil and terrain characteristics lying outside the command areas of the existing irrigation systems in the island's dry and intermediate zones²⁶ where water remains the major constraint for agricultural development. Hence, there has been increasing emphasis on the

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26 Sri Lanka is divided into three climatic zones (wet, intermediate and dry) on the basis of rainfall. Although the total precipitation received does not warrant the term "dry zone," it is defined on the basis of the concentration of rainfall and the presence of an effective dry period.

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utilization of the groundwater resources with a view to tapping the agricultural potential of these lands.

Except in the Jaffna Peninsular in the extreme north of the island, where the rich aquifers are associated with miocene limestones, groundwater was never used on a large scale elsewhere in the dry zone. Nonetheless, many studies have indicated the potential of groundwater resources for improved cropping and livestock farming in the dry zone (Fernando 1973; Madduma Bandara 1977, 1979, 1984; Water Resources Board 1984; and Land Commission 1987). Realization of the need to utilize such resources particularly for the benefit of those farmers who do not have access to irrigated farmlands, inter alia, led the government of Sri Lanka (GOSL) to assist in the construction of shallow dugwells for agricultural purposes. Assistance took the form of a subsidy to construct a well of stipulated dimensions and was administered through the Agrowells Program. The two government agencies directly involved in the implementation of the Program are the Provincial Department of Agriculture (PDA) and the Agricultural Development Authority (ADA).

METHODOLOGY

The present paper makes an inquiry into the Agrowells Program in the Kurunegala District of Northwestern Sri Lanka with a view to highlighting: (i) the initial problems it has faced, (ii) the implications for sustainability, and (iii) attaining sustainability for future groundwater development. Conclusions are drawn with reference to a rapid appraisal of the Kurunegala District Program in the light of the field evidence from two villages, i.e., Nochchiya and Epaladeniya (see Figure 6.1). The villages are purposively selected from two agro-ecological zones with varying cropping systems. Nevertheless, both villages have agrowells given by the PDA and the ADA.

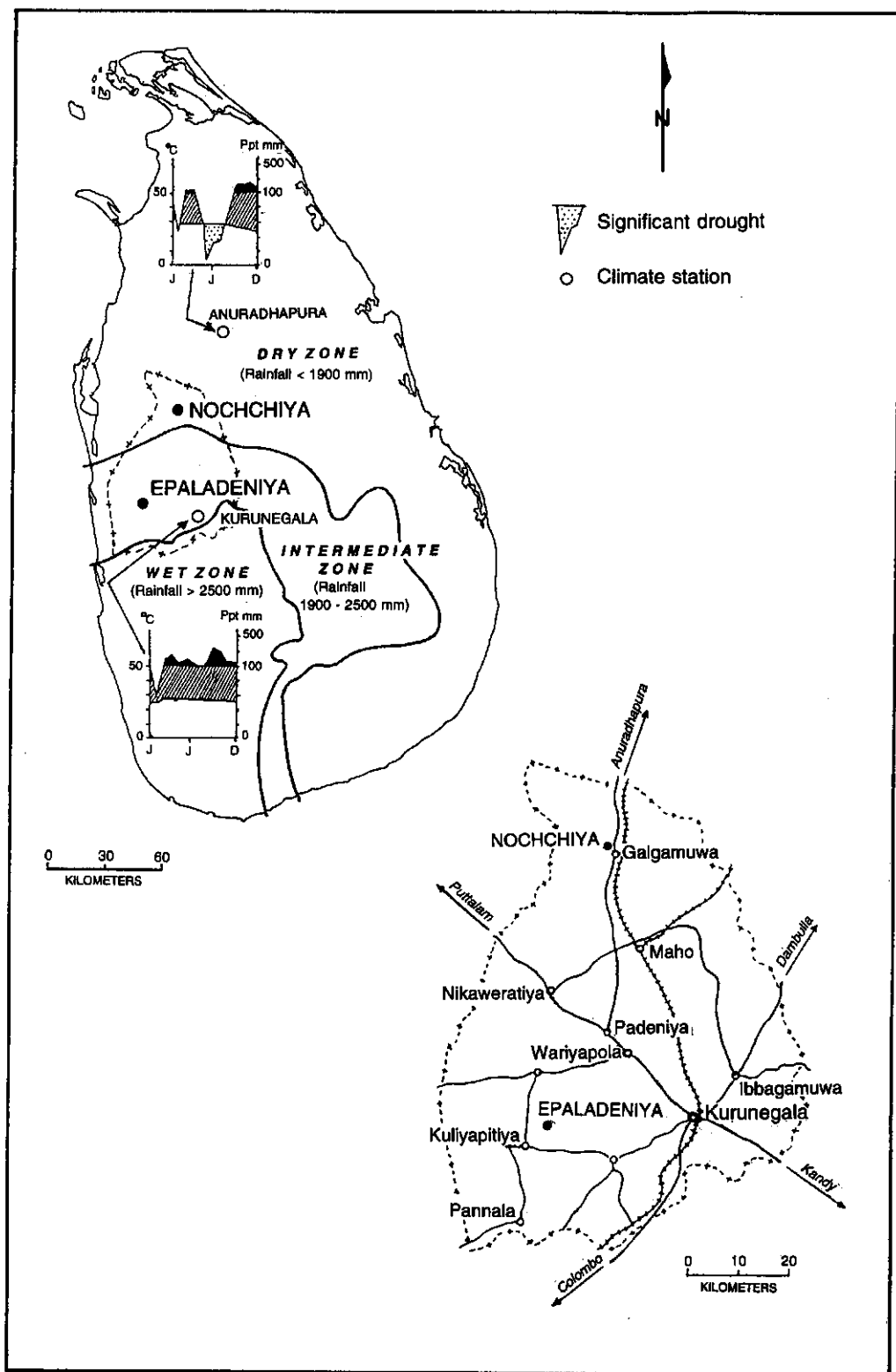
THE VILLAGE PROFILES

Nochchiya is a tank village situated about 8 kilometers (km) west of Galgamuwa, a small township in the dry zone. The mainstay of the economy of the village is rice cultivation which is restricted to the rainy season, *maha*. The village tank provides supplementary irrigation for the rice crop during this season. Cropping during *yala*, the dry season is uncommon at Nochchiya. However, few farmers have used their domestic wells particularly to grow vegetables on a restricted basis. On the whole, majority of the farm families are below the poverty threshold²⁷ and have no access to off-farm employment.

The second village—Epaladeniya—which is located in the intermediate zone is better endowed both with respect to the amount of rainfall received and the socioeconomic standing of the villagers. Here the *yaya*, rice tract, is entirely rain-fed in *maha* and the cultivation during *yala* has been irregular. Nevertheless, the majority of the households have substantial incomes from coconut, rice and betel.

²⁷ Rs.700 (US\$17) per month is considered as the poverty threshold in Sri Lanka for official purposes.

Figure 6.1. Location of study villages, Nochchiya and Epaladeniya.



CHARACTERISTICS OF THE AGROWELLS PROGRAM

Both government agencies implementing the Program utilized the village-level societies and *Grama Niladharis*²⁸ to create an awareness about the Program and to familiarize the application procedure. In both cases the selection of the beneficiaries rested in the hands of a committee comprising local-level officials. However, the Program administered by the PDA and the ADA slightly differed with reference to the extent of the subsidy and the envisaged tenurial conditions under which the well was operated.

The PDA Program

The PDA inaugurated its Agrowells Program in 1989, where a dugwell of 5 meters (m) in diameter and 7.5 to 10 m in depth was subsidized to the extent of Rupees (Rs) 20,000 (US\$476). This amount has been increased to Rs 25,000 (US\$595) with effect from January 1992. The first instalment is released only after the successful completion of a test well of about 1.2 m in diameter. As the wells are given only to farmer groups under the PDA Program, group formation had to precede the application. Solidarity of the group was anticipated on a continuing basis for effective water distribution and promotion of cash crop farming through groundwater utilization. Contrary to expectations, group formation has been confined to meet the specific requirements in the application procedure. It is observed that the groups in both villages are not *bona fide*. Instead of the active farmers who should comprise the group, the names of the family members, relatives and neighbors who are not much interested in utilizing groundwater for agriculture have been included.

At Epaladeniya, only the leader of the group in whose land the well is located, is engaged in intercropping betel wines in his coconut land. None of the other four members has an interest in farming. The leader has got his own water pump. However, he has not tapped the maximum potential of the well as he is unable to command the heavy labor requirements of the betel cultivation which supersedes other crops with reference to returns. It is observed that Epaladeniya has a long tradition for betel cultivation which has been irrigated from domestic wells as the need arises. With the introduction of the Agrowells Program the village received 1 group well and 6 individual wells. All recipients of agrowells in the village have more than 0.4 hectare (ha) of coconut lands partly intercropped with betel and the income level of the villagers are much above those of Nochchiya. At Epaladeniya the introduction of the Agrowells Program has not led to a completely new cropping pattern, but it has been instrumental in strengthening and expanding the existing intercropping system. The choice of other field crops is limited in this village as they should essentially be suitable for intercropping with coconuts.

However, such restrictions do not exist in many areas where groundwater development has proceeded. Author's experience outside the study locations in the same district confirms that the dynamic farmers who utilized groundwater to grow commercial crops on an organized basis accrued much profit. Spread effects of these ventures among the farming community have been noteworthy.

The situation at Nochchiya stands in contrast to that of Epaladeniya. The former village exhibits a marked concentration of precipitation received within four months of the year, and cropping during yala is not at all possible without recourse to irrigation. Thus, the provision of agrowells is considered to be a welcome gesture by the farmers at Nochchiya as the utilization of

28 A village-level officer belonging to the lowest hierarchy of the administrative setup.

groundwater can not only promote dry season cropping but also save at least a portion of the rice crop in maha if the water supply from the tank is reduced to critical levels. However, the location of wells in the yaya (field tract) itself or in the adjoining lands is necessary for this purpose. Presently this village has one group well given by the PDA and three individual wells sponsored by the ADA. In addition, the village has been given three more wells by a nongovernmental organization which has sponsored rural development programs in Sri Lanka.

A group of four farmers received the PDA agrowell at Nochchiya. The group comprises the leader, one of his relatives and two neighbors, each possessing more than 0.4 ha of land. The well is located in the land belonging to the leader. One member of the group has already severed his connections with the group owing to a personal disagreement with the leader and the other two still cultivate small extents of about 0.1 ha in their own landholdings. Once the leader completes his round of irrigation, others obtain the leader's water pump on hire to irrigate the crops in rotation.

It is observed that no conflicts have arisen pertaining to the distribution of water during the two seasons which were cultivated under the well. Nevertheless, the volume of water that can be stored in the well seems to be inadequate to crop more than 0.3 ha during the dry months. Two active members of the group other than the leader feel that they will not be economically benefitted by cultivating the present extent as they have to bear added costs for pump hires. Hence, they wish to withdraw allowing the leader who had been instrumental in getting the well and who possesses the means to lift water, to continue with cultivation. In both villages, for all intents and purposes, one individual, the group leader, exerts his authority in operating the well.

The group well subsidy also specifies that whenever the land in which the well is constructed belongs to an individual the plot of land with the well has to be separated and vested with the Agrarian Services Committee²⁹ of the area by a title deed. Similarly, the owner of the land is expected to guarantee that he will not deny the other members of the group free access to the water source. It is observed that this condition has not been fulfilled by the group leaders in both villages. Authorities also find it difficult to enforce the procedure as the owner is in no way compensated for forfeiting a portion of his land on behalf of the group.

In each village, the subsidy for the group well has been obtained and the extra costs in completing the well have been met by the respective leaders in whose land the wells are located. It is evident that the other members of the group are hesitant to commit financial resources when there is no guarantee about the water rights. Purchase of water pumps through bank loans has also posed problems to members other than the leader, as they are not assured of continuing incomes from farming through the utilization of groundwater.

No special marketing arrangements or credit facilities have been provided to the beneficiaries. Farmers use the existing marketing channels to sell their produce and to purchase the necessary inputs. The village fair constitute the most common marketing forum. However at Epaladeniya, farmers have formed a Betel Growers' Association with a view to establishing linkages with export markets. It should be noted that this development is not a direct outcome of the Agrowells Program.

The ADA Program

The ADA launched its program of assistance to agrowells in the Kurunegala District during 1990. It took the form of a subsidy of Rs 15,000 (US\$357) disbursed in three installments. This amount

²⁹ These committees with farmer representation of the respective areas have been established under the provisions of the Agrarian Services Act of 1979.

has been increased to Rs 20,000 (US\$476) from January 1992. As in the case of the subsidy granted by the PDA, here too the first instalment is released only after the successful completion of a test well.

A noteworthy contrast of the ADA activity from that of the PDA is the grant of the subsidy exclusively to individuals. However, the ADA has specified conditions such as the possession of a farmer identity card, membership of the pension scheme³⁰ for the farmers and the ownership of undeveloped land exceeding 0.4 ha subject to a maximum extent depending on the present use. A beneficiary should also be a resident in close proximity to the location of the well and should not be a defaulter of a loan taken from a bank.

Even if a farmer becomes eligible under the land ownership/operation criterion of a maximum of 0.4 ha, he should be in a position to command financial resources to complete the test well in order to get the first instalment of the subsidy. It is observed that the subsidy can cover only a part (25-50 percent) of the total cost of a dugwell. Entire expenses for a well range from Rs 30,000 to 60,000 (US\$714-1,428) depending on the soil conditions, mode of excavation, material used for well lining and expenses for labor and masonry. Hence, the poorer farmers are automatically excluded from the Program as the cost of constructing an agrowell is beyond their means; nor are they in a position to obtain pumps for lifting water.

AGROWELLS PROGRAM: LESSONS LEARNED FROM EXPERIENCE

Although the programs administered by the PDA and the ADA are at the early stages of development, it is possible to make some observations with a view to rectifying the initial errors and focusing attention on the sustainable development of the groundwater resources in the hard rock areas of the Kurunegala District. Detailed surveys to ascertain the extent and the spatial distribution of the groundwater resources have not preceded the promotion of agrowells. However, hydrological surveys were conducted in isolated locations of the Kurunegala District by the Water Resources Board (Wijesinghe 1990). Present practice followed by the implementing agencies is to ascertain the water availability on the basis of farmers' test wells. One-meter depth of water within the first 6 m and a recharge rate of about 100-125 liters (l) during the first hour after emptying are considered to be adequate indicators to suggest water availability for the grant of a subsidy.

Significant aquifer drawdowns leading to water shortages are not evident in the study locations or in the neighboring areas and the level of recharge is satisfactory with the existing extents of cropping. It is pertinent to note that the farmers still cultivate restricted areas under the wells and year-round cropping is not at all practiced. Hence, it is of vital importance to watch the behavior of the aquifers very closely with the increasing extraction of groundwater. Thus, the haphazard development without recourse to scientific investigations should not proceed further.

30 All farmers in the country are expected to join a pension scheme under the Farmer' Pension and Social Security Act of 1987

IMPLICATIONS FOR SUSTAINABILITY

Past experience shows that immediate attention should be drawn to a number of factors which are of crucial importance vis-a-vis the sustainability of groundwater utilization. They are as follows:

- i) Many wells have been completed recently and the farmers do not have adequate experience of the water requirements of the crops grown, specially during the dry months. Similarly, they do not seem to have a clear idea of the irrigation intervals. Thus, the existing crops are often over-irrigated or under-irrigated.
- ii) Farmers are still unable to judge for certain the exact extents that can be cropped under one's own agrowell on a year-round basis. It is reliably understood that the officially predicted potential at the inception of the Program (i.e., 0.8 ha) cannot be realized throughout the year. Cropping in the dry season is restricted even to less than 40 percent of the stipulated extent.
- iii) When the genuine farmer groups are formed, involvement of too many cultivators has led to unrealistic economic expectations and disillusionment.
- iv) Institution building to cater to the new demands of commercial crops has not received the attention of the implementing agencies of the Program. As the subsidy covers only a part of the cost of a well, meeting the credit needs of the farmers to buy water pumps and the necessary inputs to expand the cultivation of field crops seems to be of crucial significance.
- v) With the increasing demand for agrowells more attention should be paid to the spacing of the wells. The present specification of 100 m between two agrowells does not take the existing small diameter wells for domestic cum agricultural purposes into consideration. However, close spacing of wells may lead to reduced yields and restriction of the area under cropping, thus jeopardizing the economic interests of the farmers who ventured into groundwater irrigation. Further, it will negate the positive aspects of the Program.
- vi) Effective farmer participation is neither promoted by the authorities nor is it forthcoming. Although a group has been formed owing to the personal initiative of one farmer who becomes the leader in order to obtain the subsidy, farmer groups have not consolidated after the construction of the agrowell. Past experience shows that with the utilization of groundwater for cropping the groups often disintegrated and cultivation got restricted to the leader's own plot. Individual owners of the agrowells feel that interaction among the beneficiaries is not a dire necessity as both irrigation and cropping is the concern of one person. However, group activity specially in the fields of input supply and marketing, participation in the Program through formal or informal meetings and sharing of experiences can be of mutual benefit to the farmers.

TOWARD FUTURE SUSTAINABILITY

It is imperative that the present strategies should change toward more sustainable use of the groundwater resources. The agencies concerned should think "beyond the well" and try to evolve farming techniques and cropping patterns which can utilize the available groundwater to the utmost benefit of the farmers and to the country at large. Adaptive research will be of much

significance to solve area- or farm-specific problems such as water quality, soil reaction and adaptability of crops. High-value crops with low water requirements and scope for livestock farming should receive sufficient attention in the research programs.

“Season mentality” of the dry zone farmers should essentially be changed with the development of the groundwater resources. Year-round irrigation should replace the existing yala and maha seasons. Periods of harvesting, particularly of vegetables, can easily be adjusted to coincide with the periods of high demand owing to shortage of supply.

Since the ultimate objective of all these changes is to give the maximum benefit to the farming community, strategies should be evolved to seek the active participation of the farmers. Utilizing the existing institutions for awareness creation programs, encouraging the less active farmers to share the experiences of the successful ones, convincing the farmers about the advantages of group action, increase of farmer-agency interactions, making the beneficiaries partners to the action-oriented research programs and involving farmers in monitoring and evaluation activities are some fruitful strategies to promote farmer participation. Farmer representation in local-level committees pertaining to groundwater development will be a significant step forward as the beneficiaries will thus be involved in the decision-making process. Effective farmer training in irrigation methods, water management and pump maintenance as well as the introduction of appropriate agronomic practices should form integral parts of the future groundwater development programs.

CONCLUSION

Experience with the Agrowells Program shows that it will not reach the poorer farmers with small plots of land. As the full potential of the agrowells are still not realized it is too early to come to definite conclusions. However, in the light of the field evidence, it is possible to highlight some basic problems such as the failure of the members of the group wells to perform up to expectations, over-estimation of the irrigation potential of the agrowells, inadequate attention paid to suitable agronomic practices, lack of preparation on the part of the implementing agencies to cater to the farmer needs during the post-construction period and inability to mobilize effective farmer participation. Hence, it is imperative that the existing strategies for groundwater utilization should change toward more effective policy orientations aiming at sustainable development.

ACKNOWLEDGMENTS

The author wishes to thank the officers of the Agricultural Development Authority who provided data and spared time for discussions; Prof. M. M. Karunanayake, University of Sri Jayawardenepura, for valuable comments; and Mr. G. F. de Alwis, Staff Cartographer, for drawing the illustrations.

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Sustainable Groundwater Development and Management in Nepal: Major Issues Confronted by a Development Bank in Nepal

Ujjwal Pradhan³¹ and Ganesh Thapa³²

ABSTRACT

GROUNDWATER EXTRACTION WITH newer technologies and its use in Nepal are very recent as compared to some other South Asian countries. The Agriculture Development Bank/Nepal (ADB/N) has been intimately involved in groundwater development for the past two decades. It is very probable that, in the future, the functions of the Bank will be limited only to lending activities without the technical support. Were it to be so, the Bank will need to find avenues for filling in the newly created vacuum if irrigation development is to be fully realized.

Therefore, this paper assesses the institutional capacity and the adequacy of irrigation support services to shallow tube wells (STWs) by the ADB/N by analyzing several systems supported by the Bank. The economic performance of the selected STWs is also presented. Suggestions are made for enhancing the Bank's institutional capacity regardless of whether it retains technical support as one of its functions.

The paper also addresses the issue of subsidy and its impact on groundwater development. It concludes with issues that confront STW development and sustainability in Nepal, in view of the positive contribution that ADB/N can make toward the goals of irrigation development in the country.

INTRODUCTION

Groundwater development potential in the Tarai of Nepal is estimated to be 250,000 hectares (ha). In addition, there is a potential for groundwater development for conjunctive use in the surface command areas in some 150,000 ha. Total area irrigated using groundwater in the Tarai is estimated to be about 110,000 ha, of which about three-fourths is under farmer-managed tubewells and the rest is under agency management. Thus, the present groundwater development constitutes only a small fraction of the total potential.

About 70 percent of the total irrigation coverage in Nepal is under farmer-managed systems. Several government agencies have provided technical and financial inputs for irrigation

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development. The approaches and procedures guiding their public interventions have varied. Agencies have been either amalgamated, separated, or fragmented within and between ministries. ADB/N involvement is in the farmer-managed category and that too through the provision of loans and subsidies. However, some grant assistance is provided for technical and managerial support. ADB/N is mainly involved in small surface irrigation, shallow tubewells and other types of technologies; while the other major irrigation institution, the Department of Irrigation (DOI), is involved in all types of surface irrigation and groundwater systems through grant assistance or through donor loans. While it would be useful to compare and contrast the impact of the grant and loan/subsidy systems on the irrigation performance and implementation process, the focus of this paper will be on the impact of loans/subsidies on the economic performance of some of the selected ADB/N STWs as studied by the International Irrigation Management Institute (IIMI).

IRRIGATION INSTITUTIONS AND POLICIES: IN THE CONTEXT OF NEPAL

Ever since the Third Five-Year Plan, the government has accorded high priority to irrigation development. However, it was only since the Sixth Plan that the government has emphasized equity and access to resources for the welfare of small and marginal farmers. New approaches and policies with the objective of improving irrigation planning and implementation were introduced in the Seventh Plan.

In 1988, the government formulated working policies on irrigation development for the fulfillment of basic needs (HMG/MOWR 1988). Salient features of these policies were as follows: (i) Farmer participation was made compulsory for all stages of the project cycle, while operation and maintenance, and capital costs were to be shared by the beneficiaries and the government; (ii) The National Irrigation Development Committee was formed to formulate working procedures, establish priorities, fix targets and coordinate all the agencies concerned with DOI and ADB/N as the main implementing agencies; (iii) ADB/N was allotted 227,000 ha (28 percent of total) to be further irrigated by the end of the century; (iv) Cost of construction was to be shared by the beneficiaries and certain subsidies were to be provided for groundwater systems; and (v) Operation and maintenance of small- and medium-scale surface systems, STW projects and deep tubewells were to be undertaken by the beneficiaries.

This new policy was to be implemented by means of two Action Plans. One for turning over some systems constructed and presently managed by DOI to farmers for operation, and the other to increase participation of farmers in the management of jointly managed systems.

The scenario regarding irrigation development by the government was that there were several agencies drawing from different sources of funding and a multiplicity of approaches regarding the implementation of projects. Project financing was in the form of outright grants, or partial loans with a substantial grant component, or a combination of grantees' contribution usually in the form of labor. Varying input levels, financial or otherwise, were required from the beneficiaries. The degree of beneficiary involvement during the projects differed from one agency to another and even from one project to another within the same agency. Different agencies approached the issue of operation and maintenance of the systems differently after completion. Some handed the systems over to the users, while others continued to control with minimal farmer input.

In view of such a fluctuating yet dynamic irrigation scenario and experience in Nepal, the various objectives and Action Plan documents are currently being consolidated into a new

irrigation policy document. The objectives of the proposed new irrigation policy (still in draft form) are as follows:³³

- i) To promote farmer organization participation in the irrigation sector through cost-effective, economical, and environmentally sustainable investment of irrigation development that contributes to a reliable increase in agricultural production and productivity.
- ii) To integrate all support services crucial to irrigation expansion.
- iii) To reorganize the management and technical units of DOI so as to support irrigation development objectives.
- iv) To maximize the involvement and participation of beneficiaries so as to decrease government responsibilities in irrigation implementation and thereby promote local resource mobilization and self-reliance.
- v) To support personal and community efforts in irrigation development.
- vi) To support and strengthen the capacity of other nongovernment and government agencies in irrigation development.
- vii) To support and enhance research capabilities of national institutions in irrigation technology and management.

It is with this evolving policy backdrop that we now turn to the analysis of ADB/N and the performance of the STWs that it has helped to install.

ADB/N'S IRRIGATION LENDING POLICIES

ADB/N reviews and appraises the borrower and the enterprise in accordance with policies and regulations approved by its Board of Directors. The salient features of the lending policy cover (i) eligibility, (ii) borrower participation and loan limit, (iii) security, (iv) interest rates, and (v) approval procedure.³⁴ ADB/N may finance 100 percent of project investment costs of irrigation when lending to small farmers.

Originally, the Bank tried to overcome capital constraints in the private sector for irrigation development through financing. It was realized that credit for irrigation development alone is not enough, and therefore, the Bank provided technical support for the irrigation sector both in the identification of suitable technologies and system development (IIMI 1991). Now, ADB/N is a major institution in irrigation development in Nepal. In search of newer and more appropriate technologies, ADB/N has propagated shallow tubewells, dugwells, rower pumps, and treadle pumps in the Tarai, in thousands of hectares utilizing groundwater potential.

33 As of 30 March 1992.

34 For details, see IIMI 1991.

ADB/N's STW Implementation Process³⁵

By 1990, more than 20,000 STWs covering nearly 80,000 ha of irrigated area were financed by ADB/N. IIMI's report notes that in actual implementation, however, the availability of materials, the availability of drilling contractors, etc., have been determinant factors.³⁶ ADB/N provides both financial as well as technical assistance for installing STWs in the form of the appointment of driller technicians, supply of materials, and regular follow up and supervision of the performance of the units. In SFDP areas, the members are provided loans for STWs as community schemes. A pre-condition for a community scheme as laid down by ADB/N is that the members should have their lands contiguous to one another. Prior to approaching SFDP for loans, the interested members have to acquire a group recommendation for the loan through group decision. This decision is conveyed to the SFDP and since the loan is provided on the basis of group collateral the group itself should have credit-worthiness based on past performance. The whole group is at stake with the loan and the whole group is responsible for loan repayment. The group then decides on each member's repayment share.

In the non-SFDP, those who require loans have to first form a group. Yet, they are treated as individual borrowers who will have to provide with collateral also on an individual basis. The repayment is on the basis of the land in the command area of the scheme. Sometimes the loan is disbursed in the name of a single member of the group and the beneficiaries decide among themselves each individual's share. The Bank treats these as individual loans, thereby reducing transaction costs.

The Bank also provides 40 percent subsidy on the total cost and also on the pump sets. In community schemes, 75 percent subsidy is provided.

Economic Performance of ADB/N STWs

Six clusters of shallow tubewells (STWs) comprising 24 STW units were selected for the IIMI study, with two clusters each from the eastern, central and western Tarai. Each cluster included 2 to 5 units of STWs. The area irrigated by a unit of STW varied from 1.07 ha to 2.62 ha, with an average of 1.85 ha (see Table 7.1).

Average cropping intensity increased by 54 percentage points following STW development. This increase mainly came from the expansion of area under dry season crops like wheat. Another important consequence of STW development has been the substitution of rice-based cropping patterns for maize-based patterns in the eastern Tarai, and the substitution of high-value crops like vegetables for low-value crops in the central and western Tarai sites.

Significant yield gains in wheat (42%) and rice (41%) were achieved in STW sites after irrigation development. Yield gains were less dramatic for maize (21%). Among vegetable crops, potato showed the biggest potential for yield increase. The adoption of modern varieties of rice, maize and wheat and fertilizer application rates increased in most areas of the scheme.

³⁵ For more details, see IIMI 1991.

³⁶ For example, in 1989/1990, there was a drastic drop in STW installation due to the India/Nepal Trade Impasse and the general turmoil in the country.

Table 7.1. Summary of performance of STWs at selected locations.

Scheme	Region	Area irrigated (ha)	Hours of operation (Hrs/yr)	Cropping intensity		Yield (mt/ha)					
						Rice		Maize		Wheat	
				Before	After	Before	After	Before	After	Before	After
Belbari	Eastern	2.62	193	220	245	2.1	2.4	—	—	—	1.6
Bajjnathpur	Eastern	2.30	271	197	257	1.5	2.2	1.0	1.8	—	1.6
Chandranighapur	Central	2.28	149	213	297	1.6	2.3	1.8	2	1	1.6
Gunjanagar	Central	1.71	128	216	222	1.5	2.6	1.9	1.8	1.3	1.4
Mahadevpuri	Western	1.07	120	149	240	1.4	2.5	1.4	1.9	1.4	2
Puraina	Western	1.33	138	180	238	1.8	2.4	0.7	1	1.1	1.9
Average		1.89	167	196	250	1.7	2.4	1.4	1.7	1.2	1.7

Table 7.2 summarizes economic and financial rates of return to STW irrigation in the sample sites. The internal rate of return (IRR) was higher than 25 percent in all six sites, indicating high benefits to society from investment in this technology. STWs are also financially attractive to farmers as shown by the average benefit-cost ratio (BCR) of 1.33. The estimated financial IRRs are high even though there seems to be considerable under-utilization of STWs. The average utilization of 167 hours per year is considerably lower than the recommended utilization of 800 hours per year. This indicates that there is a high potential for greater utilization of STWs, with corresponding increases in returns.

Table 7.2. Summary estimates of economic and financial returns to STW irrigation at selected locations.

Scheme	Economic returns		Financial returns			
			At full cost of investment		Excluding subsidy in investment	
	BCR	IRR (%)	BCR	IRR (%)	BCR	IRR (%)
Belbari	2.33	112.2	1.24	33.2	1.49	62.2
Bajjnathpur	2.06	104.4	1.56	65.7	1.77	108.0
Chandranighapur	2.47	137.0	1.55	61.5	1.82	108.4
Gunjanagar	1.35	36.6	1.29	36.4	1.57	70.4
Mahadevpuri	1.54	47.8	1.23	31.4	1.48	57.4
Puraina	1.28	28.3	0.89	7.3	1.14	25.9
Simple Average	1.84	77.7	1.29	39.25	1.55	73.0

Notes: BCR = Benefit-cost ratio.
IRR = Internal rate of return.

Subsidies and their Impact on Groundwater Development

Subsidies are essential if private returns do not justify an investment which is otherwise socially beneficial. They may also be required to induce farmers to adopt a new technology. However, results of the financial analysis show that investment in STWs is financially attractive to farmers even without the 40 percent subsidy provided by the government. The average BCR of 1.33 and IRR of 41 percent are comfortably above the threshold of private incentive. In computing financial rates of return the opportunity cost of labor was assumed to be equivalent to the market wage rate. The BCR and IRR would be even higher than the computed values if a lower value for the opportunity cost were assumed. Thus, subsidies on STWs are not justified on efficiency grounds.

The proponents of irrigation subsidy argue that subsidies on groundwater development are essential to benefit small farmers. However, available data show that the groundwater program has so far benefitted mostly large farmers who need such subsidies least. For example, a 1986 survey of 248 STW owners distributed throughout the Tarai indicated an average landholding of 6.9 ha, and that pumpset owners fell within the top 10 percent of Tarai farmers by farm size (World Bank 1990). Thus, if the groundwater program is to meet the equity objective, careful targeting of subsidies will be crucial. This also calls for an active promotion of group ownership and use of STWs.

A more serious constraint to the continuation of subsidies on STWs is the limited availability of funds for groundwater development. Limited government funds for irrigation subsidies restrict the potential for groundwater development, as annual allocations of subsidy are exhausted within a few months. However, under this situation, a disproportionately larger section of the rich and the influential compete successfully for the subsidy.

The level of subsidies varies among different agencies involved in irrigation development. The groundwater systems developed by the Department of Irrigation require farmers to share only part of the operation and maintenance costs. In contrast, farmers who borrow from the Bank for groundwater schemes shoulder between 25 to 60 percent of the construction and maintenance costs as their responsibility. Thus, the implicit level of subsidy is much higher in DOI schemes than in the Bank-supported projects. In view of the economic analyses of the Bank-supported schemes, there is a need for critical review of government policies on subsidies for the irrigation sector.

A related subsidy issue is an assessment of the real rate of subsidy on STWs and the likely distortions on account of subsidy. Many respondents in the IIMI Survey expressed the opinion that subsidy should be measured relative to world prices and not to domestic prices, which are generally distorted. It was found that many domestically manufactured pumps and accessories were more expensive than similar products marketed in India and other countries and hence farmers were receiving a lower subsidy than they would have received under a free trade regime. Comparative data show that an STW installation (including pumpset) using Indian equipment costs Rupees (Rs) 6,361 less than what it costs using locally manufactured pumps and accessories. The Bank's requirement to finance only locally manufactured pumps and accessories implies that inefficient domestic industries are subsidized at the cost of farmers and the government. The price differential between imported and domestically manufactured pumps and accessories leads to a lower level of subsidy (23%) than the intended one (40%). The policy implication is that farmers should have a choice in the selection and purchase of equipment.

ASSESSMENT OF ADB/N SUPPORT TO STWs

Though ADB/N provides technical support for groundwater development, the IIMI research revealed that the number of technical staff is extremely inadequate to cover the large area under its program. The Bank also provides technical and financial support to the private sector by providing loans for establishing workshops, importing spare parts, purchasing boring equipment, leasing out pump sets to boring mechanics, and also providing training on STW installation to interested mechanics.

The STWs are owner operated and in the case of community schemes they are managed through mutually agreed arrangements. The beneficiaries are also responsible for repairs and maintenance. It was observed that where there was a lack of specialized mechanics many less skilled local mechanics did the repairs often aggravating the pump's condition rather than repairing it. There was better private sector support and easy access to this sector for repair and maintenance of STWs in areas near larger commercial towns.

Major Findings of ADB/N Pertaining to STWs

The economic analysis shows that there is greater payoff to society from investing in surface, shallow and sprinkler systems, i.e., most of the irrigation projects undertaken by the Bank.

A summary of the major findings specific to STWs as reported in the IIMI study are as follows:

- i) Financial returns to STW schemes indicate that STWs are highly profitable to farmers.
- ii) ADB/N's STW Program has benefitted small farmers also by providing STW units to groups of small and marginal farmers under community irrigation schemes.
- iii) The utilization rate of STWs is low in terms of area irrigated, hours operated and range of crops irrigated.
- iv) The absence of competition in the pump set market has effectively reduced the subsidy provided to the farmers by the government and has also led to poor after-sale services.
- v) ADB/N's present level of technical manpower is inadequate to support its groundwater development program.
- vi) The present level of training support to farmers on STW operation is generally inadequate.

PROPOSED STRUCTURAL CHANGES WITHIN ADB/N AND THE POSSIBLE AGENDA

In a recent MOU between ADB/N and ADB, Manila, for the proposed Sixth Agricultural Credit Project from the Manila Bank, the ADB/N is to undergo structural and functional change with a movement away from the prevailing technocratic institutional culture toward a "proper" banking culture focusing only on lending activities. As a condition for the loan as well as disbursement, ADB/N is to cut all nonbanking functions, including all technical advisory functions (other than those fully funded, including overhead costs, by other donor agencies) and farmer training from its purview, and will concentrate its efforts and funds only on its primary banking functions. These

nonbanking technical services divisions include the surface and groundwater irrigation sections. Technical staff, if retained by ADB/N are to be assigned as loan officers.

It would therefore be essential for ADB/N to reorient its programs and its method of project monitoring and evaluation. The technical expertise, previously in-house, will now be undertaken from outside (mainly from the private sector) since the Bank will henceforth concentrate only on lending activities. In the light of this new development, the capacity of ADB/N staff will have to be enhanced in its lending programs in irrigation development.

The following institutional development activities will be important:

- i) Develop methodologies for appraising loan requests from farmers for specific irrigation sub-projects.
- ii) Assess the capacity as well as draw up the necessary qualifications and competency of the private sector agencies which are potential project implementors.
- iii) Develop an appropriate, participatory monitoring and evaluating system for the project, including indicators of project performance (which will be partly based on farmers' own performance criteria), reporting systems and formats, etc.
- iv) Develop a procedure for monitoring the project and its implementor (i.e., NGO or private sector) in terms of project performance, and recommend timely corrective action on irrigation management and farmer participation.

Thus, to develop such in-house capacity the following would be important: (i) Inventorize and assess international and local NGOs and private firms that can provide services to ADB/N either in training for other agencies or as implementors themselves; (ii) Determine the necessary qualifications and training for such agencies of the private sector to fulfill objectives of irrigation development and draw up guidelines for selection of implementors for ADB/N; and (iii) Carry out the above mentioned activities in a couple of pilot areas (having different irrigation technologies and topographies) to field test the procedures developed.

Unless this type of in-house capacity to assess and monitor the private sector is built, a vacuum (that was previously filled by ADB/N) would be created. As was pointed out, if the ADB/N STWs had performed economically well, they could have still received more technical support from ADB/N. In fact, one of IIMI's recommendations was to enhance the technical support to be provided by ADB/N to STWs for sustainable development. Again, a donor has "forced" a structural and functional change on the borrowing institution but the fact remains that if technical assistance is to be relegated to the external, this must be managed and monitored by ADB/N. It should not be forgotten that the ADB/N did not commence its work only as a lending institution. It was realized from the very beginning that technical support was absolutely important if ADB/N's loans were to be effective. If the present ADB/N administration feels that it should only be a lending institution, then it must also consider the replacement of technical expertise somehow so that the loans can continue to be effective.

If the proposed or constricted role of ADB/N from a development bank to a commercial bank (to support privatization and the private sector) focussing on rural enterprises is to be adopted, at least at the initial stage, the market has to be managed, rather than expecting the market forces to fill in the gap.

Within the Bank itself there should be that in-house capacity to monitor and assess the private sector's technical expertise and also to facilitate enhancing the private sector in the technical roles previously accomplished by the Bank.

CONCLUDING REMARKS

This paper has examined ADB/N's support to STWs and the economic performance of those STWs in terms of sustainable support to STWs and the sustainability of STWs. It was found that the current level of subsidies needs to be reduced to distribute benefits to a larger section of the society and to target the marginal farmers as the real beneficiaries. Suggestions have been made for a new role for the Bank and its technical component will have to be phased out.

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SYSTEM MANAGEMENT AND PERFORMANCE

water users association

Sustainability of Groundwater Farmer-Managed Irrigation Systems

Manuel Olin³⁷

ABSTRACT

THE SUSTAINABILITY OF a groundwater-based farmer-managed irrigation system (GW FMIS) cannot be guaranteed, but if the necessary conditions are not provided its demise is assured. A groundwater-based water users association (GW WUA) will be unsustainable if it cannot raise sufficient funds and manage its money, if it cannot obtain quality maintenance and repair (M&R) services on site, if the necessary spares are not available, if the tubewell (TW) suffers frequent breakdowns in mid-season, or if the energy supply is unreliable.

Subsidized financing of M&R by the government is in the long run detrimental to the WUA as they are unsustainable. Eventually government priorities change. Provision of these services by the government prevents the spread of expertise and the development of a market for M&R services. Thus there is no backup source when the government ceases to provide them.

This paper describes the concept of sustainability, the approach for achieving it and the conditions necessary. Application of this approach is being tested in the Bhairawa-Lumbini area of Nepal.

INTRODUCTION

There are many reasons why a GW FMIS may not be sustainable. Clearly, a basic set of conditions for sustainability must exist for such a system. There must be a reliable source of water, a reliable source of energy, the mechanical and physical design must satisfy engineering and equitability criteria (water must reach all users) and other basic requirements must be satisfied. However, even if all of the above are met, the system may still not be sustainable.

There are two issues which are critical. An effective response to them is a necessary condition for irrigation system sustainability. This paper describes both issues, but focuses on one which is less familiar and more in need of discussion. An approach to create the necessary conditions and its application are also discussed with reference to the Bhairawa-Lumbini Project in Nepal.

The two issues are as follows:

- The high cash requirements of GW FMIS.

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- The need for a reliable M&R support service.

Only the latter issue is elaborated in this paper. Experience with FMIS has been mainly with gravity surface water (SW) schemes. There is a tendency to try to apply the SW experience to GW FMIS on the assumption that all FMIS are the same. While there certainly are similarities between all types of FMIS regardless of the water source, ignoring the differences may prove fatal to the GW system, and a great cost to the government which promoted the scheme, and to the farmers who invested effort, money and hope in the enterprise.

In this paper a plan of action is proposed for making GW FMIS sustainable. The circumstances under which GW FMIS are unlikely to be sustainable and where they should not be promoted, are also indicated as a corollary.

DIFFERENCES BETWEEN SURFACE WATER AND GROUND-WATER FMIS

There are some basic differences between groundwater (GW) and surface-water (SW) based irrigation systems. The major ones relevant to this discussion are indicated below:

- GW systems based on tubewells (TWs) are cash intensive since they require the purchase of goods and services for operation and for M&R. Energy (electricity or diesel fuel), spare parts and skilled labor for M&R must all be bought for cash. SW systems are normally labor intensive since members normally supply the bulk of the labor inputs. In most cases, the major input in SW operation and M&R is relatively low-skilled labor.
- In the absence of preventive maintenance, GW systems are unforgiving. Unmaintained GW systems are prone to total failure. Poorly maintained SW systems perform poorly but do not normally break down totally. (I do not refer here to natural catastrophes such as floods which may wash away the intake.) Preventive maintenance is indispensable to the good functioning of the pumping and distribution equipment. Break downs occur when the equipment is operating; any stoppage when the pump is operating is critical, as the entire investment in the crops up to that time, as well as any potential profit from its sale, is at risk.
- The fixed location of the TW determines that M&R services be mobile. M&R services must reach the site of the TW; most of the equipment cannot be brought to the workshop for repair or requires expert dismantling and reinstallation of the component.
- M&R of pumping equipment require highly specialized skills and familiarity with the equipment. Relatively low-skilled labor can repair an SW system. M&R for TWs is totally dependent on specific skills not available to the users of the irrigation systems (knowledge of mechanics and electricity and, more particularly, familiarity with the equipment installed).
- Equipment repair requires a stock of spare parts, usually imported. While SW systems require few spares, TW M&R is dependent on spare parts and in particular on imported spare parts, since the pumping equipment is imported. Ordering of spare parts when they are already needed to carry out a repair, would normally put the pumping

equipment out of commission for the remainder of the season, and possibly, even longer.

CONDITIONS NECESSARY FOR SUSTAINABILITY OF GW FMIS

As a prelude to the discussion, the term “sustainable” must be defined. Sustainability is the ability to continue in existence indefinitely and the ability of the water users association (WUA) to irrigate continuously from its TW, without directed intervention or support from exogenous forces. Stated simply, sustainability means that the irrigation system will continue to function even after the lenders or donors have pulled out.

While there is no way to guarantee that a GW FMIS will be sustainable, it is clear that it will *not* be sustainable *if*:

- The irrigation system does not generate sufficient cash income for its members to cover the costs of operation and M&R.
- The group does not have an organized, accepted, understandable and equitable system for generating the funds and sharing the costs of operation and M&R among its members.
- A reliable service infrastructure to maintain and repair the equipment, obtainable in the nearby vicinity, is not available.
- A supply of skilled labor familiar with the equipment installed is not available.
- A sufficient stock of commonly required spare parts is not available.

Obviously, the converse of the above are necessary conditions for sustainability. *All of the above* must be provided as necessary conditions of sustainability. It is essential then, that every GW FMIS project include these components in their plans and their implementation programs.

The above may be divided into two basic fields of action as follows:

- The water users.
- The service sector.

Assisting the water users is a recognized field of action to all familiar with the FMIS concept. In the case of GW FMIS, the field of action must be broadened to deal with and emphasize training and assistance in all the fields related to cost sharing and money management. Due to lack of space in this paper, the approach to this issue will not be discussed.

The service sector is a less common field of action. This paper makes an argument for the participation of the private sector in GW irrigation system development. While the need for farmer participation in irrigation projects is already accepted, broader community participation is required in the case of GW FMIS.

TRADITIONAL DELIVERY OF M&R AND THE SUSTAINABILITY PROBLEM

Commonly, M&R are provided through a project authority or through a government service. They are financed by the government or by outsiders such as a foreign nongovernment organizations (NGOs). The M&R services are generally provided free of charge to the WUA or at a nominal cost.

Because the M&R services are provided free of charge or at highly subsidized rates, no private sector M&R services can develop; there is no market demand for it. A single supplier is the sole source of the service and the sustainability of the GW FMIS is dependent exclusively on it. If it should cease to exist, the irrigation systems too will eventually cease to exist.

Once project financing comes to an end, there is no longer any source available to finance the provision of M&R services. What is worse, whatever experience gained over the years is normally lost when the employees of the project move on to other government services, or when they look for and find other work, or when the service continues to be provided in name only. (Government employees are rarely the entrepreneurial type and do not often set up their own businesses.) Spares are not purchased, fuel for vehicles is rationed, the vehicles are not repaired or replaced and eventually only salaries are paid. Under these circumstances, no M&R services are provided and ultimately all tubewells break down. Furthermore, literature on the subject indicates that even before the collapse of the government, M&R services provided were rarely satisfactory. (Jackson 1991 and Pant 1984).

Subsidized financing of M&R, and nonmarket provision of M&R services are, in the long run, detrimental to the WUA, as this type of service is unsustainable. Eventually government priorities change, funds from international loans run out and NGO energies get diverted to the latest international crisis. Provision of these services by a project authority or government organization prevents the spread of expertise and the development of a market for M&R services. With no demand for the service, no supply develops. There is no backup source of M&R when the government ceases to provide it.

CREATING THE NECESSARY CONDITIONS

M&R services must exist in the vicinity of GW irrigation systems. The services should be provided by private workshops which would be accountable to the users for the quality of their work. M&R work paid for by the users would assure them that the workshops are accountable. Moreover, M&R services must be profitable to the suppliers so that they will continue to provide them. There should be a sufficiently large number of workshops and/or tradesmen to keep prices at a reasonable level and to provide backup support if some workshops should go out of business. Any sustainable solution must be financially sound and locally based.

But how are these conditions to be created? This concept hopes to stimulate the development of workshops by local entrepreneurs. As in the case of farmer participation, the approach to the service sector should be initiated at the beginning. The service sector should be informed from the outset of the planned irrigation development project. Their interest and their active participation should be sought and encouraged.

The failed approach of "handing over" completed irrigation projects to the farmers after everything is in place, is likely to fail in the service sector as well. Establishing M&R services and "handing over" to the private sector (privatizing) is not likely to succeed. Here, the irrigation

system will not be designed on a scale manageable by small entrepreneurs and its systems will be incompatible with the way things are done in villages.

The private sector should be offered an "in" from the outset. A project M&R service should not be set up. No government monopoly or insurmountable competition should be introduced. Instead, private entrepreneurs willing to undertake M&R services should be encouraged and assisted to do so.

The proposed action plan is as follows:

- Spreading word in villages and nearby urban centers and creating an interest in M&R services.
- Offering training courses in all aspects of equipment M&R.
- Providing advise on tools and equipment needed to provide M&R services.
- Providing advise on recordkeeping and on how to run a workshop.
- Assisting in obtaining loans to purchase tools, equipment and spares.
- Assisting entrepreneurs to establish contacts with equipment suppliers.
- Accrediting workshops to carry out M&R work.
- Offering contracts to carry out necessary M&R work during the commissioning period.

For the commissioning period during which the project is responsible for maintaining and repairing the pumping equipment, the project authority would pay a private workshop the price of the service. While commissioning is normally only for one year, it may cover a fairly long period if there are many TWs in the project starting up over a number of years. Furthermore, even within one year, much experience can be gained.

The WUA must, as a condition for receiving the TW, agree that for a fixed period (say for five years) they will contract with an approved workshop to have their pump serviced. This would simultaneously create a market for M&R services and assure good maintenance at least during the first few years. It would also establish a tradition of good practice which, it is hoped, would continue beyond the minimum time period agreed upon.

WUAs should be free to select the workshop of their choice from among a group of, say three workshops, which would serve each area. They could switch from one workshop to another from time to time if they are dissatisfied with the service.

It should be the role of the project authority or the government service promoting irrigation development to take the necessary actions to create M&R services to promote farmer participation in the project.

One of the more problematic issues is the need for preventive maintenance. This is never obvious and might seem to the WUA to be a waste of money. The project authority must promote the idea to the WUA in all ways and at all times. Sound principles of preventive maintenance must be inculcated from the beginning and continuously promoted.

BHAIRAWA-LUMBINI PROJECT AND APPLICATION OF THE APPROACH

A few words of description of the Bhairawa-Lumbini Groundwater Irrigation Project (BLGWP) in Nepal and what is being done there is in order here. The consultants for the project, Tahal Consulting Engineers Ltd., are applying the above approach to the project.

BLGWP in the western region of Nepal has already installed 64 TWs in the Stage I area, all of which are already operational. Another 38 in the Stage II area are in the process of installation and will be operable shortly. During the coming years, 78 more TWs are planned for the development of an area denominated as Stage III. All TWs are operated by electric power. A typical TW in Stages I and II serves about 120 hectares (ha) consisting of about 80 families.

By the year 2000 a total of about 180 TWs will be operational. Over 14,000 families farming about 22,000 ha will be served by TWs in the area.

Stage I had no farmer participation component. It was designed and implemented in the traditional way with all decisions being taken by professionals employed by BLGWP. All investment costs and, until this year, all operation and M&R costs were covered by the project authority. Until now, M&R have been the responsibility of the BLGWP. At an advanced phase of Stage II, elements of farmer participation were introduced. Stage III will be based completely on farmer participation principles.

Analysis has shown that the costs of operation and of M&R can easily be borne by the farmers enjoying the benefits of irrigation. Both the plans and impact studies made in the field have shown that increased production which results from higher yields per crop, from greater intensity of land use and from a transfer to higher-value crops leaves the farmer with a sufficient cash income and surplus. Moreover, the farms are easily accessible, thanks to good roads developed in the framework of the irrigation project so that crops can be easily sold.

Calculations have shown that costs of operation and M&R would be roughly US\$50 per ha, of which US\$40 are for operation (electricity and pump operator) and US\$10 for M&R. These are average figures and considerable variation may be expected among the TW units. In practice, the charge for water which the WUA will levy from its members will not be divided by area but by actual consumption.

The M&R activities of the BLGWP are classified into the following categories:

- Routine preventive mechanical and electrical maintenance.
- Heavy preventive mechanical maintenance.
- Mechanical repair.
- Electrical repair.
- Pipeline distribution system and outlet repair.
- Civil maintenance and repair (buildings, structures, canals and access roads).

The latter two—pipeline distribution system and outlet repair, and civil maintenance and repair—require skills such as plumbing and masonry, which are generally available in the surrounding areas. Many farmers are themselves familiar with this type of work. Routine preventive maintenance (the first item above) is now included among the duties of the pump operator. Accordingly, less emphasis is placed on these subjects in the program to develop a private sector M&R support service. The program focuses primarily on mechanical and electrical M&R and sets out to create a source of such M&R services.

An activist approach to the development of an M&R support system has been adopted to stimulate the private sector in this field, as the capabilities will not develop unaided. The program includes providing information, offering training courses, and disseminating the knowledge and the lessons of experience and assistance in obtaining credit. The program includes training since many tradesmen show an interest in order to assure a sufficient supply and to provide for competition among them. Accreditation of workshops satisfying requirements for M&R will also be done. Handbooks on routine mechanical and electrical maintenance and on civil maintenance that can be handled directly by the WUAs or the pump operator will also be prepared.

While promoting the development of an M&R support system, it is recognized that many WUAs may not observe the prescribed procedures without the necessary coaching. Therefore, information on the importance of preventive maintenance and its benefits will be continuously disseminated to WUAs through an intensive program of meetings.

The project authority will undergo a role revision in the field of M&R. Its new role, in addition to promoting the creation of a private sector M&R service, will be to define maintenance activities and their frequency; to plan equipment, tool and spare parts requirements; to define training requirements; to prepare manuals and handbooks; to accredit workshops; to provide M&R services by means of contractors during an interim period and to supervise the quality of M&R carried out by contractors. It will cease to provide M&R services by means of its own employees.

PROBLEMS ENCOUNTERED AND FORESEEN

The fact that BLGWP has already been operating for about eight years under a different concept makes the change difficult. This is due to the discomfort that WUAs feel about taking responsibility and about having to cover M&R costs, to skepticism in the private sector about the change in approach and to internal professional interests against the new approach.

A transition period is planned as the change cannot be abrupt: in the absence of an existing private M&R support service, BLGWP is the only body capable of providing the necessary services at present.

Close monitoring of the process is planned. This is a new approach and corrective actions may be necessary and should be taken with minimum delay whenever problems surface.

CONCLUSION

The approach presented above has been developed in order to assure the long-run sustainability of the irrigation systems. It was adopted simultaneously with the adoption of the farmer participation approach and is still in the early stages of development and application. The approach is still being tested and the team is learning and improving on the approach as work progresses.

The basic concept of private sector M&R support services promises long-run sustainability of GW-based irrigation systems. Unfortunately, government-provided M&R services do not promise long-run sustainability and even in the short run they are often unsatisfactory.

For long-run sustainability, GW irrigation systems should not be dependent on government or NGO support, as ultimately such support is inevitably withdrawn. Active assistance in the development of a private M&R support system and abstention from establishing government-run M&R systems are the essentials of this approach.

As a corollary to the analysis in this paper, GW irrigation systems are unlikely to be sustainable in the following situations:

- In projects which do not offer a high cash return to farmers for their produce.
- In remote areas far from urban centers capable of providing the necessary M&R support.
- In a cluster of TWs not large enough to offer economic opportunities to the private sector.

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Utilization of Water under Different Deep Tubewell Management Systems in the Rajshahi Area of Bangladesh

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ABSTRACT

A STUDY WAS conducted in the deep tubewell (DTW) irrigation projects of Rajshahi. The DTWS were operated under four different management systems, i.e., Barind Integrated Area Development Project (BIADP) of Bangladesh Agriculture Development Corporation (BADC), BADC Rental Program, Rental-Rajshahi Krishi Unyan Bank (RAKUB), and private systems (owned by farmers).

In BIADP Project, informal groups are provided with deep tubewells and the groups are to pay irrigation charges based on estimated command area. Management responsibility lies with the farmer groups or the leaders of such groups but BADC retains enough control on the wells to ensure that irrigation charges are paid by the group.

The farmer groups pay BADC an annual rent of Taka (Tk) 5,000 (approximately US\$135.14) in the rental program. The groups are responsible for operation and maintenance costs. BADC retains some responsibilities for repair, but has little control over management aspects.

The government has been selling DTWs to farmer groups since 1973. The groups are responsible for all aspects of operation and management.

The rental program of BADC is supported by RAKUB for seasonal crop production credit requirements. Credit is provided for operation and maintenance (O&M) and other relevant services.

Rajshahi is a dry area of the country where temperature ranges from 5 to 46°C and total rainfall during the months of May to September is around 1,200 millimeters (mm). A negligible amount of rain occurs during the months of October to April. The soils range from clay to loam with seepage and percolation rates of 2.3 to 3.5 mm/day. The dominant cropping patterns of the area are boro-fallow-aman, wheat-aus-aman, and potato-aus-aman. Water distribution in each DTW is characterized by block rotation as well as by head-, middle- and tail-rotation systems. The designed discharge of each DTW was 56.6 liters per second (lps). But actual discharge varied from 26 to 51 lps. Discharge of all the wells were below the designed capacity. Full irrigation was applied for the boro season and supplementary irrigation was applied during the aman season.

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INTRODUCTION

Deep tubewell (DTW) irrigation is an important means for rice cultivation during the dry period in Bangladesh. There were about 25,000 DTWs in the field irrigating 610,000 ha of land which constituted 19.6 percent of the total irrigated area of the country. By the end of the Fourth Five-Year Plan (FFYP) there may be another 17,500 DTWs which may irrigate an additional area of 430,000 ha (Planning Commission 1990).

The Bangladesh Water Development Board (BWDB) started its irrigation program in 1964/1965. BADC joined the program in 1967/1968. Both BWDB and BADC are autonomous public agencies. Deep tubewells of BWDB are managed by the agency itself. But the BADC DTWs are operated under several ownership and management systems. Some are managed by BADC itself as in the case of the Barind Area Integrated Development Project (BIADP) and others are rented and privately owned by formal or informal farmer groups. The management systems of the study sites included the following:

BADC's Barind Integrated Area Development Project (BIADP)

In this program informal farmer groups are provided with wells and required to pay irrigation charges based on the estimated command area. BADC provides repair and maintenance services to a value of up to one-third of the charge. The farmer groups collect a fee from the irrigators to meet the costs of the BIADP charge, any further repairs, fuel and oil and the salaries or honoraria of the tubewell managers, operators and drainmen. Management responsibilities lie with the farmer groups or their leaders, but BADC retains enough control on the wells to ensure that irrigation charges are paid by the groups.

BADC Rental Program

BADC has a number of DTWs under its rental program. These wells were installed between 1967 and 1978 and were rented to farmer groups (both formal and informal). In the 1980s, BADC tried to sell the wells to the groups but this effort was mostly unsuccessful. As a result, the rental program continues. The farmer groups pay BADC an annual rent of Tk 5,000. The groups are responsible for operation and maintenance costs. BADC retains some repair responsibilities but has little control over well management. The tubewell managers collect fees to cover operation and management as well as the rental charges, but it is seldom that the rent is paid to BADC.

BADC Rental Program Supported by RAKUB

Under this program the DTW rental group receives O&M credit and other backup services from the bank. The bank helps in the management of funds and the collection of irrigation charges from the various irrigators. The RAKUB Program worked well up to 1990, but came to a standstill in 1991.

Private Ownership and Management

The Government has been selling DTWs at subsidized rates to farmer groups since 1979. The groups are responsible for all aspects of operation and management. Most of these farmer groups exist in name only with the wells being owned and run by one or a few individuals. Capital loans were taken to purchase the wells, but the level of loan repayment was very low, despite the fact

that the fees collected from the farmers were sufficient to pay the loan installments as well as O&M costs.

OBJECTIVES

- i) To identify major characteristics of the systems.
- ii) To examine the status of water utilization performance of the alternative systems under study.
- iii) To suggest measures of improving system performance.

RESEARCH SITES

The Bangladesh Rice Research Institute (BRRI) and the International Irrigation Management Institute (IIMI) research group selected a number of tubewells in the Rajshahi region under BIADP. These tubewells were Amtali-1 and -2, Sarengpur-1 and -2, Fazilpur-2, Ramnagar-2 and Sarmangla-1. Another six tubewells rented by BADC to farmer groups were also selected for the study. These tubewells were Mahabathpur-2, Buckshimal, Darshanpara, Shakua, Haridagachi and Dural-3. In three of these six wells the farmer groups were provided with production costs (including irrigation costs) by RAKUB. These tubewells are Shakua, Haridagachi and Dural-3. In the same area three additional wells owned by farmer group were also selected. These tubewells are Palasha, Moheskondi and Bakshail.

METHODOLOGY AND MEASUREMENTS

Relevant data/information for the study were collected from both primary and secondary sources including farmers, farmer leaders, agency officials, official records, studies and research reports and farmer group records. Methods included were participant observation, discussions with officials, farmers and farmer leaders, and maintenance of weekly records of DTW performance, etc.

The research project was initiated with the measurements of rainfall, seepage and percolation, evaporation, water adequacy and water distribution equity, and monitoring of discharge and duration. In addition to the above water management parameters, crop production aspects were researched through field trials and monitoring of farmer management practices, yield and input use.

Rainfall

In Barind and Mohanpur, rainfall was measured by True-Check rain gauges in the research site.

Irrigation Water Flow Measurement

Irrigation water flow was measured at deep tubewell discharge boxes to quantify the water available in each of the DTW areas. Measurement was made by the use of cutthroat flume, V-notches and pitot tubes.

Measurement of Conveyance Losses

Conveyance losses at tertiary, secondary and main canals of the DTWs were measured by the inflow-outflow method.

Evapotranspiration

Evaporation (EV) was measured from a United States Weather Bureau class A pan. In this study, potential evapotranspiration (ET) rate for rice was considered equal to the class A pan evaporation rate for the same day. Review of literature suggests that for rice, ET equals EV over the growing season more or less close to unity when water is not a limiting factor (Bhuiyan 1982; Kampen and Levine 1970; and Sevendsen 1983). Daily measured evaporation data were used to compute weekly and seasonal evapotranspiration values.

Seepage and Percolation

Seepage and percolation was measured by using the water subsidence technique (Giroan and Wickam 1976). In this method the water loss from a rice field takes place as evapotranspiration (ET), surface drainage (DR), and seepage and percolation (S&P). If no water is added to or drained from the field, then the total water used would be due to ET plus S&P and would be reflected by a corresponding subsidence or loss of head of water on the rice field surface. Assuming that daily evapotranspiration is computed from evaporation pan data and subtracted from this head loss fall in depth of water, the remainder of the daily fall in water level is equal to the S&P rate provided there is no surface water flow into or out of the rice field.

Water Use

Water used in the project area was either from irrigation sources or from rainfall. Water use status was evaluated in terms of, water used for land soaking and land preparation up to transplanting, seasonal water use and nonbeneficial water supplies prior to seedbed preparation.

Yield Assessment

Yields were assessed on the basis of crop cuts taken in each season in the 30 selected plots, one from each deep tubewell area. Crop-cut samples were taken in each season to estimate yields. For crop-cut samples, a five square meter (m^2) sample area was harvested from each plot taking $1 m^2$ harvests from five different locations of the plot. The harvest was threshed and the grain yield measured. Moisture content of the grain was determined by a moisture meter. Yield was adjusted to 14 percent moisture content and expressed in kilogram per hectare (kg/ha).

RESULTS AND DISCUSSION

Characteristics of System Management

For attaining the objectives of irrigation, all systems of management have to perform certain irrigation management tasks which have been categorized and listed by various authors in different ways. Uphoff (1986) identifies twelve irrigation management activities which he has grouped into three broad categories i.e., (i) organization and management activities, (ii) physical system activities, and (iii) water use activities. Svendsen and Small (1990) categorized the activities of an irrigation system into six (which they called) "primary irrigation processes," i.e., planning, designing, construction, operation of facilities, maintenance, and application of water to the land.

In this section of the paper, the main focus was on the identification of salient characteristics of the four DTW management systems under study, with reference to some of the management tasks identified by different authors as noted above. As background material, certain general attributes of the tubewell systems include the following:

Pump and Well Attributes

There was wide variation in the ages of the DTWs of the different management systems. The oldest DTWs belong to the rental and rental-RAKUB systems, their average age is 15 years. The most recently installed DTWs are privately owned. All of the sample DTWs of the latter category were commissioned in 1989. The BIADP DTWs are relatively new, their average age being 4.7 years. All the sample DTWs utilize turbine pumps, and are operated with diesel.

Command Areas

The majority of the DTWs were installed in suitable locations for achieving maximum command area. The topography with reference to the command areas of DTWs of rental and rental-RAKUB systems are sloped, while those of private DTWs are medium sloped, and those of BIADP DTWs are medium sloped and terraced. The canal networks of rental, rental-RAKUB and BIADP DTWs are simple in the sense that they have a few branch channels. In contrast, in the private DTWs, the canal network consists of a large number of main and subsidiary canals and channels.

Water Allocation

In Bangladesh, if a farmer has land under the command area of an irrigation system, he is entitled to get water from the system provided he pays irrigation fees and abides by the rules and norms decided by the system management in the common interest of the irrigators.

In case of DTW irrigation, a farmer's perceived entitlement to water is strongest if the DTW is rented and managed by a group of farmers of which he is a member, and the entitlement is weakest if the DTW is owned and managed by a few farmers not including himself. In a system when a DTW is owned by a public agency and managed jointly by a farmer group and a public agency, and where water is delivered on payment of a specified irrigation fee, a farmer's entitlement to water becomes strong but not as strong as in the case of a rental DTW managed by his own group.

Farmer Organizations for Managing the Systems

All sample DTWs except those under private management have farmer irrigation organizations. These organizations are informal in the sense that they are not registered groups or cooperatives.

All of the DTWs, however, have irrigation management committees consisting of nine-to-eleven members. When there are irrigation groups, the managing committees (MCs) of such groups automatically become the irrigation management committees (IMCs). One observation of the research team is that the irrigation groups in all management systems under study are defunct for all practical purposes. They seem to exist mainly on paper. The IMCs/MCs too, are not very active. Irrigation tasks are managed primarily by the manager of a group in collaboration with one or two other persons.

Water Distribution

Mostly, DTWs followed a rotational distribution of water under which system the management divided the entire command area into blocks. The number of blocks in the rental system ranged from 3 to 6, in the rental-RAKUB from 3 to 4, in private tubewells from 2 to 4, and in the BIADP System from 2 to 5. The blocks were divided in two ways: (i) in terms of head, middle and tail, and (ii) in terms of rotational sector.

Operation, Repair and Maintenance of DTWs

In each of the systems, DTW had an operator who is under the direct control and supervision of the manager. In the private system, repair and maintenance of DTWs is the responsibility of the tubewell owners. BADC, which is the supplier of DTWs, is under agreement to supply the services of mechanics up to five years from the date of sale of a DTW. In the rental, rental-RAKUB and BIADP systems, repair and maintenance responsibilities lie with the BADC which owns the DTWs. In rental and rental-RAKUB, the farmer groups are required to pay Tk 1,000 (approximately US\$27.03) per year for free supply of some spares. The groups included in the study did not pay this amount but decided to purchase their spares from local markets. In the BIADP System, the cost of spare parts in excess of one third of the fee paid by farmers to the BIADP authority, was borne by farmer groups.

Water Availability and Utilization

The designed discharge of each tubewell was 56.6 lps but actual discharge was less than the designed. Among Barind tubewells the maximum discharge of 51 lps was recorded at Amtoli-1 which was 8 percent less than the designed and the minimum of 28.3 lps at Sarengpur-2 which was 50 percent less than the designed discharge. In Mohanpur area the maximum discharge of 50.2 lps was recorded at Buckshimul which was 11 percent less than the designed, and the minimum of 26.6 lps at Mohabatpur-2 which was 53 percent less than the designed discharge (Table 9.1).

In terms of the area irrigated during *kharif*-1 season, in 1990, it was found that the private DTWs performed best followed by the rental DTWs. On the average, for each cusec discharge, a private tubewell irrigated 15 ha and a rental tubewell irrigated 13.23 ha (Table 9.1). The performance of rental with RAKUB DTW was 12.81 ha while the BIADP DTWs covered only 10.3 ha. The performance in 1991 followed the same trend as in 1990. Area per cusec discharge under private, rental and BIADP were 13.2, 10.3 and 8.1 ha, respectively. However, none of the systems was able to achieve a practicable command area.

Table 9.1. Designed and actual discharges, command areas, and irrigated areas of the selected tubewells (boro seasons 1990 and 1991).

Location	Designed discharge (lps)	Command area (ha)	Actual discharge (lps)		Irrigated area (ha)	
			1990	1991	1990	1991
<i>BIADP Rental DTW</i>						
Sharangpur-1	56.6	24.3	26.9	39.9	17.5	18.2
Sharangpur-2	34.0	18.2	28.0	28.3	10.7	8.9
Sharmongla-1	56.6	24.3	37.1	33.1	4.4	2.0
Fazilpur-2	56.6	24.3	34.0	45.6	14.8	9.7
Amtoli-1*	56.6	24.3	49.3	51.0	-	-
Amtoli-2**	51.0	21.9	28.0	33.0	6.8	-
Ramnagar-2	56.6	24.3	34.2	37.1	14.2	14.0
<i>IFAD DTW, Mohanpur</i>						
Shakua**	56.6	24.3	52.1	-	13.5	-
Haridagachi**	56.6	24.3	40.0	-	18.4	-
Durail-3	56.6	24.3	45.3	47.5	30.4	20.0
<i>Rental DTW, Mohanpur</i>						
Mohabathpur-2	56.6	24.3	53.2	48.1	23.6	20.9
Bakshimul	56.6	24.3	48.1	50.2	28.3	15.0
Darshanpara**	56.6	24.3	36.8	-	12.8	-
<i>Private DTW, Mohanpur</i>						
Palsa	56.6	24.3	49.3	45.5	27.1	22.3
Moheskondi	56.6	24.3	51.0	41.6	27.7	24.3
Bakshail	56.6	24.3	47.3	44.5	23.7	14.7

* There was no boro rice crop in 1990 and 1991.

** There was no boro rice crop in 1991.

Notes: DTW = Deep tubewell.

BIAD = Barind Integrated Area Development Project.

IFAD = International Fund for Agricultural Development.

Water Productivity

On the average, water productivity for private and rental with RAKUB were 7.63 and 5.73 kilogram per hectare-millimeter (kg/ha-mm), respectively. The performance of rental tubewells was 5.40 kg/ha-mm, while the BIADP tubewells had 5.10 kg/ha-mm (see Table 9.2). The performance in 1991 was not similar to 1990. Productivity of water in 1991 under private, rental and BIADP were 6.63, 6.6 and 4.2 kg/ha-mm, respectively (Table 9.3).

Table 9.2. Water availability and productivity of selected tubewells (boro season 1990).

Location	Actual discharge (lps)	Total operating hours	Water depth (mm)	Rainfall (mm)	Total water (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)
<i>BIADP Rental DTW</i>							
Sharangpur-1	26.9	977	540	171	711	5,000	7.0
Sharangpur-2	28.0	1,108	1,045	171	1,216	5,420	4.4
Sharmongla-1	37.1	300	890	171	1,061	5,230	4.9
Fazilpur-2	34.0	1,207	984	171	1,155	5,320	4.6
Amtoli-2	28.0	632	938	171	1,109	5,600	5.0
Ramnagar-2	34.2	1,133	989	171	1,160	5,425	4.7
<i>IFAD DTW, Mohanpur</i>							
Shakua	56.6	548	613	171	784	3,610	4.6
Haridagachi	56.6	790	617	171	788	3,606	4.6
Durail-3	56.6	750	402	171	573	4,590	8.0
<i>Rental DTW, Mohanpur</i>							
Mohabathpur-2	56.4	677	550	171	721	4,453	6.1
Bukshimul	56.6	877	537	171	708	3,000	4.2
Darshanpara	56.6	471	480	171	651	3,833	5.9
<i>Private DTW, Mohanpur</i>							
Palsa	56.6	690	451	171	622	5,566	8.9
Moheshkondi	56.6	599	397	171	568	5,233	9.2
Bakshail	56.6	590	546	171	717	3,446	4.8

Notes: DTW = Deep tubewell.

BIAD = Barind Integrated Area Development Project.

IFAD = International Fund for Agricultural Development.

Field-Level Water Use Efficiency

Water use efficiency was 92 percent for Barind tubewells and 76 percent for the Mohanpur area (Table 9.4). The soil type of Barind was silty clay and it was loamy in Mohanpur. A low water use efficiency which may be attributed to light soil type was observed in Mohanpur. Table 9.5 gives the seepage and percolation rates for the Barind and Mohanpur areas.

Crop Yield

Under irrigated conditions, farmers grew only rice during the kharif-1 season. Crop-cut yield records in 1990 show that yield was highest in BIADP DTWs (5.3 t/ha) followed by private DTWs (4.75 t/ha). The lowest yield was recorded in rental DTWs (3.76 t/ha). In 1991, farms under private DTWs got the highest yield (5.6 t/ha) followed by rental and BIADP farms (Tables 9.2 and 9.3).

Table 9.3. Water availability and productivity of selected tubewells (boro season 1991).

Location	Actual discharge (lps)	Total operating hours	Water depth (mm)	Rainfall (mm)	Total water (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)
<i>BIADP Rental DTW</i>							
Sharangpur-1	39.9	1,046	788	39	827	4,492	5.4
Sharangpur-2	28.3	748	809	39	848	4,250	5.0
Sharmongla-1	33.1	196	1,423	39	1,162	3,925	3.4
Fazilpur-2	45.6	881	1,427	39	1,466	4,777	3.3
Amtoli-1*	—	—	—	—	—	—	—
Amtoli-2*	—	—	—	—	—	—	—
Ramnagar-2	37.1	1,273	1,148	39	1,187	4,641	3.9
<i>IFAD DTW, Mohanpur</i>							
Shakua*	—	—	—	—	—	—	—
Haridagachi*	—	—	—	—	—	—	—
Durail-3	47.5	740	634	59	693	5,010	7.2
<i>Rental DTW, Mohanpur</i>							
Mohabathpur-2	26.6	735	571	59	630	4,527	7.2
Bukshimul	56.2	650	748	59	843	4,585	5.4
Darshanpara*	—	—	—	—	—	—	—
<i>Private DTW, Mohanpur</i>							
Palsa	31.13	706	579	59	638	5,911	9.3
Moheshkundi	41.60	695	663	59	722	5,704	7.9
Bakshail	30.33	512	639	59	698	5,097	7.3

* There was no boro crop.

Notes: DTW = Deep tubewell.

BIAD = Barind Integrated Area Development Project.

IFAD = International Fund for Agricultural Development.

Distribution of Water Among Farmers

It has been mentioned earlier that in 1990 almost all of the sample farmers received water reasonably on time and in sufficient quantity leaving no problems of distributional equity during that year. During 1991 however, in the rental DTWs, farmers of all categories stated that they did not receive water in time and in sufficient quantity.

Table 9.4. Field-level water use efficiency for rice growing period (boro season 1991).

DTW	Irrigated area (ha)	Water applied (mm)			Water required (mm)			Water use efficiency (%)
		IR	RF	Total	EV	S&P	Total	
Sharangpur-1 (Barind)	18.2	830	39	869	579	225	804	92
Moheskundi (Mohanpur, private)	24.3	650	59	709	274	262	536	76

Notes: IR = Irrigated.
 RF = Rain-fed.
 EV = Evaporation.
 S&P = Seepage and percolation.

Table 9.5. Seepage and percolation (S&P) rates (boro season 1991).

Month	Number of effective readings	Barind Area*	Number of effective readings	Mohanpur Area*
		Average S&P (mm/day)		Average S&P (mm/day)
March	115	2.40	125	3.60
April	130	2.30	140	3.55
May	150	2.20	170	3.45
Average		2.30		3.53

* Weighted by number of samples.

Note: S&P = Seepage and percolation.

Suggested Strategies for the Improvement of System Performance

- i) Discharge capacity of a DTW is limited and there is no scope for increasing it. Presently the DTWs are operated for 8 to 10 hours a day. Irrigated area per DTW can be easily increased by increasing daily operating time to 16 to 20 hours. An increase in operating hours will supply a greater volume of water for an additional area under each DTW.
- ii) Presently, the rotational system of water distribution is not practically followed; consequently a huge volume of water is misused resulting in poor area coverage. There

is no hard and fast rule for water distribution by any agency though it is a key factor in improving the area coverage. Rotational water distribution should be followed on the basis of blocks as well as water requirements of particular crops.

- iii) A diversified cropping plan should be adopted for maximizing the use of land and water resources while cropping schedules should be adjusted so that aman cultivation can take advantage of the maximum rainfall period.
- iv) The Bangladesh Rural Development Board and co-operative societies should come forward for the management of systems.
- v) The canal network should be properly designed for smooth distribution of water.

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Minor Irrigation Development: A Key for Sustainable Agricultural Development in Bangladesh

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ABSTRACT

IN BANGLADESH, OPTIMUM use of water resources and especially irrigation water should be an important strategy for increasing and sustaining increased agricultural production. Minor irrigation covered about 93 percent of total irrigated area in Bangladesh during the years 1989/1990 and according to government projections, would cover about 90 percent by the end of the Fourth Five-Year Plan, 1994/1995 (Ghani and Rana 1991). About 58 percent of total irrigated area during 1989/1990 was and 63 percent of the irrigated area in 1994/1995 will be covered by groundwater. Minor irrigation systems are almost entirely managed by the farmers/beneficiaries. Public intervention is only at the time of developing irrigation facilities (renting of low-lift pumps and installation of deep tubewells). Therefore, about 90 percent of the irrigation systems will continue to be farmer-managed irrigation systems in Bangladesh. But these facilities are operating at about 50 percent of their rated capacities. Improvement in the management and utilization levels of minor irrigation systems in the country, therefore, can cause significant improvements in overall irrigation performance. Studies in the Ganges-Kobadak (G-K), North Bangladesh Tubewell Project (NBTP), Kahalu area of Bogra and Rajshahi areas during 1989 and 1990 dry seasons indicate that water use values for rice cultivation are 0.32, 0.18, 0.96 and 0.39 hectare per liter per second (ha/lps) (or 3.13, 5.56, 1.04 and 2.56 lps/ha), respectively. Productivity of water are 3.6, 3.8 and 5.5 kilograms per hectare-millimeter (kg/ha-mm) for G-K, NBTP and Rajshahi areas, respectively.

In G-K and NBTP, irrigation systems are operated and maintained by government agencies, whereas, in Bogra and Rajshahi study areas operation and maintenance are done by the farmers. From the water use and productivity figures it can be concluded that farmer-managed systems are performing better. However, it has been observed that even these systems fall short of the desired levels. Performance of minor irrigation systems can be improved by adopting water management strategies such as improvements in reliability of water supply, provision of improved operation and maintenance, fixation of irrigation targets per unit of irrigation delivery and diversified cropping plans. These practices could lead to the accrual of additional benefits from the irrigation facilities.

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INTRODUCTION

Bangladesh is located in the lowlying delta of one of the largest river systems in the world and is subject to alternating annual periods of extreme excesses and deficits in rainfall, recurring floods and cyclonic storms. The major portion of the water resources are available during the monsoon months (mostly June to September) causing flooding over about 57 percent of the total area of the country (Planning Commission 1990). Over the 10.36 million hectares of rice land the flood regime stands as 36 percent under less than 0.3 meter (m) depth, 35 percent under 0.3 to 0.9 m depth and 2 percent under over 3.0 m water depth during the flooding season. (Bangladesh Agricultural Research Council and Ministry of Agriculture—BARC and MOA—1988). Therefore, 71 percent of the rice area or about 62 percent of the net cultivable area can be brought under year-round cultivation if irrigation facilities are developed. However, only about 30 percent of the cultivated land has access to some form of irrigation, whereas the irrigable area is about 84 percent and the irrigation potential of the country based on available water resources is about 76 percent (Master Plan Organization—MPO—1991). Due to skewed distribution of available water (river flow) and annual rainfall, only about 40 percent of the cultivable land (9.03 million ha) is cultivated during the winter months.

Water resources of Bangladesh exist in two forms, i.e., stream flow mostly coming from catchment areas outside of the country, rainfall and surface runoff from within the country, and groundwater. The country does not have much control over surface water and most of this flow (about 121 million ha-m) comes during June-September which causes flooding. Most of the streams remain dry or nearly dry during November to May, and therefore cannot be used as a reliable source of irrigation unless some form of augmentation facilities are created. Therefore, the most dependable irrigation source is groundwater extraction. About 58 percent of the total irrigated area during 1989/1990 was and 63 percent of the irrigated area in 1994/1995 will be covered by groundwater (Ghani and Rana 1992). Minor irrigation (irrigation using low lift pumps, deep and shallow tubewells, hand tubewells and doon and swing baskets) has been in the past and is expected to stay so in the near future as the driving force behind irrigated agriculture in Bangladesh. Improvements in management and capacity utilization of minor irrigation systems, therefore, will have a significant impact on the agricultural growth of the country. This paper will focus on different management types of irrigation systems in some selected areas of Bangladesh, their utilization levels, water productivity status and their impact on further improvement.

METHODOLOGY AND MEASUREMENTS

Studies were conducted in the Ganges-Kobadak (G-K) Project, North Bangladesh Tubewell Project (NBTP), Rajshahi area (within and outside Barind Integrated Area Development Project or BIADP) and Bogra area (Kahalu) to establish management type and status and water use status. Study sites and relevant measurements are briefly described as follows:

Ganges-Kobadak Project

The Ganges-Kobadak (G-K) Project is the first and still the largest irrigation project in Bangladesh. It pumps water from the Ganges River and distributes over the project area through gravity canal networks (main, secondary and tertiary canals and field channels). Pumping capacity is 153 cubic meters per second (m^3/s) and irrigable area is about 141,700 ha. Three secondaries, three tertiaries and fifty observation plots were selected to represent the head, middle and tail reaches

of main, secondary and tertiary canals, respectively. Studies in G-K area started in 1981 but only 1989 and 1990 data have been used in this paper to be compared with NBTP, Rajshahi and Bogra findings.

North Bangladesh Tubewell Project (NBTP)

Twelve deep tubewells were selected to study input use, management practices and improved allocation and equitable distribution of irrigation water and increasing irrigation efficiency, service area per unit volume of available water and for increasing production. This study was also initiated in 1981 but data of 1989 and 1990 will be used for this paper.

Deep Tubewells in Rajshahi Area

Sixteen deep tubewells were selected in Rajshahi area for water management-related studies. Out of 16 sample deep tubewells 7 were under BIADP management, 3 deep tubewells under each of IFAD, Rental and Private management categories.

Deep Tubewells in Bogra

Bogra is the most intensive tubewell irrigated area in Bangladesh. Ten deep tubewells were monitored for discharge, irrigated area and operating hours and fluctuation of water levels. All of these tubewells were installed by the Bangladesh Agricultural Development Corporation (BADC) but are managed and operated by farmers.

RESULTS AND DISCUSSIONS

Average water use status under different irrigation systems are presented in Table 10.1. Water use status in Bogra area is much higher than in other areas. G-K Project data have been presented to compare status of gravity irrigation with deep tubewell irrigation systems under different managements. Utilization status in terms of area coverage per unit discharge in Bogra is 3 to 5 times higher than that in Rajshahi and NBTP areas. In Rajshahi area tubewells are under government agency and private management whereas in NBTB all the sample tubewells are under government agency management (Bangladesh Water Development Board). It is clear from this table that agency-managed systems are irrigating a much lower area than their potential. One of the major reasons for low irrigation coverage may be low operating hours (Table 10.2) which is 6.12, 5.05 and 10.3 hours on an average for NBTP, Rajshahi and Bogra areas, respectively. The operating hours per day in the dry season should be higher (16 to 20 hours), for best utilization of the expensive equipment and for bringing more area under cultivation.

Table 10.1. Average water use status (ha/lps) in the selected locations in Bangladesh during the dry seasons of 1989 and 1990.

Sample location	G-K (ha/lps)	NBTP (ha/lps)	Rajshahi (ha/lps)	Bogra (ha/lps)
1	0.28	0.09	0.56	0.87
2	0.33	0.18	0.35	1.00
3	0.32	0.11	0.09	0.56
4	0.34	0.17	0.33	0.82
5	0.40	0.15	0.24	0.85
6	0.09	0.17	0.40	0.79
7	0.51	0.18	0.24	1.44
8	0.31	0.12	0.33	0.96
9		0.30	0.48	0.68
10		0.26	0.61	1.66
11		0.15	0.39	
12		0.33	0.22	
13			0.61	
14			0.54	
15			0.45	
Average	0.32	0.18	0.39	0.96

Notes: G-K = Ganges Kobadak Project.
NBTP = North Bangladesh Tubewell Project.

Productivity aspect of the irrigation water was analyzed and for G-K, NBTP and Rajshahi areas, and on an average, the corresponding values are 3.6, 3.8 and 5.5 kg/ha-mm, respectively (Table 10.3). It is also revealed from Table 10.3 that water productivity is higher under privately managed tubewells than under agency-managed irrigation systems. In the real sense, irrigation systems in Bangladesh are either partially or fully managed by the farmers/beneficiaries. In agency-managed minor irrigation systems only the equipment is managed by the agency personnel whereas distribution and management of irrigation water and the cropping plan are entirely in the hands of the farmers. Government Agricultural Extension Department offers some limited advisory service to the farmers. In large lift-cum-gravity irrigation systems, operation and maintenance of the main systems and water distribution up to tertiary level are managed by agency personnel and distribution and utilization of water at farm level are managed by the farmers.

Irrigation coverage, operating hours and water productivity figures in the study areas reveal that there is potential for improvement. However, planning at the project and national levels do not show any signs of improvement. It can be observed from Table 10.4 that the major contribution to the increase in the total irrigated area will be through minor irrigation.

Table 10.2. Average daily operating hours of the deep tubewells in NBTP, Rajshahi and Bogra areas in Bangladesh during the dry season of 1989 and 1990.

Location	NBTP (hours)	Rajshahi (hours)	Bogra (hours)
1	4.2	6.5	9.0
2	5.0	7.4	12.6
3	5.0	2.0	9.1
4	4.6	8.0	16.5
5	10.2	4.2	4.8
6	8.3	7.6	10.4
7	6.8	3.7	11.8
8	5.8	5.3	10.3
9	5.8	5.0	8.0
10	7.3	4.5	10.4
11	2.9	5.8	
12	8.1	3.1	
13		4.6	
14		4.0	
15		4.0	
Average	6.12	5.5	10.3

Table 10.3. Productivity of water in selected sites in Bangladesh during the dry season of 1989 and 1990.

Location	G-K (kg/ha-mm)	NBTP (kg/ha-mm)	Rajshahi (kg/ha-mm)
1	2.95	3.95	3.4
2	3.01	3.76	3.5
3	3.44	3.93	5.8
4	3.15	4.13	4.4
5	3.25	4.07	3.1
6	3.75	3.79	4.3
7	4.85	3.70	6.9
8	4.78	3.84	6.9
9	3.22	3.60	3.8
10		3.80	7.5
11		3.53	5.1
12		3.13	5.5
13			4.9
14			5.4
15			4.9
Average	3.60	3.77	5.5

Notes: G-K = Ganges Kobadak Project.
NBTP = North Bangladesh Tubewell Project.

Table 10.4. Irrigation achievement and target of irrigation coverage under different systems in Bangladesh (in percent, and total in thousand hectares).

Program	1972/1973	1977/1978	1979/1980	1984/1985	1989/1990	1994/1995
Gravity (%)	5	6	6	8	7	10
LLP (%)	45	48	41	29	25	23
Trad. (%)	43	32	29	14	10	4
DTW (%)	6	12	17	17	16	15
STW (%)	1	1	6	31	40	47
HTW (%)	—	1	1	1	2	1
Total (%)	936	1,133	1,413	2,484	3,090	4,790
increase over 1972/1973 (%)	—	21	51	165	230	412
HYV rice coverage (%)	—	—	—	27	38	46

Source: Third Five-Year Plan and Fourth Five-Year Plan (draft).

Notes: LLP = Low lift pumps. DTW = Deep tubewells.
STW = Shallow tubewells. HTW = Hand tubewells.
Trad. = Traditional methods like doon, swing basket, etc.

Percent increase in total irrigated area during 1994/1995 as compared to 1972/1973 is projected to 412 percent (total irrigated area would thus be 4.8 million hectare). Shallow tubewells will cover the maximum (47 percent) irrigated area during 1994/1995. Most of the increase in total irrigation coverage will be through increased number of irrigation units (Table 10.5). It can be observed from Table 10.5 that percentage increase in number of irrigation equipments during 1994/1995 over 1977/1978 would be 104, 370, 3,859 and 650 percent for LLP, DTW, STW and HTW, respectively. That shows a significant increase in numbers. However, irrigation coverage per unit of these irrigation modes over the period indicates practically no change in per unit irrigation coverage under LLP and DTW during 1977/1995, and in shallow tubewells during 1984/1995 (Table 10.6). These observations point to the fact that the irrigation development strategy of Bangladesh is still based on the creation of new facilities rather than improving performance of the existing and newly created facilities.

Table 10.5. Irrigation development status under different programs (number of irrigation units) in Bangladesh.

Program	1984/1985 (%)	1989/1990 (%)	1994/1995 (%)
LLP	31	63	104
DTW	128	303	370
STW	1,119	1,484	3,859
HTW	400	650	650

Source: Third Five-Year Plan and the Fourth Five-Year Plan (draft).

Notes: LLP = Low lift pumps. DTW = Deep tubewells.
STW = Shallow tubewells. HTW = Hand tubewells.

Table 10.6. Irrigation coverage per unit of irrigation mode in Bangladesh during the study period.

Program	1977/1978 (ha)	1984/1985 (ha)	1989/1990 (ha)	1994/1995 (ha)
LLP	14.9	15.0	13.0	14.5
DTW	18.2	24.3	16.7	20.0
STW	0.8	5.0	6.3	4.5

Source: Third Five-Year Plan and Fourth Five-Year Plan (draft).

Notes: LLP = Low lift pumps. DTW = Deep tubewells.

STW = Shallow tubewells.

CONCLUSION

Irrigation facilities in Bangladesh are highly under-utilized. Irrigation coverage per unit discharge is low. Even during the dry season, facilities are operated for a less number of hours which can easily be doubled. Present operating hours of deep tubewells vary from about 5 to 10 hours per day which could readily be increased to 16-20 hours per day. Water productivity and yield levels are also low, and could be increased with locally available technology. Efforts should be made to irrigate entire flood-free areas and target cropping intensity for these areas should be about 300 percent. A production target of 10 tons/ha grain should be fixed for flood-free irrigated areas for justifying investments in irrigation and for making the country self-sufficient in food production.

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Case Study of Management of Three Deep Tubewells in Tangail, Bangladesh

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ABSTRACT

THE OPERATION OF irrigation systems on three deep tubewells in Tangail District, Bangladesh, was monitored from 1989 to 1991. These systems used buried cement concrete pipe to distribute water from the tubewells, to irrigate diversified crops during the dry season.

This paper focuses on the management of the deep tubewells and the irrigation systems. Each tubewell was installed by the government agency (the Bangladesh Agricultural Development Corporation or BADC) following application from a cooperative of villagers (*Krishak Samabay Samity or KSS*), that took out a loan to purchase the tubewell. In principle the KSS owned and managed the tubewell, but in practice it was dominated by a few prominent individuals.

The paper describes the membership of KSS on each tubewell, their participation in the management of the system, the management structure and KSS meetings. It also describes the financial arrangements made for operating the tubewell. Budgets were prepared each season, but not followed. Varying records of loan repayments of the three KSSs are also discussed.

The utilization rates of all the tubewells were disappointing, averaging 3.88 hours per day at a discharge of about 35 lps compared to the design of 56 lps. The irrigated areas were typically less than half the design (40 ha), and irrigation intervals were high. The reasons for this poor performance were found to be a combination of social, managerial and agro-economic factors, and these are discussed in the paper.

The management and operation procedures are compared with the recommendations of the Irrigation Management Programme (IMP) and possible improvements are discussed. These include moving to systematic irrigation of fields fed by the same branch, instead of the current erratic distribution of water under the farmers' fuel system.

This case study illustrates some of the difficulties of Farmer-Managed Irrigation Systems (FMIS) where farmers' resources are unevenly distributed, particularly in the complex technical and management environment of deep tubewell irrigation.

The study was undertaken as part of a UK/Bangladesh research project on buried pipe distribution systems for surface irrigation which was funded by the Overseas Development Administration, UK.

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INTRODUCTION

In Bangladesh, irrigation water is mostly distributed by earthen open channel systems. However, in areas with undulating topography and light textured soils, earthen open channel systems are found to be inconvenient and inappropriate both technically and economically. Under this situation a buried pipe distribution system (BPDS) was considered to be a better solution. BPDS was introduced in Bangladesh about a decade ago. Since then, a number of buried pipe (BP) systems, mostly cement concrete (CC) pipelines, have been installed by several organizations.

Tangail Agricultural Development Project (TADP) is one of the few organizations which has been constructing BP systems for the Krishak Samabay Samitis (KSSS) which are farmers' cooperatives. TADP with assistance from the German Agency for Technical Cooperation (GTZ) has been working in the eastern part of Tangail District for promoting irrigated agriculture using deep tubewell (DTW) with BPDS. To date it has constructed a total of 79 BP systems, both full and partial. Most of these schemes have been encountering leakage, as well as operational and management problems. Unfortunately, no dependable studies so far have been made to evaluate the system performance and put forward recommendations for further improvement. Under the circumstances, this case study was carried out on three BP schemes installed by TADP at Taltoplapara, East Kutubpur and Shaplapara during 1989 and 1991. This study was undertaken jointly by the Bangladesh Agricultural Research Institute (BARI) and the Loughborough University of Technology (LUT), UK, with funding from both LUT and the Overseas Development Administration (ODA), UK. The overall objective of the study was to carry out a detailed case study of constructional, operational and management experiences of irrigated agriculture with BPDS. The specific objectives were to study (i) the technology of BPDS, (ii) the water management and agronomic practices under BPDS, and (iii) the operational and management aspects.

This paper contains the study results mostly related to the third objective and a part of the second objective.

METHODOLOGY

The study area falls under Madhupur Tract which has silty clay loam soil, undulating topography, annual rainfall of about 2,100 mm, mean monthly temperature of 11 to 39°C and relative humidity of 49 to 88 percent. November to April is the water deficit period. Diversified crops were grown, mainly rice (transplanted aus, aman and boro), wheat, water melon, soybean and banana; and the cropping intensity of the area was 233 percent.

Discharge from the DTW and at the outlets were measured using cutthroat flumes and 90° V-notch. Operational procedures were observed in the field and relevant data were obtained from the pump log books and the block registers. Data recordings in the log book and the register were routinely checked by the project staff. Data related to socioeconomic and management aspects were collected partly by interviews, partly by checking the scheme records and partly by direct field observations. Additional information was collected from TADP reports to supplement the project data.

RESULTS AND DISCUSSION

Water Users, KSS Membership and Management

The three schemes had an average of 62 water users (Table 11.1) of whom 68 percent were KSS members who were irrigators. Another survey of TADP (Mayer 1991) on 40 schemes showed an average of 59 water users per scheme of whom 60 percent were KSS members.

Each KSS possesses a six-member management/standing committee, first formed at the time of registration and then elected, for the overall management of the schemes. But in practice, the president and the manager act as the chief executives. Table 11.1 shows that on the average only 40 percent of desired weekly meetings were held with poor attendance of the water users. The main issues discussed were the seasonal budget, loan situation, fixation of irrigation charges, oil charges, driver's salary, etc. In most (50 to 80 percent) cases, the manager was the chief decision maker.

Table 11.1. Information on KSS management.

Parameters	Schemes		
	Taltolapara	East Kutubpur	Shaplapara
1. Water users	42	44	42
a) KSS members (during study)			
b) non-KSS members	19	19	20
2. KSS meeting			
a) desired number	20	20	20
b) held: i) number	10	8	6
ii) percent	50	40	30
3. Members present per meeting (%)	15-20	10-56	29-56

Note: KSS = Krishak Samabay Samity.

Ownership of Deep Tubewell

Each deep tubewell was sunk by the Bangladesh Agricultural Development Corporation (BADC), a government agency, following the application from a KSS after downpayment, which was made out of cash or loan to buy the tubewell. The BPDS was installed by the TADP and handed over to the KSS at subsidized cost to be paid in instalments. In principle, the KSS owned and managed the tubewell and the BP system, but in practice, it was dominated by a few prominent individuals.

Water Charges

All the three KSSs practiced "own fuel" system. Therefore, water charges included oil cost, repair and maintenance, staff salary and instalment of DTW and BPDS. Usually, this total cost was distributed over the total irrigated area and water rate was charged as Taka (Tk) per decimal (Table

11.2). There were many defaulters in water charge payments. Maximum water charge (85 percent) was collected at East Kutubpur, Bangladesh Rural Development Board (BRDB), with the help of the police. Police actions made the farmers anxious about the loan payments and some of them repaid them by selling out lands, which could have serious social consequences. The main reasons for not paying the water charges in time were the lack of responsibility and sincerity toward the KSS, lack of coherence in the group, factional problems, crop failure and, in the case of some farmers, financial inability to make payments.

Table 11.2. Information on financial aspects.

Parameters	Schemes		
	Taltolapara	East Kutubpur	Shaplapara
1. Water charge			
a) system	Cash payment	Cash payment	Cash payment
b) rate (Tk/decimal)			
i) rice	2	5.50	4
ii) nonrice	1	1.75	2 and 1
c) collection (%)	70	85	64
2. DTW loan			
a) amount due (Tk)	1,43,640.00	1,84,680.00	1,43,640.00
b) amount paid			
i) Tk	92,512.00	89,819.00	68,210.00
ii) percent	64	48	47
3. BP loan			
a) amount due (Tk)	31,552.80	27,700.00	26,190.00
b) amount paid (Tk)	0.00	0.00	0.00

Note: Tk 1.00 = US\$38.8 in 1992.

A survey by TADP (Mayer 1991) on 40 schemes indicated that 23 percent of KSS farmers practiced the cash payment system, 17 percent the sharecropping system and the remaining KSSs were using sharecropping for certain crops and cash payment for other crops.

Loan Situation

Table 11.2 shows that none of the schemes recovered their due loans completely. The reason for nonpayment of loans was either because the farmers did not pay water charges in time or because the money collected was used in personal business of the manager, or both. The government policy of exempting agricultural loans up to Tk 5,000.00 was another reason for the nonpayment of loans (Rashid et al. 1992). Table 11.2 also shows that no payment was made against the buried pipe loan by any of the schemes. Whenever an instalment was due, the management raised the question of repairing the leaks of buried pipes and avoided payment.

Pump Operation and Water Distribution

Very low pump operation was observed (12 percent of advised) and 3 to 4 outlets were used each day. The main reasons for this low utilization were the poor management, own fuel system, high fuel cost, smaller command area and non/under-irrigated diversified cropping (as it was not obligatory to grow irrigated crops within the command area).

The very limited number of outlets (about 20-21) of two cusec capacity was found inadequate for the prevailing field situation. This resulted in long earthen field channels and caused higher conveyance losses (Rashid et al. 1990). The condition of most of the field channels were poor. Generally, they were undersized, uncompacted, irregular in shape and had very low banks. About half of the channels were constructed during the irrigation period on a very temporary basis. Overflow of irrigation water above the banks was a regular feature. Yet under own fuel system it was difficult to divide the flow between the farmers. No maintenance work was observed during the study. One cusec outlet operating two at a time should have been more appropriate.

Because of own fuel system water was supplied to farmers according to the sequence of arrival at the pump house. This led to frequent switching between pipelines and resulted in unnecessary losses of water by repeated filling of the pipelines. This problem can be solved following the line rotation. Farmers are to be grouped outletwise, i.e., water supply to the farmers under an outlet should be completed and then moved to the next outlet. Under own fuel system, different grade fuels were used which created trouble for the engine. Switching over to project fuel system may be beneficial.

Pump and Outlet Discharge

Tubewell discharges of the schemes were found to be in the range of 29 to 39 lps compared to the design discharge of 56 lps and that of outlet was found in the range of 27 to 31 lps (Table 11.3). These variations were due to own fuel system, low channel capacity and change in the depth to static water level.

Average conveyance loss in the pipeline was found to be 0.37 lps/100 m by tank test and 0.57 lps/100 m by inflow-outflow method, and the rates for the earthen channel were found to be 7.56 lps/100 m by inflow-outflow method. Conveyance losses on eight schemes in Tangail District were reported to be 0.33 lps/100 m by tank test and 0.69 lps/100 m by inflow-outflow method in the pipelines and the measurement was 7.69 lps/100 m by inflow-outflow method in the earthen channel (Rashid et al. 1992).

Irrigation Practices

No scientific or recommended irrigation scheduling was followed and the large variation in irrigation intervals was noticed. In general, the practiced irrigation interval was longer than the recommendation for most of the crops. The reasons for the large interval were the use of own fuel system, high fuel cost, waiting for rainfall, the low collection of oil charge and the shortage of operating funds. Water adequacy (supply/demand) was determined for boro rice and was found to be less than 1 (Table 11.3) which meant under-irrigation. Area under irrigation by farm category is shown in Table 11.4.

Repair and Servicing

Pump servicing and pipeline repairing costs are shown in Table 11.3. None of the schemes practiced preventive maintenance and breakdown repairing was observed everywhere, as a result

pumps were performing poorly (usually running at lower speed and discharging less). All schemes experienced leakages in the pipelines. Too many leakages at East Kutubpur (41.02 leaks/100 m length of pipeline) were due to bad quality pipes (hand made) as well as due to bell-mouth sockets and spigot joints used in this scheme.

Table 11.3. Pump operational information.

Parameters	Scheme			
	Taltolapara	East Kutubpur	Shaplapara	Remarks
1. Pump operation				advised
a) hours/day	4.49	2.22	4.92	20
b) days/month	18	16	17	26
2. Discharge (lps)				designed
a) pump	31	39	29	56
b) outlet	27	31	27	-
3. Conveyance loss (lps/100m)				
a) pipeline				
i) tank test	0.50	0.29	0.33	
ii) inflow-outflow	0.58	0.68	0.45	
b) earth channel				
i) inflow-outflow	8.56	6.82	7.30	
4. Leakage repaired (number)				
a) pipe body	28	184	10	
b) joint	145	541	34	
c) total	173	725	44	
d) per 100 m	7.9	41.02	2.37	
5. BP repairing cost (Tk/year)	1,450	9,000	650	
6. Pump servicing cost (Tk/year)	800	10,250	4,600	
7. Water adequacy (supply/demand)	0.93	0.95	0.89	

Note: Tk 1.00 = US\$38.8 in 1992.

TADP's survey (Mayer 1991) on 40 schemes reported that only 48 percent of the DTWs were serviced during *rabi* season; in all cases lubricating oil was changed (average 3.8 times); fuel filters were changed in 72 percent of the cases, 60 percent of the DTWs had at least one breakdown during 9 days on average; 37 percent of the repairs were carried out by BADC, 27 percent by TADP (on-the-job training program), 26 percent by KSSs themselves (local mechanics, pump

operators, etc.), and the rest of the 10 percent by Upazilla Central Cooperative Association (UCCA) mechanics.

Table 11.4. Area under irrigation by farm category.

Farm category	Cultivated land per farm (ha)				Total
	High land	Medium-high land	High land	Medium-high land	
Landless	0.05 (80)	0.01 (20)	—	—	0.06 (100)
Marginal	0.19 (63)	0.07 (21)	0.02 (7)	0.03 (9)	0.31 (100)
Small	0.25 (41)	0.12 (20)	0.18 (30)	0.05 (9)	0.60 (100)
Medium	0.76 (59)	0.17 (13)	0.11 (9)	0.24 (19)	1.28 (100)
Large	1.12 (34.5)	0.15 (4.5)	0.58 (17.5)	1.42 (43.5)	3.27 (100)
All farm	0.47 (43)	0.10 (9)	0.18 (16)	0.35 (32)	1.10 (100)

Note: Figures in parentheses indicate the percentage.

Command Area

The irrigated command area varied considerably from year to year in the range of 9 to 29 ha compared to that on intended command area of 40 ha. In general, this does not appear to be a shortcoming in the BP system, rather this was because of poor management and inadequate extension services. The reasons for low command areas were the poor KSS management, own fuel system, non-rotational water distribution, lack of leadership in the KSS, reluctance of large farmers to cultivate all their lands and farmers' preference of other businesses to agriculture.

Land Utilization and Land Ownership Patterns

Different uses of land under the three schemes in the rabi season of 1989/1990 are shown in Table 11.5. Figure 11.1 shows the land ownership pattern and acreage owned by the different classes of farmers as indicated by TADP from their survey of 40 schemes.

Cropping Pattern and Crop Diversification

Diversified cropping pattern of the area constituted mainly of rice, wheat, water melon, soybean and banana and the cropping intensity was as high as 233 percent. Under these three schemes wheat was the major crop followed by boro rice during the rabi season. However, a different

picture is shown by a TADP report (Mayer 1991) on 40 schemes in the area (see Figure 11.2). Table 11.6 shows the crop diversification in the areas.

Table 11.5. Land utilization pattern under three schemes in the rabi season, 1989/1990.

Parameters	Scheme		
	Taltolapara	East Kutubpur	Shaplapara
1. Irrigated cultivation			
a) Total (ha)	18.87	9.25	20.66
b) Percent	43.43	22.25	49.70
2. Non-irrigated cultivation			
a) Total (ha)	1.97	2.54	2.12
b) Percent	4.54	6.10	5.12
3. Area available for cultivation			
a) Total (ha)	5.33	3.90	4.39
b) Percent	12.25	9.39	10.58
4. Orchard			
a) Total (ha)	0.25	0.08	0.25
b) Percent	0.57	0.20	0.60
5. Forest			
a) Total (ha)	0.70	1.89	1.99
b) Percent	1.61	4.55	4.78
6. Pond			
a) Total (ha)	0.18	—	0.14
b) Percent	0.42	—	0.33
7. Fallow			
a) Total (ha)	16.60	23.90	12.01
b) Percent	37.18	57.51	28.89
8. Total land under scheme			
a) Total (ha)	43.46	41.56	41.56
b) Percent	100	100	100

Note: Area unavailable for cultivation includes mosque, homestead, bazaar, etc.

Use of Inputs

TADP survey on 40 schemes revealed that 64 percent of the farmers used fertilizer and pesticides, 35 percent fertilizer only, and 3 percent pesticides only; 76 percent of the crops grown were HYV (rice mainly); 6 percent of the farmers used tractors for plowing; and 7 percent applied improved in-field irrigation techniques (mainly field preparation for vegetables).

Figure 11.1. Land ownership pattern by different classes of farmers in TADP areas.

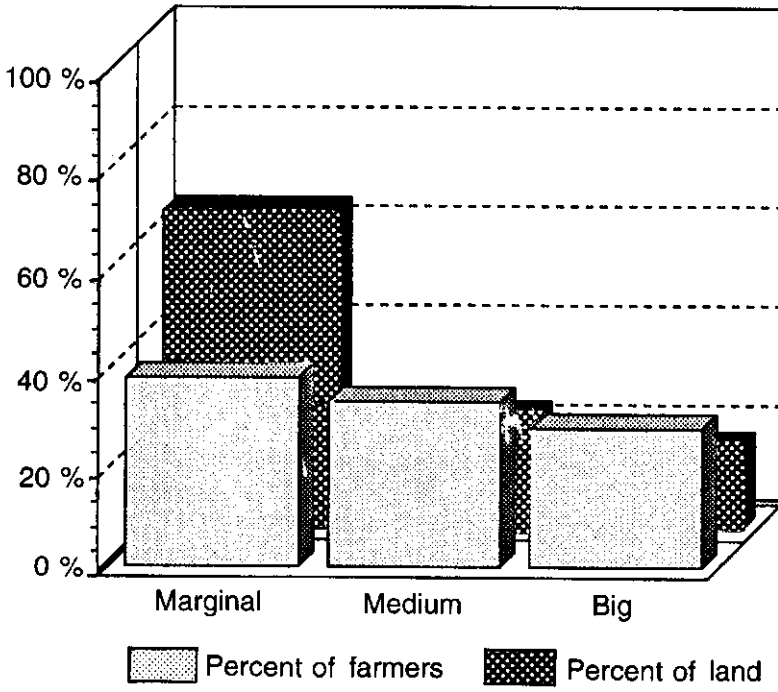


Figure 11.2. Crop diversification in TADP areas.

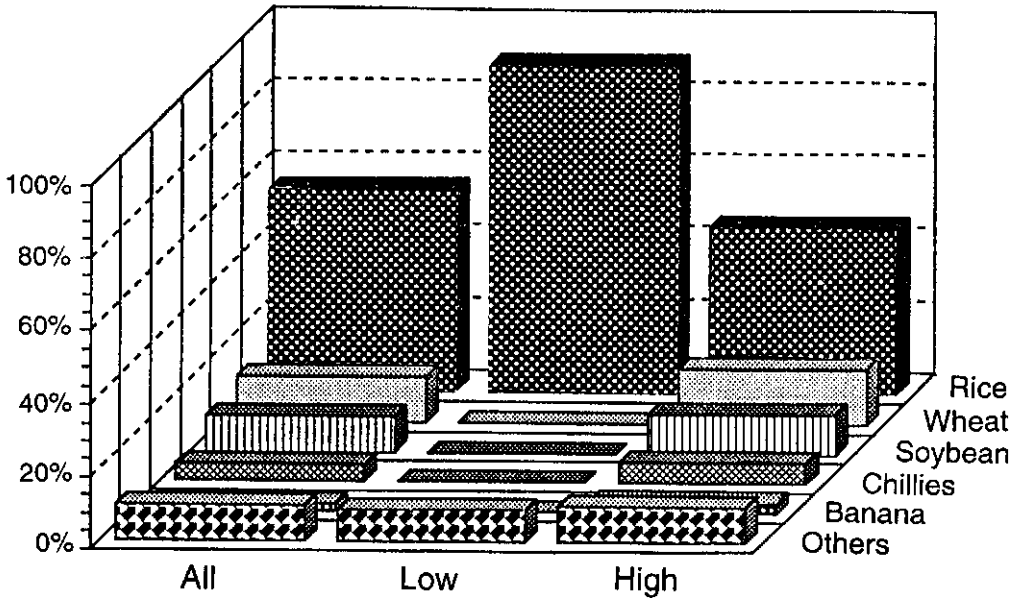


Table 11.6. Crop diversification.

Number of different crops	Command area (%)		
	All	Low land	High land
0	4	0	6
1	23	80	14
5	23	20	23
10	40	0	46
12	10	0	11

Extension Services

Extension services were inadequate. Out of the government departments and the donor agencies, only TADP was found active in the project areas. For the improvement of the schemes effective extension services (both in agronomic and in water management aspects) and effective scheme management were judged to be essential.

CONCLUSION AND RECOMMENDATIONS

The study area contained varied topography and dispersed housing. Under the situation, BP systems were found to be effective for distributing irrigation water over the command area.

The average irrigated area was only about half of the intended command area. The inefficient management system and inadequate extension services were the reasons for this low irrigated area but not the shortcomings of the technology. Extremely low pump operation (3.88 hours/day and 17 days/month) and too many fallow lands (about 40%) were observed. To improve the economic performance of the BP systems, these constraints need to be overcome.

Two cusec outlets and their limited numbers (20-21) were found inadequate under the prevailing operational and field situation. One cusec outlet, one for each 2 to 3 acres (1 acre = 0.40 ha), and operating two at a time would be more appropriate.

Instead of own fuel system, project supply fuel and line rotational water distribution system can enhance engine life, reduce conveyance losses and increase pump operation and hence command area. Routine preventive maintenance should be practiced.

Effective extension services, both in agronomic and in water management aspects, are most essential to make the buried pipe schemes more attractive and profitable.

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Experience of Community-Managed Tubewells in the Command of a Surface Irrigation Project

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ABSTRACT

THE FARMERS OF an area situated in the tail end of a branch canal offtaking from the lower-middle reaches of the eastern main canal of Gandak Project, which was planned to provide surface irrigation to the western part of North Bihar, took an assertive initiative of rejecting the planned extension of canal irrigation on account of its doubtful benefits and definite damages to their area. Instead, they took the positive action of providing themselves with groundwater irrigation. They formed a registered society, named as Vaishali Area Small Farmers Association (VASFA) in 1971 charged with the responsibility of installation, operation and maintenance, and management of tubewells, the number of which grew to 36 during the course of a decade since the inception of VASFA. An experience of about two decades of the functioning of VASFA and the performance of the irrigation system provided by it indicate that VASFA was eminently successful in achieving its purpose and objective. Non-expansion of VASFA's irrigation membership, the stagnation of the number of tubewells under its management and other developments in the area indicate that the experiment of VASFA in its original form and activities is not replicable for other areas, primarily due to the change in the techno-economic context. However, the basic lessons of VASFA, i.e., adoption of an irrigation strategy appropriate to the agro-hydro-ecological regime of the area, farmers' control and management of irrigation and community initiative and action in the face of inaction or misaction of the government are universally relevant for development of sustainable and productive irrigation in North Bihar and other areas having similar socio-economic and agrohydrological conditions.

INTRODUCTION

Nature has endowed North Bihar with extremely favorable resource factors for high agricultural production: fertile tracts of land capable of supporting multiple crops, congenial agroclimate providing an year-round growing season, ample water to satisfy all crop water requirements, sufficient manpower with skill and a longstanding tradition of agriculture. High and increasing

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population pressure on the inelastic land resources of the region and consequent encroachments in the flood plains of the rivers have led to inadvertently made interferences into the region's agroecological regime. Hence, the soil-water balance for productive agriculture has progressively deteriorated, resulting in decreasing agricultural productivity and production. Agriculture being the dominant economic activity of the region and the mainstay for the living of more than 80 percent of its people, this has led to increasing impoverishment of the teeming millions inhabiting the region, which in the past centuries was the center of prosperity in the Indian subcontinent.

It has been widely accepted that in order to realize the high agro-potential of the region, its agriculture has to be freed from the vagaries of an erratic monsoon and the soil water balance has to be effectively and sustainably restored and maintained. It was in this context that the essential role of irrigation for this humid alluvial plain was keenly perceived. Thus, two major irrigation projects, Kosi and Gandak, were implemented in the sixties and early seventies to provide irrigation to approximately 1,050,000 and 1,350,000 hectares (ha) of gross command area in the eastern part and the western part, respectively, of North Bihar.

More than two decades of experience in irrigation through these two projects have clearly brought forth a disquieting feature about their performance. While these projects, which are essentially state administered surface irrigation systems, have not achieved the envisaged outcome of increased production from irrigated agriculture, they have given rise to some adverse and counter-productive features in certain parts of their command areas. However, the initiatives and actions taken by the farmers, who were exposed to the benefits of irrigation but suffered from the inadequacy, unreliability and ill-effects of the state administered surface irrigation systems, have not only improved the performance of irrigated agriculture but also saved the systems from apathy and rejection by the adversely or indifferently affected intended beneficiaries. This paper deals with one such case study located in the command of the Eastern Gandak Canal.

ORIGIN AND GROWTH OF A FARMER ORGANIZATION

Some farmers of an area situated in the tail ends of Vaishali Branch Canal, taking off at 558 Reduced Distance (RD) of Tirhut Main Canal (TMC), decided to organize themselves primarily in order to provide themselves with irrigation facilities. Several factors were at work to motivate the farmers toward this decision.

First, this area was inhabited preponderantly by small and marginal farmers who were incapable, financially and otherwise, of taking individual and independent actions in this matter. Second, the dreadful experience of drought which occurred twice with considerable severity in the middle- and late-sixties in most parts of the Bihar plains, including this area, and which woefully deprived them of the base of their subsistence by badly affecting agriculture, had brought forth the stark realization of the hazards of rain-fed agriculture, and consequently, of the imperativeness of protective coverage of their sole means of livelihood by irrigation. Third, programs launched under various government sponsored or government supported schemes to help agriculture in general, and to promote installation of tubewells for irrigation in particular, such as under the Freedom from Hunger Campaign, prompted the farmers to organize themselves in order to derive maximum advantage from them. And last, was the provision of inspiring leadership by a social organizer, Mr. K. D. Diwan, who acted as a catalyst with zeal and dedication in the extant situation. A registered society in the name of Vaishali Area Small Farmers Association (VASFA) was formed in 1971, the membership of which was open to small and marginal farmers of that area.

The dominant aim and activity of VASFA were installation, operation and maintenance, and management of tubewells for providing irrigation benefits, primarily, to its members and,

secondarily, to even its nonmembers. The fact that this area was imminently going to be covered by canal irrigation under the Gandak Project was no solace to the farmers of this area. Being situated in the tail end of a branch canal off-taking from the lower-middle reaches of a long main canal, the farmers knew of the uncertain benefits due to inadequacy or unreliability to which the supplies to their area will be necessarily subject, as well as of the unwelcome cost of waterlogging and loss of valuable lands which the construction and operation of canals would entail. In fact, they perceived the proposed extension of the distribution system of canal irrigation to their area as a potential threat, and one of the first things they did after formation of VASFA was to petition to the Gandak Project authorities to abandon the plan of extending the canal network to their area.

Taking advantage of technical assistance available under a few government sponsored schemes and of loan facilities offered by the banks, VASFA succeeded in installing 10 tubewells right in the first year in 1971 and another 16 in the following year. An additional 5 tubewells were installed in 1973 and a further 4 in 1975. Finally, one more tubewell was added to the VASFA managed group of tubewells in 1982, taking the total number up to 36.

This group of 36 tubewells was located in 15 villages of Vaishali and Saraiya blocks in the districts of Vaishali and Muzaffarpur, respectively. These tubewells are concentrated in three clusters which may be denominated as Vaishali Cluster having 16 tubewells, Bibipur Cluster with 13 tubewells and Madarna Cluster with 6 tubewells. The tubewells are of the sizes 10 centimeters (cm) and 15 cm with an approximately 50 meter (m) average depth of boring. They mostly have dually powered motors, diesel as well as electricity, of capacities varying from 6.5 to 8 horsepower (hp) for diesel pumps and 7.5 to 10 hp for electric pumps. The command areas of these tubewells depend upon several factors and vary from 4 ha to 18 ha. A typical command of a tubewell is illustrated in Figure 12.1. An aggregate of 317 ha is under the command of these 36 tubewells, benefitting about 780 VASFA members. The relevant details of these tubewells are given in Table 12.1.

ORGANIZATION OF IRRIGATION THROUGH COMMUNITY TUBEWELLS

Irrigation through the group of 36 tubewells is managed through a 3-tier structure, as indicated below, under the overall stewardship of VASFA.

- i) *Tubewell Committee.* VASFA members under the command of each tubewell, numbering generally 20 to 25, constitute the Tubewell Committee and elect an honorary *Dalpati* (group leader) who heads the Committee and who is an ex-officio member of the executive committee of VASFA. He is assisted by an honorary manager/secretary who maintains all accounts and records. An operator for the tubewell is appointed by the Committee and he is paid on the basis of the running hours of the tubewell. The Committee is responsible for fixing the cropping pattern to be followed in a particular crop season, for deciding the priority in distribution of water which is generally on first-come first-served basis, for the fixation of the water rates to be charged from the beneficiaries and for the collection of charges which is done in advance.

Table 12.1. VASFA tubewells and their salient features.

Sl. number	Tubewell number	Village and block	Installation year	Construction cost		Size (cm)	Command area (ha)	Capacity of motor (hp)	
				(Rs)	(US\$)			Diesel	Electric
1	V1	Chakramdas(V)	1971	16,987	680	15	9.80	10.0	10.0
2	V2	Chakramdas(V)	1971	26,049	1,042	15	16.52	8.0	10.0
3	V3	Bania(S)	1972	15,659	626	10	10.00	-	7.5
4	V4	Bania(S)	1972	23,701	948	15	10.05	6.5	10.0
5	V5	Bania(S)	1972	15,482	619	10	7.33	6.5	-
6	V6	Bania(S)	1971	30,496	1,220	15	12.60	6.0	10.0
7	V7	Prahladpur(V)	1971	27,677	1,170	10	5.38	6.5	-
8	V8	Bania(S)	1972	21,340	854	10	6.26	6.5	7.5
9	V9	Bania(S)	1972	11,786	471	10	8.05	-	7.5
10	V10	Chakramdas(V)	1972	13,719	549	10	11.82	-	7.5
11	V11	Lalpara(S)	1972	2,012	805	10	10.10	8.0	7.5
12	V12	Chakramdas(V)	1972	8,343	334	10	5.88	6.5	-
13	V13	Ufraul(S)	1972	6,790	272	10	8.40	6.5	7.5
14	V14	Vaishali(V)	1972	4,753	190	10	7.63	-	-
15	V15	Vaishali(V)	1972	24,719	989	10	8.15	-	7.5
16	V16	Lalpara(S)	1982	7,660	306	10	2.60	5.0	-
17	M1	Madarna(V)	1971	15,456	618	15	13.10	-	10.0
18	M2	Madarna(V)	1971	14,475	579	15	6.17	6.5	-
19	M3	Madarna(V)	1973	19,160	766	10	6.87	6.5	-
20	M4	Madarna(V)	1973	17,132	685	10	5.04	6.5	-
21	M5	Haharo(V)	1973	12,905	516	10	8.18	6.5	-
22	M6	Haharo(V)	1973	17,457	698	15	12.84	6.5	7.5
23	M7	Haharo(V)	1973	15,755	630	10	3.89	6.5	7.5
24	B1	Bibipur(V)	1971	10,299	412	10	6.91	6.5	7.5
25	B2	Bibipur(V)	1971	17,623	705	15	13.48	-	10.0
26	B3	Bibipur(V)	1971	15,879	635	10	7.92	-	7.5
27	B4	Manora(V)	1971	18,840	754	15	8.83	8.0	10.0
28	B5	Afjalpur(V)	1972	16,333	653	10	8.91	6.5	7.5
29	B6	Manora(V)	1972	12,395	496	10	17.20	-	7.5
30	B7	Manpura(V)	1972	13,454	538	10	7.39	6.5	7.5
31	B8	Bibipur(V)	1972	11,370	455	10	7.52	8.0	7.5

(Continued on p. 132.)

Table 12.1 (continued).

32	B9	Bankhobi(V)	1972	17,469	699	10	1.72	8.0	7.5
33	B10	Belwar(V)	1975	17,044	682	10	12.06	-	7.5
34	B11	Belwar(V)	1975	17,131	685	15	17.86	-	7.5
35	B12	Belwar(V)	1975	12,162	487	10	6.91	6.5	7.5
36	B13	Belwar(V)	1975	11,517	461	10	4.86	-	7.5

Notes: (S) For Saraiya Block in Muzaffarpur District.
(V) For Vaishali Block in Vaishali District.

- ii) *Zonal Committee.* Each of the three clusters of tubewells constitutes a zone which elects an honorary zonal head, called *Pradhan*, who is an ex-officio vice-chairman of VASFA. The Zonal Committee helps the member farmers in the zone to get, apart from water, other agricultural inputs such as seeds, fertilizers and pesticides. It is also responsible for settling disputes that may crop up among the farmers in the zone.
- iii) *Apex Body.* An Apex Body for the management of all 36 tubewells is constituted by all Dalpatis and a few nominated members representing the bank, a cultural organization called *Vaishali Sangh* and related agencies. This body elects a chairman who, in consultation with the Dalpatis, nominate a secretary. The posts of chairman and secretary are honorary. Apart from co-ordinating the activities of the three zones, this body is responsible for planning and execution of new tubewell projects, procuring other agricultural inputs, liaisoning with the concerned government departments and other agencies, running the central workshop for repair and maintenance of tubewells, arranging technical assistance from the outside as well as training and employment of the members or dependents of the members.

The water rates are fixed on the basis of operation, maintenance and repair costs of the tubewell including remuneration paid to the operator as well as depreciation cost for repayment of loans. They vary from tubewell to tubewell as well as from time to time. The beneficiaries are charged on the basis of hours of operation of the tubewell to irrigate their respective plots. Charges are to be paid in advance based on the allotments of running hours. During 1991 Kharif, the water rates charged were Rs 15 (US\$0.6) and Rs 20 (US\$0.8) per running hour of the diesel pump for members and nonmembers, respectively. For electric pumps, the corresponding charges are less.

PERFORMANCE OF THE FARMER-MANAGED IRRIGATION SYSTEM

Provision of irrigation through cooperatively owned and managed tubewells was a venture in both cooperative action as well as in rejection of what was perceived as an imposition of an inappropriate and counter-productive irrigation system. Based on the experience of about two decades, the performance of this venture can be analyzed in search of lessons to be learnt from a farmer-managed irrigation system. Such an analysis should be done on the basis of both agricultural performance as well as organizational performance.

Agricultural Performance

The agricultural performance of this farmer-managed irrigation system can be best appraised with reference to that of the state administered and managed irrigation system prevailing in nearby areas having similar agroecological, hydrological and other relevant conditions. The VASFA Irrigation System differs from the nearby irrigation system in the following two significant ways:

- i) While the VASFA Irrigation System is based on the exclusive use of groundwater, the nearby system dominantly uses surface water distributed through canals.
- ii) In operation, each tubewell commanding a maximum area of 18 ha is independent of other tubewells in the VASFA System and hence is more responsive to the needs and requirements of the beneficiaries as it is more amenable to their control and management. The canal water supplies to the nearby counterpart areas are hydraulically subject to the supplies as well as demands in other areas of the expansive command of thousands of hectares. Also, the irrigation system providing water to these areas is administered by a hierarchical bureaucracy more bound by inflexible rules and manuals than by the demands of individual farmers.

These differences in the two irrigation systems may explain substantially, if not wholly, the following comparative performances:

- i) The cropping pattern practiced in the VASFA area is more diversified than that in the canal command areas. While in the latter, mostly cereal crops and sugarcane are grown, noncereal crops like vegetables and bananas as well as nonfood crops like tobacco are cultivated, apart from principal cereal and perennial crops, in the former.
- ii) As shown by the farm productivity and input information obtained for a few VASFA areas and a few nearby canal-irrigated areas in Laloo Chapra Command for kharif 1991, the productivity in grain output is about 1.5 times in the VASFA area while the inputs in terms of fertilizer applied and manpower employed per hectare are 2 times and 3 times higher, respectively, in the latter than in the former (see Tables 12.2 and 12.3).

Table 12.2. Sample farm productivity of VASFA area under tubewell irrigation, for kharif 1991.

Tubewells	Number of plots	Total area (ha)	Irrigation (hours)	Inputs per hectare		Outputs per hectare	
				Fertilizer (ha)	Labor (man-days)	Grain (quantity)	Fodder (quantity)
V2	3	0.691	13	70	78	28.20	13.90
V6	8	1.189	11	55	77	21.95	11.02
V11	3	0.335	42	84	128	22.40	12.40
V12	3	1.630	17	58	89	20.90	10.12
B4	17	1.709	17	74	80	27.00	14.00
B7	11	1.140	00	65	89	20.48	10.50
B11	6	0.450	17	56	78	22.20	12.11

Table 12.3. Sample farm productivity of Laloo Chapra Command, for kharif 1991

Outlet number	Number of plots	Total area (ha)	Irrigation provided (mm)		Inputs per hectare		Outputs per hectare	
			Number	Depth	(kg)*	(man-days)	Grain (quantity)	Fodder (quantity)
OL1	10	0.344	5/6	125	157+610	218	16.13	19.20
OL3	6	0.708	2	125	541+212	216	11.79	14.20
OL5	7	0.668	3	125	85+150	177	18.00	21.03
OR6	17	1.488	3	100	38+548	216	17.44	20.57

* Quantity of urea + manure.

- iii) The long-term hydrological sustainability of tubewell irrigation is unambiguous. Running at an average of 4 hours per day, the tubewells in the VASFA area have served to maintain the water table within 0.5 m of rise or fall over the years. The same is not likely to be true in the canal command areas.

Organizational Performance

The experience of organizational performance of the VASFA venture for the last 2 decades is interesting but mixed. There was very rapid expansion of tubewell installations under VASFA ownership and management for the first four years after it was set up, when the number rose to 35. A lone tubewell was added to the group in 1982 after a lapse of 7 years, taking the number to 36, where it has remained stagnant since then. Considering the fact that there has always been scope and a need for coverage of more and more areas under tubewell irrigation, non-expansion of VASFA membership for the purpose is somewhat intriguing. On a closer examination of the workings of the VASFA-managed tubewells, certain facts have come to light explaining this situation. One is the emergence of conflicts among the members of a tubewell committee over certain operational aspects, such as inter-sector priority in watering. Where the leadership provided by Dalpati is not effective or where management of the day-to-day working of the tubewells is not efficient, such conflicts are more liable to emerge and to remain unresolved. In such a situation, discontentment grows among the adversely affected members. Second, the Government's scheme to provide incentives and subsidies for installation of private tubewells to individual farmers has encouraged many farmers to go for their own shallow tubewells to meet their irrigation requirements, particularly in view of the fact that in the prevailing geohydrological situation, adequate discharge of good quality groundwater is assured even at low lifts. These two factors have combined to promote installation of an increasing number of private tubewells, both within as well as without the erstwhile commands of VASFA tubewells. Added to this is the emerging phenomenon of water markets which provide a viable alternative to meet the irrigation requirements in this area. This has resulted in the decline of original commands of several VASFA tubewells as well as in the stagnation of VASFA membership, which presently stands at 782.

VASFA seems to have realized that its role of promoter and facilitator of community-managed groundwater irrigation in the face of the proposed extension of the state administered canal irrigation system to the area is essentially achieved and is not poignantly relevant today. However, VASFA, as a farmers' association has a considerable role to play in protecting and promoting farmers' interests in other spheres of agriculture. Consequent to this realization, VASFA has also opened its membership, called Action Group as distinct from

Irrigation Group, to help those farmers who are not interested in getting benefits from VASFA-managed irrigation but would like to get assistance in other areas such as obtaining loans, seeds, fertilizers, etc. On this score, the membership of VASFA is increasing and is now 886.

SOCIOECONOMIC IMPACT

No bench-mark socioeconomic survey of the area is available to facilitate an assessment of the socioeconomic impact of VASFA irrigation and related activities for the last two decades. However, a recent survey conducted in this area reveals certain socioeconomic features which help in understanding the performance, the successes as well as the failures of VASFA irrigation. An overwhelming number of people of this area, 94 percent of the population, engage in agriculture as their sole means of livelihood while the remaining 6 percent constitutes mainly of agricultural laborers. Therefore, this area is distinctly different from other neighboring areas where 12 percent to 40 percent of the people are engaged in other economic activities such as small businesses, government service, and other professions. Also, the caste composition of this area indicates that almost 97 percent of the population constitutes of upper caste and backward caste people whereas only 3 percent are scheduled caste people, as distinct from about 10 percent in other nearby areas. Also, this area is inhabited preponderantly by small and marginal farmers. About 50 percent of the farmers of this area own land up to 1 ha and another 48 percent own land of more than 1 ha but less than 4 ha. A negligible 1.5 percent of the farmers, as against 10 percent in the bordering areas, own more than 4 ha holdings.

These distinctive socioeconomic features of this area explain the origin and relative success of the VASFA experiment in farmer-managed irrigation systems. On analyzing the performance of each tubewell in the system, it is found that the few tubewells with farmers having bigger landholdings in the respective commands are more prone to disputes due to dominance of these farmers at the expense of smaller and marginal farmers. Otherwise, uniformity in the degree of dependence on agriculture, in landholding pattern and in caste composition have ensured identity of interests among the members and consequent success in performance of most of the tubewells in the VASFA System. This uniformity is also reflected in the income level of the farmers. While about 60 percent of the farmers in this area earn annually up to Rs 5,000 (US\$200) from agriculture, the annual agricultural income of the remaining 40 percent is within the range of Rs 5,000 (US\$200) to Rs 10,000 (US\$400). About 8 percent of the farmers earn incomes from other sources up to a maximum of Rs 5,000 (US\$200) annually. Thus, there is virtually a complete absence of people belonging to high income groups in this area.

Although this area is marked by a lack of general or even isolated affluence, it has been learnt through personal interviews that the socioeconomic condition of this area has undergone remarkably positive transformation during these two decades. There is visible and palpable improvement in the agricultural performance of this area compared to its pre-VASFA status. Out-migration of labor from this area has been almost completely arrested. On one point the farmers are emphatically unanimous; they will never like the canal system to be extended to their area.

CONCLUSION

In conclusion, what can we say about the nature, performance and outcome of the VASFA experiment and about the feasibility as well as the desirability of its replication for other areas?

Based on the analysis presented, it can be said that VASFA essentially represented a community action, inspired by a dedicated leadership, to fulfill an apparent and demanding need to provide irrigation in order to free agriculture, the only source of subsistence in an area inhabited preponderantly by small and marginal farmers, from helpless dependence on the vagaries of the monsoons. This action was assertive in the sense that it involved deliberate rejection of an inappropriate irrigation system of doubtful benefits and potential damaging effects to this area, and was facilitated by certain positively helpful schemes in operation at the time. The VASFA action has, by and large, achieved sustainable success largely because of the socioeconomic homogeneity and consequent identity of interests of the beneficiary farmers.

Nonexpansion of the VASFA Irrigation System and membership after 1982 is only an indication of the changed context and, by no means implies a failure of the experiment. VASFA in fact seems to be aware of this change and is in the process of adapting to it by shifting its emphasis from irrigation to other agriculture related services for the benefit of its members. The eminent success of VASFA in achieving its original objectives is testified by the improving socioeconomic status of its members from a base line of abject poverty, and the continued life and vigor of the established system.

Deriving from the fact of the nonexpansion of the VASFA Irrigation System since 1982, one can certainly say that VASFA in its original form and activities, is not replicable for other areas, primarily because the change in techno-economic context that has occurred in VASFA area is true for other areas as well. However, some very useful lessons can be learnt from the VASFA experiment and experience which will be applicable for other areas, particularly to humid alluvial plains equivalent to North Bihar. They are as follows:

- i) VASFA has advocated and promoted an irrigation system that is appropriate for the agro-eco-hydrological situation of the concerned area, which was the use of ground-water for irrigation in this case. Appropriateness of irrigation strategy is the first requisite for the success of the system.
- ii) Decentralized control and management of an irrigation system helps to make irrigated agriculture more productive and remunerative. Experience of the operation of the VASFA Irrigation System indicates that private tubewells are even more desirable in this regard.
- iii) VASFA has laid stress on community initiative and action in the face of government's inaction or inappropriate action, particularly in a matter which is so critical for the life and living of the people. This lesson is, of course, not only irrigation specific but is of wider implication and applicability.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Shri S. K. Lal, retired Chief Engineer of the Water Resources Department, Government of Bihar, for his help and guidance in the work, which has largely formed the basis of this paper. The authors also acknowledge the assistance provided by the Faculty and research personnel of the Centre for Water Resources Studies in verification and analysis of data and information which has been either incorporated or otherwise made use of in

preparing the paper. Data collected and provided by the field observers of the Water and Land Management Institute, India; field engineers of the Water Resources Department, Government of Bihar; and other related agencies under the India-IIMI Collaborative Research Programme are duly acknowledged.

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Community Sprinkler System in Sullikere Village, Bangalore Urban District, South India

D. S. K. Rao⁴⁷

ABSTRACT

DURING THE LAST three decades there has been a substantial increase in well irrigation in many parts of India. This has resulted in a sharp increase in groundwater draft, leading to a decline of water levels in many areas, particularly in the low-rainfall hard-rock (LR HR) areas, such as, the eastern dry zone (EDZ) in the southeastern parts of Karnataka State. Water level decline has depressed well yields and increased well failures, particularly in respect of borewells (BWs). This has also led to a steep increase in the cost of well construction, seriously affecting the viability of wells. As a result, many small and marginal farmers are denied access to well irrigation.

The above situation has prompted a group of 16 marginal farmers, owning a contiguous piece of 13 hectares (ha) of land in Sullikere Village of Bangalore District (Urban), to form a cooperative society (CS). The state government has given a grant to the CS for 3 BWs, 3 submersible pumpsets (SPs) and for installing a sprinkler system. The above farmers have been practicing community BW and sprinkler irrigation for the last two years, cultivating a judicious mix of perennial and field crops and deriving a steady flow of income.

INTRODUCTION

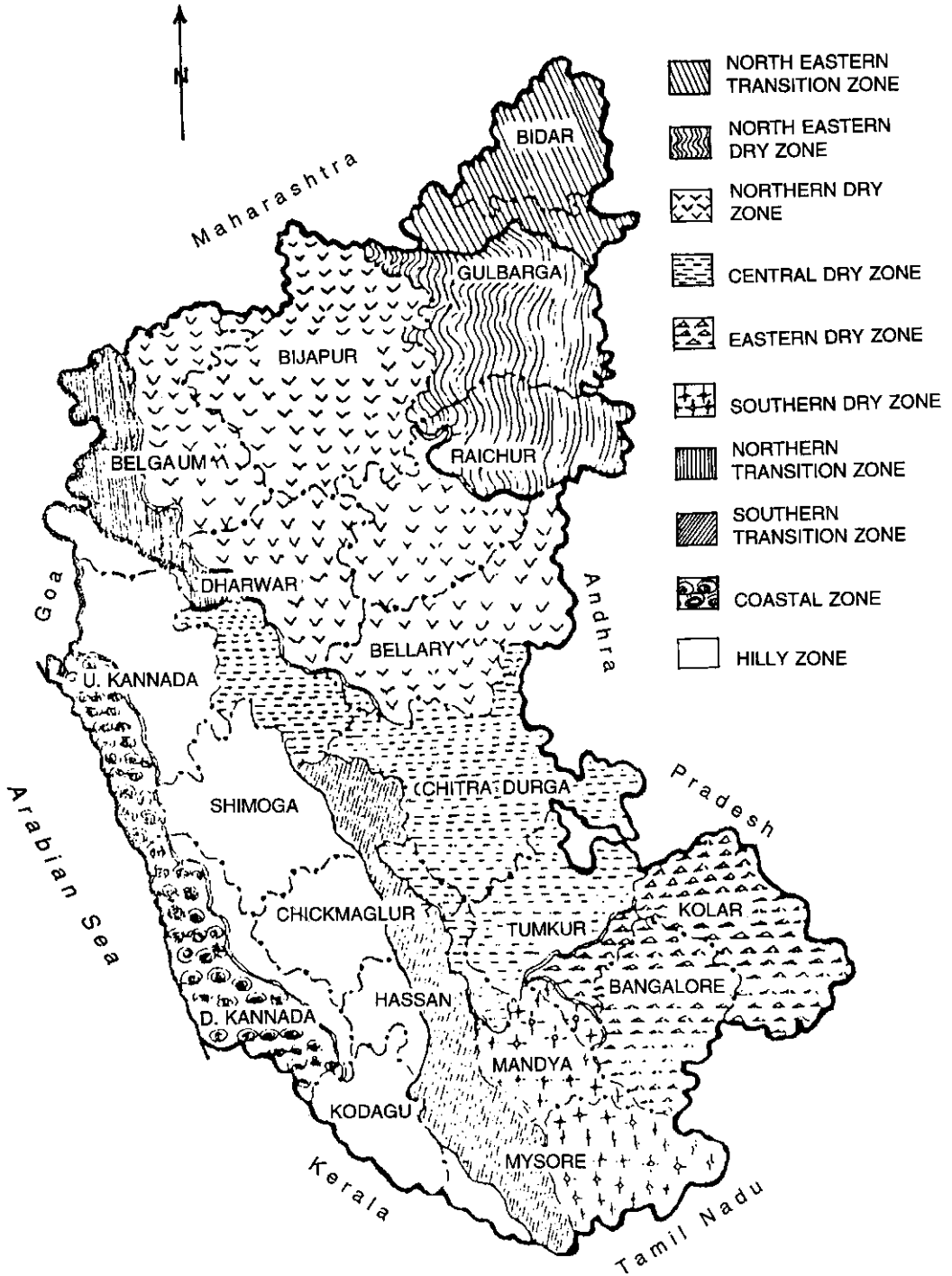
Sullikere Village in Bangalore Urban District is located in the EDZ which is one of the ten agro-climatic zones of Karnataka State (Figure 13.1). The EDZ is drought prone receiving an annual rainfall of 768 millimeters (mm) mostly during the southwest monsoon season (CGWB⁴⁸ 1987). It is an undulating terrain covered by red loamy soils.











The EDZ is occupied by hard rocks which lack primary porosity. Storage and transmission of groundwater in these aquifers take place through secondary porosity, caused by weathering and fracturing (Raju 1985). The weathered residuum extends to a depth of 5 to 10 meters (m) followed by a fractured zone, up to a 50 m depth (CGWB *ibid*). However, the occurrence of fractures below 50 m is also reported in a few areas.

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48 Central Ground Water Board (CGWB) is the apex organization in India for the exploration of groundwater.

Figure 13.1. The ten agroclimatic zones of Karnataka State.



-  NORTH EASTERN TRANSITION ZONE
-  NORTH EASTERN DRY ZONE
-  NORTHERN DRY ZONE
-  CENTRAL DRY ZONE
-  EASTERN DRY ZONE
-  SOUTHERN DRY ZONE
-  NORTHERN TRANSITION ZONE
-  SOUTHERN TRANSITION ZONE
-  COASTAL ZONE
-  HILLY ZONE

EVOLUTION OF WELL STRUCTURES

Irrigation well structures in the study area of Sullikere Village, as in other parts of EDZ,⁴⁹ have undergone an interesting evolution during the last thirty years. The first phase which lasted till the early 1960s was dominated by large diameter (cross-sectional area up to 100m²) dugwells (DWs), rarely exceeding 10 m in depth. These wells were mostly operated by bullock power. Groundwater draft from these wells was extremely low (0.30 hectare-meters per year) and the low discharge realized could hardly irrigate 0.5 hectare (ha) of less irrigation intensive crops.

Sharp Increase in Pumpsets

The second phase of development was marked by centrifugal pumpsets, which became extremely popular because of their low cost, high efficiency and easy maintenance. Installation of a pumpset (diesel or electric) enhances the discharge and consequently the command area of a well by three to four times. Moreover, it became imperative to draw more water from wells, because during this period farmers switched over increasingly to high yielding varieties of seeds and heavy doses of chemical fertilizers which demand intense irrigation.

Even while well owners were switching over to pump irrigation, new wells were coming up simultaneously in increasing numbers. Various government sponsored programs subsidizing wells and pumpsets, and the easy availability of institutional credit gave a fillip to well construction (Rao 1991). There was more than a threefold increase in the number of wells in a span of two and a half decades, increasing from 135,000 in 1960/1961, to 490,000 in 1985/1986 (Figure 13.2).

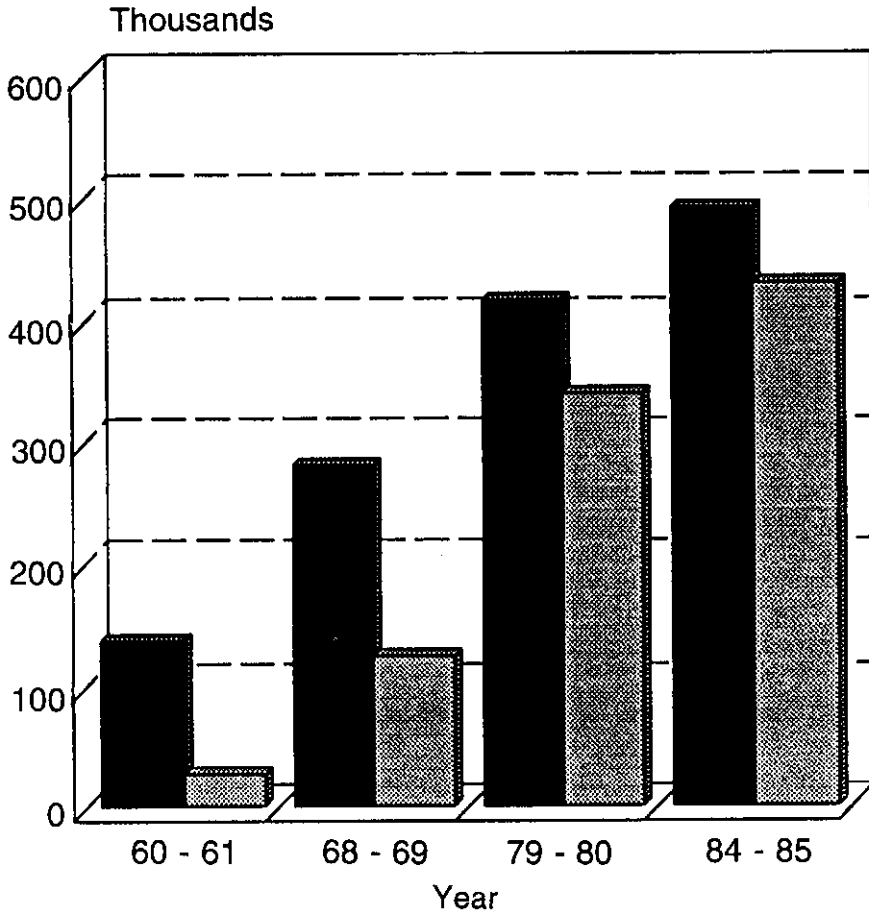
Construction of wells and installation of pumpsets were more vigorous in the EDZ. During 1990/1991, it had 12 percent of the net sown area of the state but accounted for 32 percent of the total agriculture pumpsets. This can be attributed to the heavy dependence of this area on well irrigation due to the lack of a good network of canals. Deterioration of tank irrigation also contributed to the spurt in well construction (Van Oppen et al. 1983)

Dug cum Borewells (DCBs)

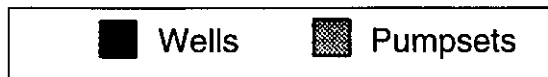
The twin effect of large-scale pumpset installation and increasing number of new wells has been devastating on the groundwater levels, particularly in the LR HR areas, forcing the farmers to deepen the DWs periodically. Conversion of DW into DCB by drilling shallow bores to chase the declining water levels was attempted by many. However, it was soon realized that DCBs had limited use because in many areas water levels receded below the suction lift of the centrifugal pumpsets, rendering the well as well as the pumpset temporarily non-functional.

49 EDZ comprises all the blocks of Bangalore Urban, Bangalore Rural and Kolar Districts, besides two blocks of Tumkur District. As statistical data for parts of the district were not available, the entire Tumkur District is considered as part of EDZ in the present paper.

Figure 13.2. Increase in wells and pumpsets in Karnataka State.



Wells	135	280	415	490
Pumpsets	27	124	338	430



Borewells (BWs)

The third phase of development, marked by the introduction of BWs, commenced in the early-1980s. These small diameter (150 mm), deep structures (about 50 m in depth) could be constructed quickly (it takes about 12 hours to drill a borehole of 50 m depth as compared to months of excavation of a DW of much shallower depth), and they also dispensed with the problem of frequent deepening required for a DW. Moreover, due to thick saturated zone available a BW

can be operated continuously. These factors encouraged farmers in the hard rock areas, particularly in the EDZ, to construct more BWs. In a short span of 5 years since 1982, borewells in the state increased fivefold. Increase in BWs is even more sharp in the EDZ (Table 13.1).

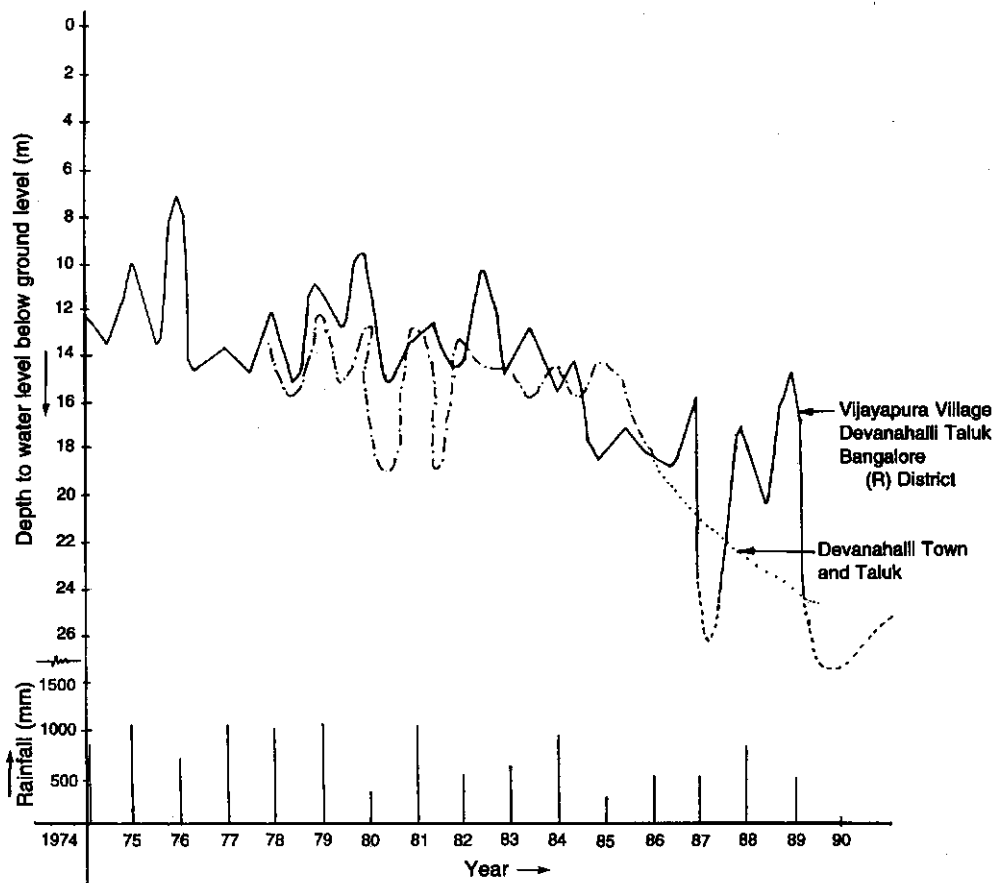
Table 13.1. Borewells in Karnataka State and eastern dry zone.

Zone	1982/1983	1983/1984	1984/1985	1985/1986	1986/1987
EDZ	3,328	5,786	9,862	15,176	19,077
Karnataka	7,855	12,935	21,136	32,385	40,923
Percentage of Karnataka borewells in EDZ	42.4%	44.7%	46.7%	46.9%	46.6%

Note: EDZ = Eastern dry zone.

Proliferation of BWs and their ability to yield more water resulted in the further decline of water levels, particularly in areas where the concentration of BWs is high (Figure 13.3).

Figure 13.3. Hydrographs of wells in the eastern dry zone, showing water level decline.



Energization Program and BWs

BW proliferation has a strong link with pumpset energization, because, unlike a DW, a BW cannot be operated without electric connection. The liberal energization policy of the SEB since 1980 has contributed greatly to the increase of BWs.

Failure of BWs

Though BWs have several advantages over DWs they suffer from the serious problem of a high failure rate. It is the experience of the state-owned Karnataka Agro-Industries Corporation (KAIC) (the nodal agency in the state for constructing BWs under government sponsored programs), that the average failure rate of BWs is 30 percent. As against this, failure in the EDZ, characterized by deep and declining water levels, is much higher, recording more than 50 percent in a few areas. In addition to high failures at construction stage BWs also suffer from declining yields as a result of fall in water levels, thus reducing the economic life of these structures drastically.

VIABILITY OF WELL IRRIGATION

Power is supplied to agriculture pumpsets in the state at Rs (Rupees) 50 (US\$2) per horsepower (hp) per year. As against the above meager revenue, the SEB incurs a capital expenditure of Rs 15,000 (US\$600) toward energization of a pumpset and recurring expenditure of Rs 6,400 (US\$256) per year toward the cost of power supplied. If subsidy on power supply is withdrawn and the cost of BW failure is accounted, the viability of BWs is seriously eroded (see Annex).

Expansion of Well Commands

It may be seen from the above that there is a need for optimizing the benefits of well irrigation. It can be achieved by expanding the command area of a well by growing high value crops, preferably those which can be irrigated efficiently through water conservation methods, such as drip and sprinkler systems. The average discharge of a BW is 2 liters per second (lps), which can irrigate about 1.5 ha. The same BW can irrigate at least 20 percent additional area if the sprinkler system is introduced (increase in command area is even higher if it is undulatory land and/or occupied by light textured soils). By shifting the crop pattern in favor of widely spaced crops, such as mango or coconut and installing the drip system, as much as 10 ha can be covered by a BW. However, the main constraint in expanding well commands in this manner is the predominance of small landholdings. In Bangalore District, in which the present study area is located, 52 percent of the landholdings are less than 1 ha (Directorate of Economics and Statistics—DES—1990). A similar picture is reflected in most other districts of the state. Therefore, expansion of well commands is possible only if small groups of farmers learn to share a well and also the sprinkler/drip system installed on it. A rare example of such an idea in practice is evident in Sullikere Village in Bangalore (South) Block.⁵⁰

50 Block is a developmental unit comprising of a group of villages. A few blocks form a district.

COMMUNITY SPRINKLER SYSTEM (CSS) IN SULLIKERE VILLAGE

The state government, under a program of uplifting the economic condition of the rural landless, gave 13 ha of land free of cost to 16 scheduled caste⁵¹ agricultural laborers of Sullikere Village. Ownership of land did not, however, improve their economic condition because of low productivity of the land due to lack of irrigation facilities. Income from one crop of ragi grown during the monsoon season under erratic rainfall conditions was grossly inadequate and the beneficiaries were forced to continue to work as laborers during the major part of the year.

The hydrogeology of Sullikere Village is suitable for groundwater development. Several government sponsored programs and institutional credit facilities were also available for construction of wells. However, the 16 farmers could not afford wells because the land owned by each of them was too small to support the investment of about Rs 50,000 (US\$2,000) for a BW, pumpset, etc. Another limiting factor was the undulating lands, which when irrigated under conventional flow irrigation, resulted in poor efficiency.

Cooperative Effort

Looking into the plight of these farmers, Mr. Basavayya, the then Block Development Officer⁵² (BDO) of Bangalore (South) Block, encouraged them to form a Cooperative Society (CS) and register⁵³ it with the state government so that they could derive the full benefit of the various developmental programs of the government.

Encouraged by the BDO, all the beneficiaries resolved to form a CS and practice community BW irrigation. Thus *Maruthi Harijana Neeravari Sahakara Sangha* (MHNSS) (Maruthi Scheduled Caste Irrigation Co-operative Society) was founded in the year 1986 with 50 members (the sixteen beneficiaries included all the major members of their families as MHNSS members). The by-laws of the co-operative were framed in the lines of lift irrigation societies (several formal societies and informal groups are operating successfully in the northern Karnataka districts of Bijapur and Belgaum and the neighboring Maharashtra State) for lifting river water for irrigation. The CS was registered with the Assistant Registrar, Bangalore (South) in June 1986. The salient points of the by-laws which were adopted by the CS are as follows:

- i) Ownership of the land continues to be with the individual members.
- ii) Members have the liberty to choose the cropping pattern.
- iii) Uniform amount of water will be supplied to the members, irrespective of the size of the holding and the cropping pattern adopted.

51 Socially and economically backward community, with several constitutional rights and privileges.

52 Middle-level state government executive charged with the responsibility of carrying out developmental work in a block.

53 Co-operative movement is widespread in India, particularly in the western and southern parts of the country. Movement of the people, for the people, and managed by the people for ensuring equal distribution of profits to all the members, is the basic concept of the co-operative movement. Any homogenous group of members (a minimum of ten) aspiring for a common cause can form a co-operative. The Co-operation Department of the state government registers the co-operatives and functions as their friend, philosopher and guide. In case of a dispute among the members, the state government acts as the arbitrator as well.

Soon after registration, the members elected ten promoters, who, in turn elected the President. A salaried secretary was appointed for correspondence and looking after the day to day functioning.

The president has completed primary schooling and is a natural leader who is capable of carrying all the members with him. He is also capable of interacting with government departments at various levels. He is the elected president since 1986 and informal discussions with the members revealed that they have no plans of replacing him.

The secretary is an employee of the local branch of a commercial bank. He has studied up to secondary school level and is capable of maintaining records and correspondence.

The nine elected promoters are in different age groups and take an active interest in the working of the co-operative. One of the promoters is a literate, middle-aged woman.

Technical Aspects of CSS, Sullikere

Action for Water Development (AFWD), an NGO with infrastructure for BW site selection and drilling, surveyed the project area in the year 1986. However, drilling of BWs was not undertaken immediately for want of funds. The beneficiaries did not have their own resources and were not eligible to receive bank loans because they had defaulted in the repayment of loans received earlier from banks. Finally, considering the socioeconomic status of the farmers, the SG granted funds for 3 BWs, 3 SPs and for the laying of sprinkler systems. Soon afterwards the AFWD drilled 3 BWs (in the year 1989/1990) which yielded 2.4 lps, 3.8 lps and 5 lps discharge (Figure 13.4). SPs of 6.5, 6.5 and 10 hp were installed on the three BWs.

Cropping Pattern

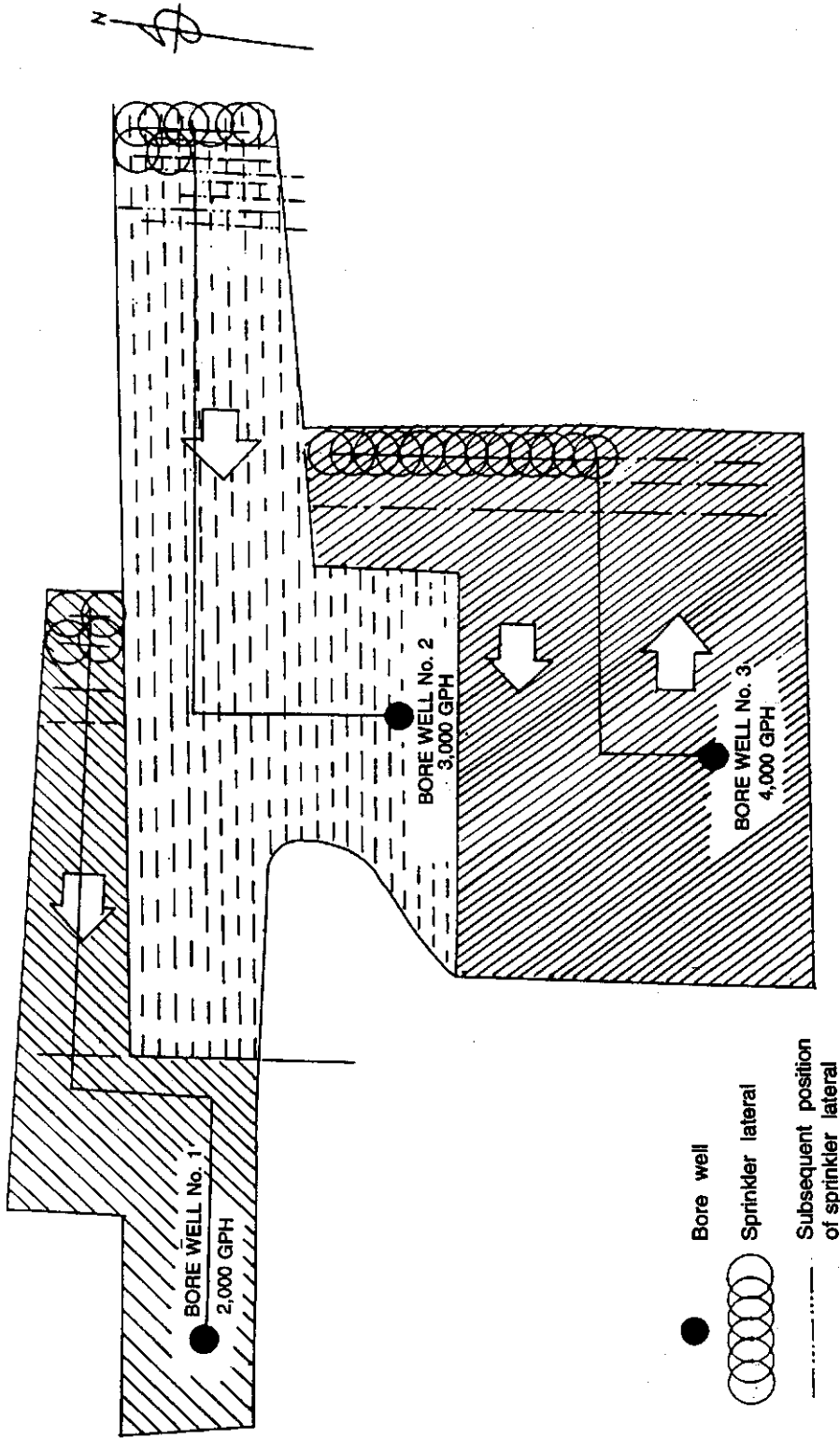
The beneficiaries had their own choice of the cropping pattern. The overall cropping pattern was, however, a judicious mixture of perennial and field crops (Table 13.2).

In view of the undulating nature of the topography it was necessary to install sprinklers without which the conveyance and application efficiency would have been low. Each BW has a definite command area depending upon its discharge. The design of the sprinkler system was based on the principle of applying 2.5 centimeter thick irrigation water, once in 8 days, by operating the system for 12 hours per day. The total discharge requirement for the above parameters worked out to 10.5 lps (90 percent efficiency) against the total available discharge of 11.20 lps. The sprinkler system was provided with aluminum pipes of 75 mm diameter and 1,800 m length for the main and lateral pipes. Altogether 21 sprinkler heads were provided with 12 m spacing.

Economics of the Scheme

Though Sullikere beneficiaries have received government grants for constructing BWs, installing pumpsets and a sprinkler system; the economics has been worked out assuming market rates for the above investments. It is observed that the scheme is thoroughly viable with the Internal Rate of Return (IRR) being more than 50 percent, when the subsidized rate for power consumption is considered. However, if subsidy on power consumption is removed, the IRR is 31 percent (It is further reduced to 23 percent if a 10 percent reduction in production is assumed).

Figure 13.4. Community sprinkler system in Sullikere Village, Bangalore (S) Block.



Note: GPH = Gallons per hour.

Table 13.2. Cropping pattern in community sprinkler system farm, Sullikere Village.

Perennial crops	<i>Kharif</i> (monsoon)	<i>Rabi</i> (winter)
Mulberry 3.2 ha	Ragi 3.2 ha	Vegetables 3.2 ha
Coconut 4.0 ha		
Mango 1.6 ha		
Banana 1.0 ha		

Management of the Scheme

Each farmer is provided water for 6 hours, once in 8 days. Shifting of the lateral pipes is the responsibility of the farmer who is going to use the sprinkler system. The CS collects only the electricity charges from the beneficiaries once a year. This amounts to a nominal sum of Rs 125 (US\$5) per ha. Whenever there is a pump break down, farmers covered under the particular pump collect money to meet the cost of the repairs. No maintenance fund is built up and repairs are carried out through ad hoc collections.

MHNSS: SCOPE FOR IMPROVEMENT IN CSS FARM

Though BWs in the study area have good and sustainable yields, the available water falls short of demand in the peak requirement period, i.e., late rabi and summer seasons. It is necessary to construct at least one more BW to ensure an adequate supply of water during all the seasons.

Fencing may be erected to protect the farm from encroachment. For effective on-farm operations and haulage of agricultural produce to the market, a tractor may be added to the assets of the co-operative.

In view of the highly fluctuating voltage conditions, the SPs are bound to get burnt frequently. Quick repair to the pumpsets is essential, without which irrigation scheduling will be seriously disrupted. For efficient management of such crises, the co-operative may build up a maintenance fund by collecting at least Rs 250 (US\$10) per ha annually from the farmers. The beneficiaries should also repay their bank loans which are presently outstanding. This will render them eligible for fresh loans and reduce their dependence on government grants for any expansion or strengthening of their farming activities.

Efforts must be made to conduct meetings of the promoters regularly, at least once a month. It is also observed that elections to the posts of promoters and president were never held after the initial elections. In accordance with the democratic norms of the co-operative, elections must be held once in three years, as stipulated by the by-laws.

CONCLUSION

The success of CSS at Sullikere could be attributed to the motivation of the BDO in forming the co-operative and to the strong leadership of the president. Realization of the members that unless they share the wells and the sprinklers, they can never have access to irrigation has strengthened the hands of the BDO and the president. Though CSS has come into existence only because of

the liberal government grants, it is a fact that successful operation of this will have a positive demonstrative effect on the marginal farmers in the neighboring areas. Concerted efforts are necessary from the extension department of the government in educating marginal farmers about the various alternatives available to them within the given resource constraints. The role of NGOs in this regard would be vital.

ACKNOWLEDGEMENTS

The author is grateful to Mr. S. C. Wadhwa, Deputy General Manager, National Bank for Agriculture and Rural Development, Bangalore, for providing facilities to complete the study and also for his able guidance. He is also grateful to his colleagues Dr. V. Puhazhendhi and Dr. D. Nageswara Rao for their help in economic analysis and data processing on the computer, respectively.

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Annex

A. ECONOMICS OF BOREWELL IRRIGATION

		With subsidy (Rs)	Without subsidy (Rs)
I	Investment cost		
	Borewells	15,500.00	15,500.00
	Pumpsets	24,500.00	24,500.00
	Cost of failure	0.00	6,200.00
	Total	40,000.00	46,200.00
II	Maintenance cost		
	Cost of power consumed/year	250.00	6,400.00
	Maintenance of pumpset/year	800.00	800.00
III	Estimated net incremental income	15,900.00	15,900.00
IV	Estimated internal rate of return	> 50%	22%

B. ECONOMICS OF COMMUNITY SPRINKLER IRRIGATION AT SULLIKERE VILLAGE

		With subsidy (Rs)	Without subsidy (Rs)
I	Investment cost		
	Borewells (3 numbers)	54,000.00	54,000.00
	Pumpsets (3 numbers)	86,000.00	86,000.00
	Sprinkler system	1,87,000.00	1,87,000.00
	Total	3,27,000.00	3,27,000.00
II	Maintenance cost/year		
	Power	1,610.00	60,000.00
	Sprinkler maintenance	3,740.00	3,740.00
	Pumpset maintenance	2,400.00	2,400.00
	Total	7,750.00	66,140.00
III	Estimated net incremental income	1,44,900.00	1,44,900.00
IV	Estimated internal rate of return	> 50%	31%

Note: All rates in Indian Rupees.
US\$1.00 = Rs 25.00.

Sustainability of Water Users Associations as Groundwater Irrigation Managers: A Case Study under On-Farm Water Management, Punjab, Pakistan

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ABSTRACT

THE PAPER DISCUSSES the water users associations; their organization and operation after the reconstruction/remodeling of small-scale community irrigation schemes (watercourses), with special reference to their sustainability as groundwater irrigation managers. Watercourses carrying canal and groundwater (tubewell water) renovated under three different categories, i.e., managed by water users associations, a government organization and a tubewell owned by a single farmer have been discussed and compared.

INTRODUCTION

Pakistan ranks fifth in the world and third among the developing countries in the size of irrigated area served by the largest contiguous canal system. The irrigation system of the Indus Basin comprises of three major reservoirs, 19 barrages, 12 link canals and 43 major canal commands. The total length of irrigation canals is 49,500 km. Tertiary irrigation unites watercourses numbering 89,000 with a total length of about half a million kilometers. The irrigation supplies are augmented by 15,500 large public tubewells and over 300,000 private tubewells.

Poor irrigation efficiency resulting from huge water losses has been identified in the century-old community watercourses at farm level resulting in low per acre yields (1 acre = 0.40 hectare). A diagnostic analysis of the Indus Basin Irrigation System, particularly at tertiary level, inspired the planners to take some immediate steps to consider the improvement of irrigation efficiency at watercourse level by commissioning an On-Farm Water Management (OFWM) Project.

Watercourse improvement envisages complete remodeling and reconstruction of community watercourses with partial brick lining and fixing of water control structures. This task is accomplished through the active participation of farmers. The water users are organized into water users associations (WUAs). The main functions of the WUAs are to arrange labor, settle all types

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of disputes amongst the shareholders, make arrangements for alternate watercourses, supervision of work and post-construction maintenance. This unique experience of farmer participation has proved very successful in the Punjab Province.

Canal irrigation is supplemented with groundwater in the Indus Basin. There are about 315,500 tubewells in public and private sectors, tapping the aquifer and serving the dual purpose of irrigation and drainage. Large size deep turbine tubewells have been installed since the sixties by the government under the Salinity Control and Reclamation Projects (SCARP). Their operation, management and maintenance are being undertaken by the provincial Irrigation Departments. The acute problem of high operation and maintenance (O&M) cost has, however, compelled the government to disinvest through transitioning. The private tubewells are more or less fractional; centrifugal pumps are installed and they are operated and managed by individual farmers.

Looking at the success of the implementation of the watercourse improvement program through WUAs, an effort for managing groundwater exploitation has also been introduced. Ten tubewells operated by WUAs were installed on a cost sharing pilot basis in Dera Ghazi Khan. The idea of installation of such tubewells would be their replication in other areas upon the success of the scheme. The present study was conducted to compare the results of different management techniques.

LITERATURE REVIEW

Malik (1981) reported on an evaluation of the private diesel tubewells provided to the farmers by the government under a subsidy scheme. The study concludes that about fifteen percent of the tubewells have been identified to be installed in the open without proper shelter, thereby, increasing the wear and tear of the machines and decreasing their operational efficiency. The study further indicates that these privately owned tubewells were mainly used for their personal requirements by the owners as only five percent of the farmers sold the tubewell water to the adjacent farmers.

Ashiq (1981) reported that during the peak demand period the SCARP tubewells remained closed either due to repairs or replacements. The study has further shown that the operators reach efficiency in their tubewell operation targets during the low demand periods. Moreover, the tubewell operators do not take an interest in their assignments. Some of them have been reported to join other private businesses and pay occasional visits to their original place of posting while others have never been seen at their job.

Shahid et al. (1990) concluded that, on an overall basis, the extent of SCARP tubewell closure in a year due to mechanical faults was estimated as 4.05 months. It was further concluded in the study that although the government is responsible for the expenses on operation of SCARP tubewells, the farmers had to pay an amount of Rupees (Rs) 245 (US\$9.8) on an average, to keep the SCARP tubewell running in order to fulfil irrigation requirements at critical stages of the crop growth. The study further reveals that farmers on 5.5 percent of the totally closed SCARP tubewells and 12.5 percent of the running tubewells were ready to take over the SCARP tubewells, out of which 56 percent were ready to take them over jointly. The reasons identified for being unwilling to take over the SCARP tubewells are indicated as high electricity bills (68 percent), lack of cooperation (51 percent), owning private tubewells (46 percent), small holdings (40 percent), high O&M costs (31 percent) and apprehension about repair and maintenance (30

percent).⁵⁵ The report further reveals that none of the associations has been found willing to buy the SCARP tubewells jointly.

Chaudhry and Yong (1989) have pointed out that the pumping schedules of the SCARP tubewells were never made compatible with estimated canal supplies and crop water requirements. The operators remain frequently absent from tubewells and allow the farmers to operate tubewells themselves. This practice resulted in the damaging of electric motors and protective devices. The pumping capacity of the SCARP tubewells has not only declined, but up to 40 percent of the tubewells are not operating due to maintenance-related defects. Maintenance has been reported to be seriously constrained due to lack of availability of funds, and when funds are available, a slow, cumbersome and centralized decision making process caused unnecessary delays in solving the problems.

METHOD AND PROCEDURE

To conduct the present study, three tubewells operated under different management systems, i.e., WUA operated, privately owned and government managed through SCARP, were selected in Dera Ghazi Khan. The idea was to compare the performance under different systems of management. The Watercourse No. 7665/L managed by a WUA located in Shahbazpur, Tehsil Alipur, Muzaffargarh District had 95 shareholders. A nearby SCARP tubewell (No. AP 366) in Punjaiwala Village located on Sabaliwala Distributary contributing to two Watercourses (7205/R and 6550/L) had a total number of 137 shareholders (51 on 6550/L and 86 on 7205/R). A private tubewell owned by Mr. Rahim Ali had five beneficiaries at the head of Watercourse No. 824/R Sultanwala, Phulan Tehsil Alipur. The shareholders irrigated through one out of every five consecutive turnouts were interviewed. However, the availability and capability of the respondents to answer the contents of the questionnaire were kept in mind while selecting the respondents.

DISCUSSION

The shareholders of Watercourse No. 7665/L, Shahbazpur were motivated to organize a WUA and improve their watercourse with the active participation of the shareholders. This WUA, was provided with a tubewell for installation at the head of the watercourse and a small agricultural machinery pool with OFWM-related implements, including land scraper, rigger, ditcher, border, disc, tractor operated rabi and kharif drills and chisel plough for their joint use under the management of the WUA.

The site for installation of the tubewell was selected by the WUA. The owner of the selected land donated one *kanal* (1/8 acre) of land to the WUA to install the tubewell. The shareholders of the watercourse arranged the well drilling at the site and contributed all the expenses in this connection. The concept of cost sharing through provision of labor (skilled and unskilled) by the shareholders and materials by the government under the Watercourse Improvement Programme, were utilized in installation of the tubewell, construction of a pump house and a water tank.

55 Percentages indicated against these reasons are not mutually exclusive.

Contributions of the beneficiaries in monetary terms created a sense of ownership and responsibility amongst the shareholders. It was experienced only in the case of tubewells managed by WUAs. All the members of the WUA considered the tubewell as their joint property. As indicated earlier, the tubewell operated by this particular WUA benefits 95 shareholders and it was operated for 1,182 hours during the last year.

After installation of the tubewell and handing over of the package of farm implements to the WUA, the management committee of the WUA was trained in book keeping, administration and management of tubewell and farm implements. The WUA had hired a full-time operator who permanently stays at the pump house and receives a monthly salary amounting to Rs 800 (US\$32).

The WUA fixed the tubewell water charges at the rate of Rs 45 (US\$1.8) per hour for tubewell with 1.80 cusec discharge as compared to the tune of Rs 60 (US\$2.4) for 1.25 cusec discharge charged by private owners. This rate has been fixed to generate the funds for the salary of a permanent operator, O&M and depreciation. Since sufficient funds are available with the association for operation, repair and maintenance, the tubewell is repaired quickly in case of any breakdown. The tubewell water is provided to the shareholder strictly at the time of their turn for canal water due to rigid *warabandi* (turn of irrigation) system. However, during canal closure periods, water is supplied on first-come first-served basis.

The shareholder intending to purchase the tubewell water deposits the amount according to his requirement on an hourly basis to the cashier of the association at least one day in advance to his turn/requirement. The cashier can keep an amount up to Rs 2,000 (US\$80) with him to cater to the current expenditure. Any amount exceeding Rs 2,000 (US\$80) is deposited in the bank. A joint account (A/c No. 1029) is being maintained in the names of the secretary and the treasurer of the association in the *Bani*. All members of the executive committee attend the office for one hour daily to enable the shareholders to place their demands for tubewell water or farm implements. The daily office opening schedule is widely publicized during monthly WUA meetings and is written on the notice board of the office of the WUA for the information of all the shareholders.

A sufficient stock of diesel, oil and lubricants are kept in store for avoiding shut downs of tubewell. In case the tubewell goes out of order, the operator informs the president of the WUA who arranges the repairs/spares immediately. The WUA tubewell was run from March 1991 up to the end of February 1992 for 1,182 hours with a total income of Rs 37,080 (US\$1,483) against overall expenses of Rs 36,202 (US\$1,448). Overall expenditure and income are given in Table 14.1.

The operation, management and maintenance of tubewell and implements through the WUA have made this institution viable, active and effective for undertaking other activities. All the shareholders of the association, under the case study responded positively to carrying out the activities besides watercourse improvement in order to convert it into a multi-purpose farmers' institution. All the shareholders are satisfied with the working of their WUA. About 95 percent of the shareholders work together for post-improvement maintenance despite there being eight types of different caste/social groups of farmers in the village. The meetings of the WUA are held regularly on the first Friday of each month and are attended by most of the shareholders.

The private tubewells are not essentially installed near the head of the watercourse, that is why the tubewells have lesser beneficiaries. There is no chance for the upstream shareholders of the watercourse to get water out of the tubewell as it is constrained by the slope of the watercourse. Such a private tubewell therefore, remains under-utilized.

The tubewell selected for this case study was located in the middle of the watercourse and has only five beneficiaries including the owner. The tubewell remained under operation during the last year only for 190 hours. The owner himself is handling the operation and maintenance of the tubewell and no independent person has been engaged by the WUA to operate the tubewell. The owner is not available most of the time as he is engaged in his personal assignments and the

shareholders cannot reach him to get water to irrigate their fields. This is another reason for the tubewell to remain under-utilized. When the private tubewell is out of order, the owner himself is responsible for its repair. He may not have the required funds and time to get it repaired immediately. It interrupts the irrigation schedule planned by the nearby beneficiaries.

Table 14.1. Monthly details of operation of WUA and SCARP tubewells, from 1991 to 1992.

Month	Water users association			SCARP tubewell monthly working hours			
	Working hours and income		Expenses (lubrication, etc.)				
	(hours)	(Rs)	(Rs)	1988	1989	1990	1991
Jan	0	0	700	981	354	236	20
Feb	15	686	1,357	00	290	210	127
Mar	8	225	180	472	252	10	00
Apr	121	4,035	3,291	339	6	30	00
May	128	3,853	4,967	190	2	20	00
Jun	140	4,202	3,812	00	00	00	00
Jul	98	2,969	3,128	00	00	00	00
Aug	226	7,079	4,913	00	00	00	00
Sep	8	289	1,394	00	00	00	00
Oct	214	5,989	4,700	00	00	00	00
Nov	23	704	1,540	360	340	00	00
Dec	201	7,049	6,220	131	20	112	255
Total	1,182	37,080 (US\$1,483)	36,202 (US\$1,448)	2,473	1,264	618	402
Net income Rs 878 (US\$35)							

Notes: SCARP = Salinity Control and Reclamation Project.

0 = No demand due to rains.

00 = Tubewell remained out of order.

Due to the monopoly of the owner, cooperation amongst the group is poor. It was noticed during this study that 83 percent of the respondents felt difficulty in getting water from private tubewells when they required. The water users of the privately owned tubewell spent less time for maintenance of their watercourse due to the inactiveness of the group as compared to the WUA included in the case study.

The third alternative observed under the case study is the SCARP tubewell, installed at the head of the two improved watercourses. It is run by the Irrigation Department under the SCARP Program. A full-time operator has been provided for the tubewell but he takes little interest in his work. Ashfaq (1981) also reported that very often some of the shareholders of the SCARP tubewells have not seen the operators at all. Moreover, some of the operators are engaged in private business rather than performing their own duties at the tubewell. Repairs of the SCARP

tubewells is a time consuming job. A lot of time is wasted on the decision making process by the government offices. Sometimes it takes even months before the SCARP tubewell is repaired. The tubewell water is provided to the shareholders strictly at the time of their turn according to Warabandi. A comparison of installation, operation and maintenance of three different tubewell categories observed under the case study is given in Table 14.2. The Table indicates that the tubewell operated by the WUA is more successful, economical and effective in terms of the hours operated annually and cost.

Table 14.2. Comparison of three tubewell operational modes in the case study.

Sr. Number	Details	Private tubewell	WUA tubewell	SCARP tubewell
1.	Source of power	Diesel	Diesel	Electrical
2.	Measured discharge	1.25	1.79	2.80*
3.	Designed discharge	na	na	4.00
4.	Annual working hours	190	1,182	1,108
5.	Utilization factor	0.026	0.16	0.12
6.	Beneficiaries	5	95	137
7.	Capital cost (based on 1991 prices)	Rs 45,950 (US\$1,838)	Rs 116,874 (US\$4,674)	Rs 1,033,785 (US\$41,351)
8.	Life assumed (years)	10	10	20
9.	Operating cost per acre-inch (Rs)	54.00	30.00	63.48
10.	Water rate charged from the beneficiaries (Rs/hour)	60	45	na
11.	Operating cost per csf per hour	48	25	na
12.	Water rate per acre-inch	74.38	79.90	na

* @ 70 percent of designed discharge.

Notes: na = Not available.

1 acre-inch = 1.03 hectare-centimeters.

WUA = Water users association.

SCARP = Salinity Control and Reclamation Project.

Possibility of disinvestment of SCARP was also explored in the case study in order to lessen the burden on the public sector. It was however observed that only 20 percent of the farmers had shown their willingness to take over the SCARP tubewells under a WUA with a cost of Rs 10,000 (US\$400) on annual installments of Rs 2,000 (US\$80). When their opinion was sought about engaging the same operator, they disagreed to do so due to high pay of the operators and their inefficient performance. The remaining 80 percent of the respondents disagreed to take over the tubewell due to high O&M costs, less cooperation amongst the farmers, poor efficiency of the tubewell and the heavy electricity charges.

RESULTS AND CONCLUSION

- i) The tubewell-owned and operated by the WUA supplies irrigation water at 30 percent less cost as compared to that of private tubewell.
- ii) The availability of water to shareholders is ensured by WUA according to the demand as compared to private tubewells where it depends on the good will of the owner and SCARP tubewells where it is attributed to luck.
- iii) Repair and maintenance of the WUA tubewells is quicker due to social and obligatory pressure of the shareholders as compared to the financial and time constraints of private owners and bureaucratic approach of the public agencies in case of SCARP tubewells.
- iv) The WUA tubewell operator, being an employee of a private entrepreneur or a nongovernmental organization (NGO), is bound to perform his duties punctually as compared to private tubewells where the owner has to perform his duties himself. In case of the SCARP tubewell operator, his salary and services are protected by the government irrespective of his absence from duty. Accordingly, this operator is far less efficient than that of the WUA.
- v) Involvement of the WUA in operation of the tubewell enhanced cooperation amongst the shareholders and thus made the WUA more active, effective and viable for taking up other activities like maintenance of watercourse, irrigation scheduling and use of implements. This, in turn resulted in better and efficient use of available water leading to increased crop yields. The WUAs are also capable of generating their own funds to carry out functions such as operation, management and maintenance of small-scale community irrigation, drainage schemes, operation of machinery pools and distribution of nonwater agricultural inputs, thus ensuring their sustainability.

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Comparative Assessment of Farmer-Managed and Agency-Managed Groundwater Irrigation Schemes in Nepal

N. Ansari⁵⁶

SYNOPSIS

NEPAL'S NATIONAL DEVELOPMENT plans have been targeting to turn rain-fed farming into irrigated agriculture in order to meet the food production needs. As surface water is not available everywhere and in required quantities all year round to increase the cropping intensity, responsible agencies of the government have been engaged in the development of groundwater irrigation schemes in the Terai and some inner valleys which have quite rich and rechargeable aquifers. However, various constraints are encountered in the implementation and management of groundwater development through deep tubewells (DTWs). On the other hand, during the last two decades a lot of shallow tubewells (STWs) have been installed by farmers themselves with the assistance of the Agricultural Development Bank of Nepal (ADB/N). The farmers draw water for irrigating their nonmonsoon crops and even during the monsoon period when the rains fail. The performance evaluation of these privately operated STWs has shown that the national average is only 2.0 hectare (ha) of irrigated extent per well as against 4.0 ha potentiality. It is because landholdings are smaller and neighboring or small landholdings do not have access to these private STWs. However, some operators do sell water to the neighboring farmers. Table 15.1 shows the present irrigation status of Nepal.

The agency-built and operated DTWs on large-project scale are performing better than the jointly managed DTWs on small scale, but the former is constrained by operation and maintenance (O&M) cost recovery. Recovery is so low that the sustainability of such schemes is at risk. The government policy is that at least O&M costs must be borne by the users but they are not willing to bear these costs. Hence, the agency has evolved a strategy to pass the O&M of the DTWs to the organized water user groups (WUGs) by stages. The sustainability issue and lessons learnt have been instrumental in changing many irrigation activities in Nepal. Now DTWs or community STWs are undertaken on the basis of meeting 75 percent of the costs by the agency. The remaining cost is shared by the users while the O&M is exclusively the responsibility of the users.

⁵⁶ Ministry of Water Resources, Nepal.

Table 15.1. Total irrigation coverage (net in '000 ha).

Region	Total cultivated area	Rain-fed area	Irrigated areas			
			Agency-managed schemes (AMIS)	Agency-assisted but FMIS	FMIS	Total
Mountains	227	193	–	15	29	44
Hills	1,055	867	15	28	153	196
Terai	1,359	638	252	161	308	721
Total	2,641	1,698	267	204	490	961

Notes: AMIS = Agency-managed irrigation systems (i.e., Department of Irrigation).

FMIS = Farmer-managed irrigation systems.

GROUNDWATER DEVELOPMENT FOR IRRIGATION

Need to Exploit Groundwater

Surface water is not available everywhere for supplying water to the potential irrigable areas. Also, existing gravity irrigation schemes are not able to meet the irrigation needs for multiple cropping. The climate is not favorable for farming all the year round to increase the cropping intensities. Hence, mostly the existing surface schemes fulfill the irrigation need as supplementary irrigation during the rainy season (monsoon) extending from June to September. Thereafter, the discharge of supply canals drops restricting water supplies to a limited extent of the command area for growing crops in other seasons. Under the circumstances, the exploitation of groundwater becomes inevitable. Fortunately, the Terai region and some of the inner valleys have rich and rechargeable aquifers both shallow and deep. In such areas groundwater can be harnessed for conjunctive use as well. In the areas where surface water is inadequate, groundwater will be the main source of irrigation. It is fully recognized that greater use of groundwater for irrigation would substantially raise the cropping intensities and incomes of the farmers. Now the farmers are being encouraged to install tubewells for supplementary irrigation of monsoon crops and full irrigation of dry season crops. Diversified cropping is introduced in tubewell schemes as there is an assured supply of water within one's control.

Historical Perspective

Surface Farmer-managed irrigation systems (FMIS) having a long history are very prominent in Nepal. Varied types of irrigation systems of all sizes have been built centuries ago. They are operated and maintained by the farmers own cooperative efforts. More than three decades ago groundwater use for irrigation was unknown except for some localized dugwells utilized for growing vegetables. But during the last two decades, the need to increase cropping intensities, has induced the farmers to install STWs of their own by tapping shallow aquifers, where available. There are some open dugwells also where static water table is high. Here farmers extract water by *suction* lift (centrifugal) pumps to irrigate the crops of their choice. Side by side with these

private STWs, government agencies have also developed quite a number of DTWs on a large-scale as well as on small-scale projects.

AGENCY- AND FARMER-MANAGED GROUNDWATER IRRIGATION SYSTEMS

Farmer-Managed Groundwater Irrigation Systems

Such systems mostly consist of STWs which are maintained and operated by the individual farmer or by a group of farmers. The ADB/N has played a pioneering role in the promotion of STW irrigation by providing financial assistance in the form of rural credit and technical assistance to a limited extent. ADB/N in accordance with its mandate has been involved in irrigation development since the 1970s. It has provided credit to individual farmers, small groups of farmers and communities mostly for installation of STWs and procurement of pumpsets. Besides treadle pumps and rower pumps, dugwells are being propagated in the Terai belt. Now thousands of hectares of farm lands are being irrigated utilizing the immense groundwater resources of the country.

Individual STWs

The government has fully encouraged the tubewell irrigation program by providing a subsidy to the farmers. The subsidy is administered by the ADB/N along with their lending. A short description of the program is given below:

- On the request of a farmer or a group of farmers, technical and geo-hydrological data are collected. The Groundwater Development Board (GWDB) under the Department of Irrigation (DOI) is responsible for groundwater exploration and groundwater resource evaluation. For any area, if sufficient data are not available then layer testing for shallow aquifers are done to assess the prospect of STWs.
- Then the applicant has to place all the documents and clearances for providing collateral to obtain the loan sanction. After the loan sanction, a loan agreement is signed between the farmer and the ADB/N.
- Pipes and other materials are supplied from the stock to the borrower farmer. If the field office does not have a stock, then a coupon is provided to acquire materials from the dealer. After successful drilling the value of materials is automatically converted into loan. If the farmer wants, he is given an additional loan for the pumpset.
- Specified drillers carry out drilling on work order from the ADB/N. Mostly the hand rotary drilling process is used. Depending on physical conditions of the Terai area average time taken is generally 5-10 days. One year's guarantee is provided by the driller during which period ten percent of the payment is retained. In general, drilling is tried at three places and if the attempts are unsuccessful it is considered to be a failure.

Community STWs

In small farmers' development program (SFDP) areas, small farmer groups are provided loans for STWs as community schemes. Farmers in one locality having at least 4 to 5 ha in holdings adjoining each other should form a group and approach the SFDP office for a loan and technical assistance for an STW unit. SFDP loan is provided on group collateral alone and the entire loan is recorded against the beneficiary group. The group repays the loan and the interest.

Group STWs

In areas where SFDP is not implemented, farmers with small landholdings form into groups for the purpose of obtaining loans for STW schemes. The process of getting a loan is same as in the case of an individual borrower. The collateral of each member is evaluated and loan instalment is divided among beneficiaries in proportion to the land irrigated. Loan amount is recorded separately for repayment. There are cases where a loan is taken in the name of one member of the group and divided among other members as well through internal arrangements. In the circumstance, ADB/N deals with one individual only.

Subsidy in Groundwater Schemes

Since the commencement of the implementation of groundwater tubewell schemes, subsidies have been provided by the government in various forms. In the initial days only drilling cost was subsidized. But during the last few years 40 percent of the total cost of the STW schemes including pumpsets is subsidized in case of individual schemes and 75 percent in the community schemes. Earlier, the subsidy was reimbursed by the government to ADB/N each year but now the total subsidy for irrigation is allocated in the national annual budget which is administered by the ADB/N and other agencies which implement the schemes.

Technical Characteristics

The depth of STWs varies by district and locality. Within 21 districts where STW irrigation schemes have been developed, the depth of wells vary between 8 to 50 meters (m) with an average of 20 m. Generally, the size of a bore is 4 inches (10 cm) in diameter and black casing pipes and strainers are used for these STWs. They tap shallow unconfined and semi-confined aquifers. All the STWs are drilled by simple indigenous methods like manual rotary, sludge and bogie. In case of DOI sunk STWs, rotary drilling machines were invariably used. The method of sinking a well depends upon the type of soil strata and depth up to which one has to go. All the wells are operated by diesel centrifugal pumps with horsepower (hp) capacities varying from 5 to 10 brake horsepower (bhp) (average of 6 bhp). In places where electric power is available farmers are desirous to electrify their units. In most districts the static water table drops down during the dry season when STWs are operated. But at the end of the rainy season it is recovered to the original status. It is estimated that by now more than 22,000 STWs are installed. Table 15.2 shows characteristics of STWs in summary form.

Agency-Managed Groundwater Irrigation Schemes

In the public sector groundwater exploitation for irrigation started in the 1970s. During 1975/1977 in the middle eastern Terai of Birganj area some 28 DTWs were installed with electric pumps in the northern part of Narayani Irrigation Project which is devoid of gravity water supply from the

canal. This includes rehabilitation of 14 DTWs drilled earlier and equipped with diesel engines. Earlier in 1968/1969 under the Minor Irrigation Program some DTWs were drilled and equipped with diesel-run turbine pumps in Sarlahi and Sirha districts and some artesian wells in Bhairahawa District. Birganj DTWs are equipped with submersible pumps with 25-30 m lifts capable of pumping 50-80 liters per second (lps). Here the net irrigable command area is 2,792 ha. All the main distribution canals are lined and have several division boxes.

Table 15.2. Characteristics of shallow tubewell units.

Valleys	Sample survey (1987/1988)	Sample survey (1990/1991)
Number of STW units	554	30
Number of pumpsets owned	352	30
Districts covered	18	6
Depth range (m)	8-50	8-35
Average depth (m)	60	47
Size of boring (casing)	10 cm	10 cm
Pumpsets	centrifugal (diesel)	centrifugal (diesel)
Horsepower range	5-10 bhp	5-8 bhp
Method of drilling	Manual rotary and rig machine	Manual rotary, sludge and bogie
Time to drill	5-10 days	5-10 days
Crops grown	Rice, wheat, maize and vegetables	Rice, wheat, maize and others
Hours of operation	119 hours	168 hours
Average irrigation per unit	2.18 ha	1.85 ha
Discharge (lps)	6-25	6-20
Cropping intensity	156% (19% increase)	241% (54% increase)

Note: STW = Shallow tubewell.

A large-scale tubewell irrigation scheme called Bhairahawa-Lumbini Groundwater Project (BLGWP) was undertaken during 1976/1983 in the western Terai where 64 DTWs, pumphouses and independent partially lined distribution channels for each well were constructed. The total irrigated area covered by the project was 7,600 ha. On an average, each unit commands a net irrigable area of 120 ha. All the units are equipped with electric pumps capable of drawing 83 to 140 lps. The depth of wells vary from 120-200 m. The water is discharged into a tank and then distributed into canals. The canals which are lined run approximately for about 400 m. Along the canal there are about 20-25 wooden slide gated turnout structures each controlling the irrigation of a 5 ha block. The cost of the project was Rupees (Rs) 256.22 million in 1984 and was financed by an IDA loan. This indicates a per hectare cost of Rs 33,000. Under the second phase of BLGWP some 38 DTWs have been recently brought under operation making altogether 102 DTWs units in the project area. Under the third phase, distribution of water will be done through buried pipe circuits.

Another large groundwater project was launched in 1971 with Japanese assistance in Janakpur Zone under the banner of Janakpur Agriculture Development Project (JADP). Under this program, exploitation of groundwater was concentrated only in three districts, namely, Dhanusa, Mahottari and Sarlahi where actual work on tubewells (TWs) started from 1985. Initiation of TW irrigation including site selection and deciding the number of wells to be drilled in an area, was solely accomplished by the JADP authorities. Although sites were proposed by the Japanese technicians, in practice the Ministry dictated site locations and plans of DTWs. Users came to the picture only when the question of land for pump houses and canals arose. Such lands were to be provided free of compensation. Due to dictated site fixations, drilling of DTWs was mostly done at places where utilization is not at its maximum. Influential people got TWs into their land and common farmers had no voice in any decision making. By the end of 1990 some 81 DTWs had been installed with a capacity to irrigate about 4,200 ha.

Another high potential area for groundwater development is Kailali and Kanchanpur districts of farwestern Terai where DOI has installed 82 DTWs. By now some 400 DTWs units are already installed in Terai districts capable of irrigating 28,000 ha. The details of their distribution is given in Table 15.3.

Table 15.3. Groundwater potentiality and exploitation.

Region	District	Potential of tubewells		Tubewells installed by 1990/1991		
		STW	DTW	By DOI	By others	Total
Eastern	Jhapa	10,546	12	6	1,533	1,539
	Morang	8,950	60	18	1,346	1,364
	Sunsari	3,400	153	53	1,762	1,815
	Udaipur	1,900	–	130	710	840
	Saptari	3,204	24	1,540	1,162	2,702
	Sirha	6,158	12	1,055	1,043	2,098
	Dhanusa	2,376	83	–	1,096	1,096
	Mahottari	3,344	88	16	625	641
Central	Sarlahi	3,780	139	–	1,321	1,321
	Rautabati	2,952	171	20	795	815
	Bara	2,971	242	–	1,357	1,357
	Parsa	2,598	154	–	200	200
	Chitwan	Investigation under progress		–	17	17
Western	Nawalparasi	2,112	45	2	194	196
	Rupandehi	3,204	227	–	1,222	1,222
	Kapilbastu	3,967	46	49	244	293
Midwestern	Dang	1,510	40	461	10	471
	Banke	1,788	19	–	718	718
	Bardia	3,798	141	–	836	836
Farwestern	Kailali	4,860	79	497	1,160	1,657
	Kanchanpur	2,392	79	603	831	1,434
						22,632

Notes: STW = Shallow tubewell. DTW = Deep tubewell.
DOI = Department of Irrigation.

MANAGEMENT AND PERFORMANCE

Farmer-Managed Groundwater Schemes

During the last two decades very heavy public expenditures have been incurred to motivate farmers in installing private STWs and pumpsets. Sample surveys of their performance and management have revealed that utilization of water and areas actually irrigated are much less than their potentialities. Generally, pumps have operated for 100-200 hours and irrigated only 2-3 ha varying considerably between locations. Therefore, the social returns do not commensurate with the government's expenses in supporting STWs. Also, benefits from the support do not reach the poorer rural communities equitably as they have small landholdings or are even the landless.

Condition of the Systems

The STW units are mostly located at higher elevations of the service area in order to facilitate distribution mostly through earthen field channels. Some farmers have permanent channels whereas others dig temporary ones to irrigate winter and dry season crops. During the rice season field-to-field irrigation which is definitely inefficient, is practiced. Even the sandy channels are not lined. Generally pumps are not installed permanently in sheds and do not have fixed foundations. They are brought to the STWs at the time of pumping. However, some farmers have constructed pump houses and division boxes. The discharge available from most of the wells is between 6 to 25 lps. In some areas the discharge decreases during the dry season. But within the monsoon season the static water table rises by 1.5 to 2 m enabling a higher discharge from a well. It is observed that an STW giving a discharge of 10 lps can irrigate 6.0 ha of farm lands if it is operated on an average of 12 hours per day during peak demand of the rice growing period.

Irrigation Practice

In most cases it is found that the STW operators use water to irrigate winter and spring crops (wheat, maize, vegetables, etc.) and rice seedbed. They use STWs when monsoon fails or when rains do not occur for a long time. In localities where supplementary gravity canals are not able to serve the full command or do not supply water during the lean period, farmers are motivated to use STWs for conjunctive use. This explains the low total annual hours of operation of an STW. The sample survey of 1988 has shown that the average STW operation was 120 hours whereas survey of 1991 shows an operation of 168 hours annually. In the former case the cropping intensity had increased by 19 percent while in the latter the increase is 54 percent mainly due to the expansion of area during the dry season to grow crops such as wheat, maize and vegetables. The average irrigation per unit STW was 2.18 and 1.85 ha, respectively, during the two surveys.

Operation and Maintenance

Operation and maintenance of the systems are carried by the individual owners including general maintenance of the pumpsets. Where the STWs are installed with ADB/N assistance, some owners have taken maintenance training. However, for major defects in pumps, they have to go to mechanics. In most systems the water use efficiency can be increased by making permanent field channels, controlling leakage by lining, etc.

Agency-Managed Groundwater Irrigation Systems

Government agencies operate and manage two types of DTW irrigation schemes, i.e., DTWs on large-project scale and DTWs on small scale. The former provides a more structured approach to groundwater development for irrigation. The experience of this type with BLGWP indicates that it can generate relatively high benefits because of specific agricultural support programs and water management activities. They have also been successful in achieving the targeted production and effecting the full utilization of the command area. Also the operating costs are minimized by use of electricity. However, high per hectare cost prohibits widespread adoption of this approach. The second type, DTWs on small-scale model, comprises localized single DTW units. Such units serve 60 to 120 ha and are equipped with permanent pump houses and distribution systems. These can also generate benefits comparable to large-project scale DTWs. However, the major difficulty here is the very low level of utilization of the command area as the farmers are not willing to bear the operating costs.

Agency-operated and -maintained DTWs are scattered in different districts of the Terai. The O&M of these DTWs are being carried out by different agencies in different ways. DTWs of some larger projects are fully operated and maintained by the concerned agency whereas some DTWs are operated jointly by users and the agency. DTWs of most of the small projects are operated by the beneficiaries but maintained by the agency. Taking into account these factors, management and performance of some of the DTW projects are indicated below:

Performance and Management of the Systems

The performance of the systems are summarized in terms of actual irrigated area by seasons, annual operating hours and irrigation intensities.

- i) The 28 DTWs under Birganj GWP is being fully managed and operated by the Narayani Irrigation Development Board (NIDB). Earlier the water service charge was levied on the basis of time of pumping demanded by a farmer. But a few years ago a flat rate of Rs 400 per ha per year was fixed. A farmer may use pumped water at any time and in any quantity; he has got only to request the operator to supply water. Still the cropping intensities have not increased as anticipated. The total command area is never irrigated. The net irrigation has been nearly 70 percent in the case of old (but improved) DTWs and 75 percent in the case of new ones. Corresponding per unit operation of DTWs averaged 600 and 450 hours. It is to be noted that average discharge of old wells is between 50 to 80 lps whereas in new wells it is 80 lps. The payment of water charge is below 50 percent and the O&M costs are subsidized.
- ii) All the DTWs under BLGWP Stage I (64 units) and Stage II (16 units) are fully operated and managed by the project itself. Here also a flat water charge of Rs 400 per ha per year is levied. Up to last year it was only Rs 200. The performance evaluation of BLGWP Stage I has shown that 89 percent of the holdings in the command area is getting water for partial/full irrigation, while the remaining 11 percent is still kept under rain-fed conditions. The percentage of irrigated area is slightly higher in larger farms. Efficient and controllable water management with effective agricultural support built directly into the project has made the Stage I area achieve full development within four years. The cropping intensity, yields and extent of crop diversification into high value crops have exceeded the appraisal estimates. Appraisal estimated that cropping intensity would increase from 118 percent to 165 percent and yield of rice from 2.0 tons per ha to 3.5 tons per ha. However, the real achievements from the project recorded 190 percent cropping intensity and a yield level of 4.0 tons per ha. In the Stage II area the

38 DTWs are being provided with polyvinyl chloride (PVC) buried pipe distribution system to overcome shortcomings in the open-channel system. At present all WUGs are actively involved in the distribution and allocation of water while the O&M is the responsibility of the project.

The payment of water charge last year was negligible due to the rise of the rate to Rs 400 per ha per year although this amount is only a fraction of the actual O&M cost. The government cannot go on bearing the full O&M cost for ever and therefore it is the policy of the agency to turnover the O&M of all the DTWs to WUGs. In the beginning, it is planned that users should pay only the electricity bill and the government will provide operators and the maintenance cost.

- iii) The JADP DTW systems are being managed jointly with the beneficiaries. The very approach to provide a DTW system to a community was to organize farmers to take the responsibility of managing it after completion. But the community was not consulted in introducing the system into the area. Politicians took the lead and WUGs could not be evolved to take up O&M of the systems which have been turned over to them after commissioning. WUGs are told to manage water distribution and, conflict resolution, adopt cropping patterns, provide diesel and lubricants, hire operators and watchmen and do minor maintenance work. However, it is not effective because the implementation process did not embrace any norms to promote WUGs as institutions of the farmers in creating feelings of belonging right from the beginning.

JADP has equipped the DTW systems with Japanese diesel-driven engines EBAR and FIAT. They consume 10 and 6 liters of diesel per hour, respectively. This cost cannot be borne by all farmers in all seasons. Hence, there is very poor utilization of the wells. They use it only for supplementary irrigation during critical times. On an average, about 30 percent of the users of a system irrigate once in the wheat season and once at the time of rice seedbed preparation. The WUGs feel that they would be able to operate the system in full when the DTWs are run by electricity.

The operation of DTWs together with their management is accomplished by the project which levies the water charge in two ways. Under the first system the user is required to pay Rs 16—only a fraction of the fuel cost—prior to pumping. Under the second, Rs 10 is payable for lubricants and the required quantity of diesel should be supplied by the user.

- iv) The SIRDP and Kailali-Kanchanpur DTWs are now operated jointly but maintained by the groundwater project of the DOI. The development approach of these DTWs was not participatory. Except for site selections, the farmers were not involved in nor were they informed of any matters during implementation. The project did not ask for any help or contribution, nor did the farmers do anything for the project. This was so because of the tradition of DOI of doing irrigation work unilaterally. The officials did not know that the O&M of these DTWs would be transferred to the users; similarly, the users were unaware of it. Now, the project has organized WUGs in each unit and asked them to operate it by themselves. Farmers are getting organized and developing norms to operate the systems. At some places users have generated funds to hire operators. All the wells are equipped with diesel-driven and battery-operated engines which are either of Japanese or Indian origin. Japanese engines consume 6 to 8 liters per hour (l/hr) whereas Indian ones consume 4 to 6 l/hr. The average discharge of the DTW is 30 to 60 lps. The record of utilization is not kept systematically. The method of operation is to bring diesel and give a nominal charge for lubricants (up to Rs 5 per hour) and get water. Farmers feel it to be very costly and they restrict irrigation as indicated earlier.

On an average, only 30 to 40 percent of the command area is irrigated. The field officers have nothing at their disposal to promote and facilitate utilization.

- v) There is a successful example of jointly developed DTWs but operated and maintained by the users alone. Dang Tubewell Project is a case in point. Three DTWs have been installed on the request of the farmers who undertook the full responsibility for O&M. The WUGs were actively involved in all the activities of implementation and during this process a feeling of ownership developed in them. They have now electrified DTW units with nice pump houses. However, their main distribution canal is still unlined for which task they are prepared to contribute 25 percent of the cost. They have approached the DOI to get the lining done. The DTWs are fully operated and maintained by the WUG of each unit and all the beneficiaries are assured of water to their satisfaction. Last year, the winter crop (mustard) yielded 4 times more with just one irrigation. During the rice growing period they pumped water as and when needed mostly at the peak season. They hire their own operators and pay electric bills which they raise on a pro-rata basis.

NEW APPROACH FOR SUSTAINABLE GROUNDWATER IRRIGATION

The performance of agency-managed DTWs based on large projects is better than DTWs of small projects. However, the recurrent cost recovery is so meager that their sustainability is endangered. The government cannot solely go on providing funds indefinitely for the O&M of these systems. Also, it would be an injustice to a large number of farmers who are operating their STWs after having shared a part of the capital cost of construction. Hence, the new policy of irrigation development specifies to transfer the O&M of the DTWs to the WUGs which have to be organized and registered under the prevalent rules. The transfer of this responsibility will occur gradually in stages. Initially the electricity bill or fuel cost shall be borne by the users. With the capacity build up, the full responsibility of O&M will be turned over to these WUGs. At present, the BLGWP is working on this policy where increasing roles are entrusted to the WUAs for water management, distribution and adoption of cropping patterns, whereas primary responsibility of O&M remains with the project. A full program is launched to promote institutions and capabilities associated with WUAs in order to convert all the DTWs to farmer management. However, there is great reluctance on the part of the farmers to take over the systems as they have had the privilege of being free riders from the beginning.

Sectoral Approach for Groundwater Irrigation Development

In retrospect, irrigation activities have now changed the main focus toward the issue of utilization and sustainability. Presently, all TW schemes are taken up on the basis of locally felt needs and demands as against the traditional supply-oriented systems. In the present context, the users are deeply involved, right from the initiation of the scheme, in contributing partly to the capital cost of construction of TWs and related structures and there is also a firm commitment of taking the responsibility of management and O&M. Since the last three years, STWs, medium tubewells (MTWs) and DTWs are making headway in the western Terai under Irrigation Line of Credit (ILC) Program assisted by the World Bank. Here, a cluster of TWs are initiated based on the genuine demand of the farmers in areas where rich groundwater aquifers exist. Farmers have to form a WUG for each unit. For a group or a cluster of TWs a farmer irrigation association (FIA)

would have to be established and registered to get legal status. Through an agreement between the DOI and the FIA, the responsibility and obligations of each party are clearly spelt out and fixed. The users mostly contribute toward the construction cost of the well and to the water distribution system. The share amount is fixed so as to ensure their commitment to construction and ownership responsibility and afterwards to the O&M of the completed TWs. Under this program users of an STW have to provide the pump and construct the distribution channels with materials provided by DOI while the TW is installed by the DOI under the subsidy scheme. In case of MTWs and DTWs contribution consists of an "outright" cash deposit (usually 5 percent) of the cost together with labor and land required for the distribution system. If an access road is desired for the cluster of wells, then the land for the purpose is provided by the FIA free of cost. The latter pays compensation if a land belonging to a non-beneficiary is acquired.

In the case of STWs, which require machine drilling, e.g., deeper than 20 m, it will be taken up under this program. Shallower STWs which can be installed by hand drilling will be normally handled by the ADB/N-STW Program.

In the coming years, quite a large development of conjunctive use of groundwater with surface water is anticipated owing to the longer gestation periods associated with larger surface schemes since their inception.

DISCUSSION

Historically, irrigation in Nepal was confined to gravity canal systems. People do not have much knowledge and experience of lifting groundwater for irrigation. One of the reasons for the slow progress of the exploitation of groundwater is the expectation of the farmers that the TWs will replace surface water use for irrigation. In fact, there is a vast difference between irrigation practices used by farmers utilizing surface water and those who use TWs for irrigation. Hence, awareness should be created not to conjoin TW irrigation with gravity canal water which is less costly and abundantly used. In general, TW irrigation development has greater chance of success if it is based on real locally felt needs and demands. That is why all the STWs that are installed at the initiation of individual farmers are working well. MTWs installed on group demand and on a cost-sharing basis have an in-built element of a sense of ownership as well. All the TWs of this type are farmer-managed and hence better utilized to grow diversified crops including vegetables and cash crops.

The DTWs on large- and small-project scales generally came to an area in the form of a top-down process. The agency personnel in these projects always worked with irrigation development targets in view. Hence, the engineering component was the decisive factor in planning and implementation and the sustainability aspect has been overshadowed. Beneficiaries were not involved from the beginning as WUAs could not be evolved *pari passu* as a body to operate and utilize the system created.

STWs are preferred and would perform better where shallow and rich aquifers are available up to a 20 m depth and also with a shallow static water table which enables farmers to pump the required discharge by a suction lift pump only. Generally, an individual farmer should initiate to own and operate an STW. If his landholding is not large, then a few farmers need to form a group to own an STW. Such STWs are encouraged where farmers are growing cash crops, vegetables and multiple croppings and where a market is available. They are also promoted where the gravity canals are inadequate to fulfil the irrigation functions or where entrepreneur farmers want to grow crops in nonmonsoon seasons. Factors such as the relative management burden, ease of implementation and cost effectiveness and availability of rich aquifers, motivated farmers of Terai Nepal into widespread use of STW irrigation. STW is attractive even for a farmer having 1.0 ha

of landholding. However, group ownership is needed to expand the per unit service area in order to permit small holdings to be benefitted from STW irrigation, thereby, promoting its wider adoption.

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Capabilities of Water Users Associations in Managing Groundwater Pump Irrigation: A Case Study from East Java, Indonesia

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ABSTRACT

MAJOR ISSUES RELATED to the enhancement of benefits from groundwater pump irrigation are resource fixity, size of investment, and costs of transaction associated with effective decisions and operations of Water Users Associations (WUAs). Sustainability of a groundwater pump irrigation system depends to a large extent on the adaptive and innovative capacity of a WUA. This paper outlines the process of adaptation and innovation of WUAs in responding to resource fixity, size, and costs of transaction based upon a case study of groundwater pump irrigation systems in East Java, Indonesia. Based upon organization performance such as pump working hours, areal utilization index, and WUA's savings and revenue, the adaptation and innovation capacity of the WUAs were evaluated and classified. The process of adaptation and innovation is analyzed with reference to crop selection and diversification, water price fixation and pricing procedures, increase of savings, management of external agents and structural changes. On the whole, this research concludes that learning capability of WUAs to recognize the problems, and to find and execute alternative solutions is one of the most important factors pertaining to the sustainability of groundwater pump irrigation.

INTRODUCTION

This study is limited to groundwater pump irrigation (hereafter pump irrigation) provided by the Government of Indonesia through a Groundwater Development Project (GWDP) operated by the Department of Public Works. Even though there is a wide range of pump irrigation schemes, the government of Indonesia plays a significant role in the development of deep well pump irrigation.

Groundwater pump irrigation development project provided by the Indonesian Government was initiated in East Java in the early-1970s. By 1990 Indonesia had 853 groundwater pump irrigation schemes (GWPIs) of which 604 were in East Java and the rest distributed in Central Java, West Java, Yogyakarta, Bali, West Nusa Tenggara, South Sulawesi and Central Sulawesi. Out of 604 schemes in East Java, 504 were deep well, 60 intermediate well, and 40 were shallow

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well. The total extent of pump irrigated land in Java are 23,380 hectares (ha), 422 ha, and 144 ha for deep well, intermediate well, and shallow well, respectively (Pakpahan et al. 1992). Even though the pump irrigated land in East Java is only about 2.6 percent of total surface irrigated land in this area, the pump irrigation in East Java serves the largest and oldest areas relative to other regions. Therefore, East Java can be treated as a good social laboratory for studying the dynamics of groundwater irrigation organization (Pakpahan et al. 1992).

Pump irrigation has been turned over to a water users association (WUA) created by the government, after obtaining services for two years from the project. The WUA should provide operation and maintenance (O&M) costs. In addition, the WUA is usually responsible for replacements. A logical consequence of this development is that the WUA has become competent to handle the problems associated with O&M and replacement. Although WUAs have no previous experience in managing GWPI, their adaptability and innovative ability have become the key factors for sustainability of the pump irrigation schemes. This paper seeks to analyze the successes or failures of WUAs in managing the resources vis a vis the prospects for sustainability of pump irrigation.

NATURE OF GROUNDWATER PUMP IRRIGATION

Pump irrigation is characterized by relatively high fixed costs, resource fixity, and considerable costs of transaction. The high fixed cost is reflected by high construction costs. For example, the total cost of deep well construction in East Java in 1990/1991 was Rupiah (Rp) 64.3 million (US\$33,840) (Pakpahan et al. 1992). The fixity of resources is indicated by the immobility of the pump and command area. This situation implies that the distribution of surplus is determined by the condition of canals throughout the command areas. Finally, managing the pump irrigation, namely, allocation of resources, distribution of outputs, maintenance of irrigation facilities, handling risks and uncertainty, and so on are not without costs. For an organization, the most important cost is costs of transaction, namely costs of managing internal affairs (coordinating all input suppliers) and costs of conducting external affairs. Such costs include exclusion costs, information costs and contractual costs (Schmid 1987).

Resource fixity, size of investment, and transaction costs of pump irrigation have a direct bearing on the organizational tasks. As indicated above, resource fixity has implications for distribution of surpluses or land rent. Immobility of asset and land rent differential provide opportunities to maintain water price discrimination depending on the location.

Size of investment implies the cost structure associated with the organization. The higher the size of investment, the larger the output required. It means a certain size of operation should be achieved for the investment to be economical. Otherwise, it will be too costly to operate the pump. This implies that the entry of customers into and the exit from a pump irrigation system have their repercussions on the organization. In other words, exit will create losses to the organization, therefore, to be sustainable the organization should be able to manage the problems associated with the exit of customers with the support from other participants.

The most important activity in any economic venture is transaction. Within the organization transaction is governed administratively, and between organizations transaction is conducted through the market process. Nature of the goods will affect the kind and magnitude of costs of transaction. High exclusion cost which is associated with nature of the goods will increase the free rider problem. Information problem will increase disputes. The higher the intra-organizational transaction costs, the lower the real output produced by the organization and the real value of the output transacted. Therefore, volume of the goods being transacted will decline. Differences in decision rules adopted by an organization will create different performance

of the pump irrigation as far as they have different abilities to control sources of interdependencies such as resource fixity or immobility, economies of size, and transaction costs.

Nature of groundwater is spatially not homogenous. We classified groundwater into deep aquifer and shallow aquifer and volcanic terrains and limestone terrains. Within these categories, we focus our study on pump irrigation in the regencies of Kediri and Nganjuk which represent volcanic terrains, and Madura Island which represents limestone terrains.

WUA PERFORMANCE

The capabilities of the WUAs are determined on the basis of their achievement (performance) that has a strong bearing on the sustainability of a pump irrigation system. Resource allocation is very significant in this context.

Resource Allocation

Land Utilization Index (LUI) and Pump Operation (PO)

Performance of resource allocation in pump irrigation is indicated by LUI and PO. LUI is defined as summation of irrigated land throughout a year divided by designed area, and PO is defined as pump working hours per year. Both LUI and PO reflect the capabilities of WUA in dealing with pump size, resource immobility, and transaction costs. The lower the value of LUI and PO given a certain size of investment, the lower the capabilities of a WUA.

Table 16.1 shows that high performance of pump irrigation utilization has been achieved by tubewell TW66 in Madura with LUI 2.35 and PO 2,395 hours, while the lowest performance has been found in TW174 in Nganjuk with LUI and PO 0.68 and 446, respectively. These figures correspond to values of cropping intensity, namely 295 percent and 167 percent for the earlier and the latter case, respectively.

This finding implies that the organizations which are characterized by low LUI and PO have low capability in managing areas of operation, therefore, they cannot control size of investment and immobility of assets. In general, WUAs that run deep well pump irrigation has better performance than that of organizations associated with shallow aquifer environments. Such environments create difficulties for the organization to deal with exit of the customers due to the entrance of private pumping into the areas or farmers investing on pumps in their own land. Even though there is a legal base for protecting the boundaries of the organization, the current performance implies that the existing transaction costs are too high to be enforced relative to the value of commodities being considered.

Conflict Resolution

Management of pump irrigation is management of conflicting interests. Conflicts between current and future generations can also arise as a consequence of scarcity of water resources. In general, where markets do not exist, conflict resolution over water resources is usually accomplished by administrative processes such as the preparation of water distribution schedules across blocks of irrigation. The higher the degree of scarcity, the higher the demand for administrative capacity.

In pump irrigation, the effective demand for water is reflected by LUI. Low LUI means low effective demand for pump irrigation water (low effective demand for water does not mean low need or low availability of water). It also means that a low degree of administrative procedure is required. For example, instead of the WUA creating a tight schedule of water distribution, water

allocation is performed on the first-come first-served basis. Nganjuk is a case in point where this basis is preferred to block scheduling. On the contrary, in Kediri and Madura where LUI is quite high, water is allocated according to a block schedule.

Table 16.1. Designed extent, LUI and PO according to aquifer and location in East Java, 1991.

Aquifer/location	Code	Areal design (ha)	LUI	PO (hour)
<i>Deep well</i>				
Nganjuk	TW152	43.93	1.29	1,751
	TW174	44.12	0.68	446
Kediri	TW10	49.21	1.40	2,120
	TW61	37.95	2.00	1,389
Madura	TW09	23.50	0.81	950
	TW66	44.20	2.35	2,395
	TW97	32.70	2.00	2,018
	TW102	32.30	1.80	658
<i>Shallow well</i>				
Nganjuk	TW116	20.54	1.02	513
	TW117	22.82	1.31	1,756
	TW138	20.75	1.20	1,631
	TW153	32.97	1.19	1,007

Source: Pakpahan et al. 1992.

Notes: LUI = Land utilization index.

PO = Pump operation.

TW = Tubewell.

Pump irrigation in Sidowareg Village, Kediri Regency, has a unique feature, namely, there are 11 units of groundwater pump irrigation in one village. The first tubewells, TW10 and TW12, were developed in 1972 and started operation in 1974. At the beginning, there was one WUA for one unit of pump. After operating for almost ten years, and after experiencing a breakdown, they found out that they cannot replace the pump by their own resources. At this juncture, a federation like organization has been created through the initiation of the GWDP. Under this setup the WUA has more power to manage the resources, particularly in dealing with assets, uncertainty, and conflicts.

Pump irrigation technically provides opportunities for water markets to operate well. It is possible because metering problems and exclusion costs are relatively low. Therefore, the price of water becomes a very important instrument for rationing while inducing an efficient water resource use. The base of pricing can be on criteria such as the cost of operation, time, crop, area, or a combination of these.

Usually, the water fee is determined on the basis of average cost that has to be borne by the WUA in providing a given quantity of water. That cost includes operational, maintenance, and organizational costs.

The implementation of water fees based upon the above costs takes a variety of forms. The condition stipulated by GRDP is that the collection of water fee should be based on a time rate. In the field situation, however, there are some modifications and/or advancements made by the organization.

Most WUAs charge the water fee using a time-based approach. In Madura, however, particularly in areas where tobacco is dominant, WUAs also use a crop base, i.e., water fee is determined on the basis of crops being watered. Different water fees are charged for rice, corn and tobacco in TW66; Madura is a case in point.

The cropping pattern in the command area of TW66 comprises of rice-tobacco-corn for the wet season, repeated by two more seasons. By 25 September 1990, rice, which is mostly planted in the wet season and only watered once or twice per season, was charged US\$16.67/watering/ha, and corn which is mostly planted at third planting season and usually watered 3 to 4 times a season was charged US\$11.11/watering/ha. Water fee for tobacco was determined differently, so as to include the whole season. In 1990, water fee for tobacco was US\$44.44/ha/season. In the circumstance, farmers had to spend about US\$17.00 to US\$34.00/ha/season, US\$33.00 to US\$44.00/ha/season, and US\$44.00/ha/crop season for watering rice, corn, and tobacco, respectively. The shares of water input in the total farm budget per hectare for rice, corn, and tobacco thus stood at 5.31 percent, 36.54 percent, and 18.8 percent, respectively.

Area crop-based pricing is found only in TW66, TW94 and TW97, all located in Madura. Rest of the samples are applying time-based pricing schemes. The crop-based scheme is more or less developed upon the knowledge of crop water requirement which is dependent on the type of crop, type of soil and season. Area crop-based pricing mechanism solves to some degree the problems associated with surpluses, and it is fair when canals are not in good quality, i.e., the farmers who operate the land at the tail end of the irrigation system pays on the basis of the extent cultivated independently from the distance of the land to the pump. However, the administrative requirements are more complicated than in the case of time-based pricing.

Outcome Performance

Outcome performance is defined as a performance resulting from the resource allocation strategies applied by the organization. Among others, there are two important outcome performances that contribute to the sustainability of the organization, namely, net return and savings. The higher the net return, the higher the capabilities of the organization to manage the resources; and the higher the savings, the higher the capability of the organization to manage maintenance, risks and uncertainties.

Table 16.2 shows that there are considerable variations in net returns and savings of different TWs. Highest performance in both net return and savings was achieved by TW66 in Madura. This high performance can be attributed to two sources, first, institutional strength manifested by leadership, discipline, loyalty, etc.; and second, relatively high value of crop, namely tobacco. The latter is indicated by non-marginal increase in net return/ha/year that is more than 60 percent, which is much higher than that of in Kediri (46 percent) and Nganjuk (35 percent).

Low performance of the other WUAs is due to bad irrigation facilities which are reflected by low LUI (see Table 16.1 above). In this context, the average pump operation is low. Therefore, net return is also low. Organizational weakness is also responsible for low returns and savings, i.e., the organization has a low ability to control sources of interdependencies.

Table 16.2. Net return and savings of WUAs according to aquifer and location in East Java, 1991.

Aquifer/location	Code	Net return (US\$)	Savings (US\$)
<i>Deep well</i>			
Nganjuk	TW152	115.44	195.56
	TW174	15.44	94.44
Kediri	TW10	590.89	na
	TW61	265.89	na
Madura	TW09	308.83	287.22
	TW66	1,686.50	4,555.56
	TW97	1,287.50	3,418.33
	TW102	615.67	333.33
<i>Shallow well</i>			
Nganjuk	TW116	4.00	na
	TW117	14.06	na
	TW138	64.61	22.17
	TW153	32.56	107.22

Source: Pakpahan et al. 1992.

Note: Net return is defined as total revenue minus total operational cost, but does not include organizational cost.

US\$1.00 = Rp 1,800.

TW = Tubewell.

na = Not available.

CONCLUSION

The variation of capabilities of WUAs in managing groundwater pump irrigation is high. Type of aquifer seems to be an important factor that conditions the capabilities of an organization. The shallower the aquifer, the higher the cost for the organization because the cost to the customers are low. The latter is possible because investment cost in shallow aquifer is much lower than that of a deeper one. Therefore, WUA type of organization is only suitable for deep well pump irrigation.

The majority of WUAs experience low performance in the light of the indicators such as LUI, PO, net return and savings. However, they operate the irrigation system under their own sources. In this sense, they have a low-to-medium degree of sustainability. If replacement cost is considered as a part of sustainability of WUAs, serious efforts are called for: (i) to increase area of irrigated land—improve irrigation canals, increase working hours, develop group farming, improve pump-farming management, improve cropping pattern, reduce operational cost; (ii) to increase farmers' ability to pay—reduce operational cost, choose high value crops, improve farm technology, economize group farming, reduce transaction costs; and (iii) to increase organizational ability—find a good leader, develop better standard operating procedures, develop better administrative structure, develop skills and knowledge of participants, develop values

conducive to organizational objectives. The case of Kediri in strengthening administrative capacity and the case of TW66, TW94, and TW97 in Madura in both improvement of pricing rules, strengthening organizational capability and other related issues, can be taken as lessons by WUAs to cope with resource fixity, size of investment, and transaction costs.

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Farmer-Managed Pump Irrigation Systems: A Case Study of Guimba-Cuyapo Network in the Philippines

Vicente S. Flores⁵⁸ and Avelino M. Mejia⁵⁹

ABSTRACT

THE PAPER PRESENTS the experiences gained and the lessons learned by the National Irrigation Administration (NIA), the Philippines, during the installation in the mid-1970s of some 35 groundwater pump systems; and in the conceptualization of feasible and affordable arrangements for the subsequent turnover of the operation and maintenance (O&M) of the schemes to Irrigators' Associations (IAs). It will also discuss the policies of the irrigation agency on pump irrigation systems, as well as the activities and programs undertaken to assist the IAs, in developing their capacities in managing the pump schemes and improving their water delivery systems, cropping pattern and schedules to overcome the high cost of electric power while still improving their productivity. The success and failure in operating the pumps will also be presented including the strategies adopted by both the NIA and IAs to overcome the problems and constraints.

Specific topics will also be included to present the various arrangements forged by the NIA and the IAs relative to the O&M of the pump systems which will embrace rental arrangements, full management takeover by the IAs and eventual ownership of the pump system. Some critical issues and problems encountered such as drawdown effects on the shallow wells used as domestic water supplies in the nearby communities, collection of water charges, shutting down of pump operations, etc., will also be discussed. Highlights of the paper will likewise include the stringent rules and regulations as well as the strategies adopted by some IAs in their quest to instill discipline among the water users particularly in implementing the planned water delivery and cropping schedules and thereby reducing O&M costs, and in their incessant desire to transform from government-dependent organizations into self-reliant and financially viable associations of formerly rain-fed farmers.

Last, the paper will provide insights into the plans of the NIA and the IAs to initiate programs toward sustaining the operation of the groundwater pump systems and in further improving the productivity of the farmlands served by the pumps. This is in line with the renewed five-year vision of the agency for a dynamic and functioning NIA and IAs working in partnership toward accelerating irrigation development and providing an efficient level of service.

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INTRODUCTION

The Philippines, though strategically located in the humid tropics and endowed with abundant rainfall amounting to about 2,000 millimeters (mm) annually, also suffers from critical water shortages, particularly during the dry season months. Further, the Philippines also faces an average of 20 typhoons per year, about 4 to 5 of which are highly disastrous and usually cause havoc to human lives, livestock, crops and infrastructures. One of the recent major catastrophes in the Philippines was the eruption, about a year ago, of Mt. Pinatubo in Central Luzon. The latest was the deluge which hit Ormoc City and caused the death of about 8,000 people.

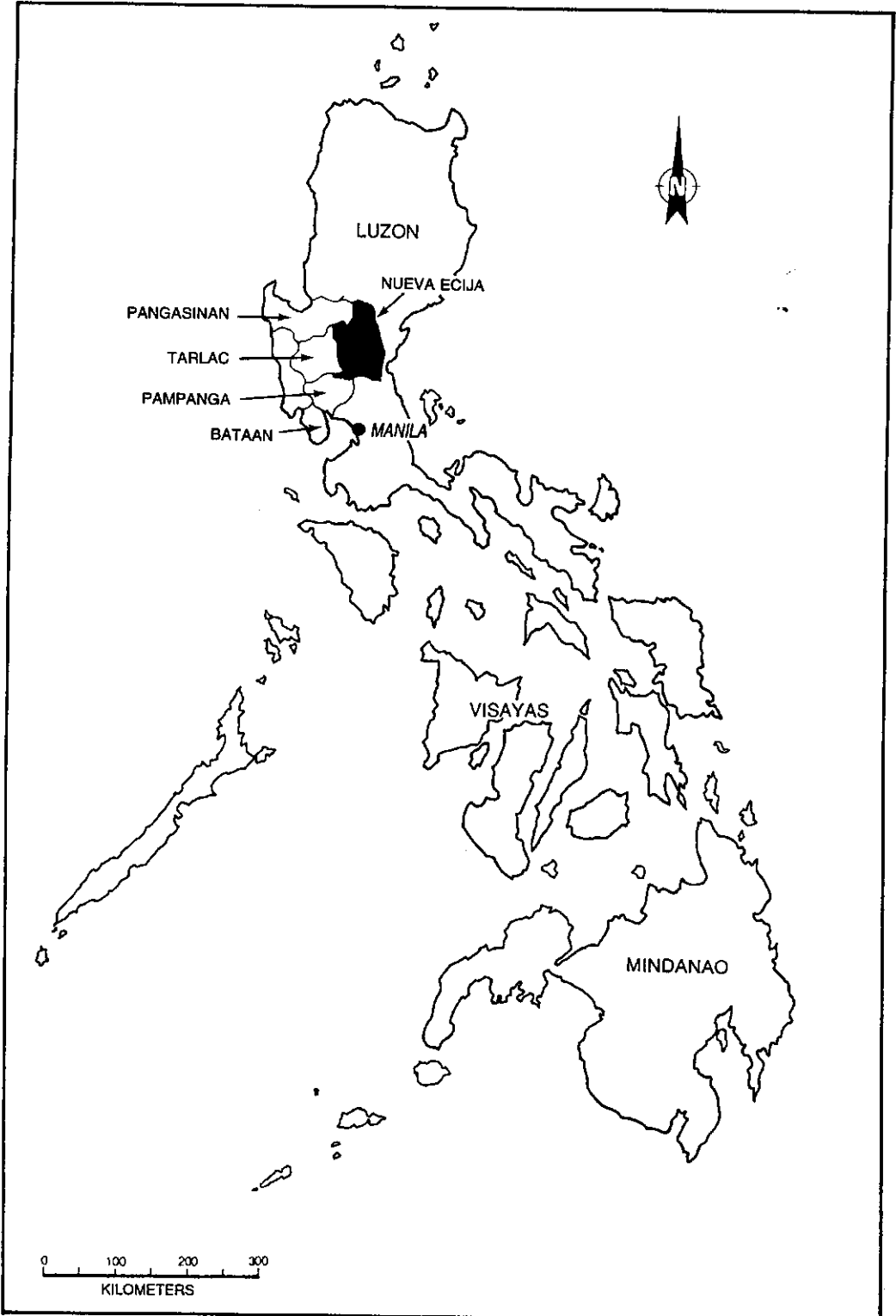
Rice is the staple food in the Philippines. But, the production of this staple and other food crops could hardly meet the demands of the ever-increasing population particularly because of the inept capacity of the Filipino people to cope with the natural disasters and, of course, due to the wide variation in rainfall distribution both in space and time. Almost all of the 2,000 mm average annual rainfall occurs during the months of June to October, considered as the wet season of the country. Very little rain is received during the season when there is abundant solar radiation and very favorable climatic conditions for crop cultivation. Despite accelerated irrigation development during the preceding two decades, there is still a sizable area (about 50 percent of the farmlands identified as suitable for irrigation) that remains to be developed. In some cases, due to the unabated denudation of the country's watersheds, portions of the areas already provided with irrigation facilities could not be supplied with adequate water during the dry season. As a result annual irrigated cropping intensity nationwide averages only 146 percent.

The NIA is the main government agency responsible for irrigation development in the country. By the end of 1991, some 1.5 million hectares (ha), or 48 percent of the 3.13 million ha of potential irrigable area, have been provided with irrigation facilities. Out of this extent 0.63 million ha are covered by national (agency-managed) irrigation systems, 0.71 million ha by communal/farmer-managed schemes and 0.15 million ha by private irrigation systems. In its mandate to accelerate irrigation development in the mid-seventies, the NIA indulged in the exploration of the country's groundwater resources and installed deep well pumps in areas not yet served by gravity irrigation systems. One of the major projects implemented by NIA for this purpose was the Central Luzon Groundwater Irrigation Project (CLGIP) with funding support from the Overseas Economic Cooperation Fund (OECF) of Japan. The project was started in mid-1976 and completed sometime in 1983. Some 215 deep wells were drilled covering about 10,000 ha within five provinces in the Central Luzon Island. This paper will present the project accomplishments and the recent developments in the operation and management of the CLGIP irrigation pumps, installed within the towns of Guimba and Cuyapo in the province of Nueva Ecija.

The CLGIP Pump Systems

The provinces covered by the Central Luzon Groundwater Irrigation Project included Bataan, Tarlac, Pampanga and Nueva Ecija of Region III and Pangasinan of Region I. Out of 215 deep wells developed by the project, 69 were located in Nueva Ecija province. The location of the province of Nueva Ecija is shown in Figure 17.1. The two towns of Guimba and Cuyapo are situated at the northwestern side of the province and are the boundary towns of Nueva Ecija with the provinces of Tarlac and Pangasinan, respectively. Relative to irrigation development, Guimba and Cuyapo have not been recipients of sizable irrigation projects except for the communal or farmer-managed gravity irrigation schemes located along the fringes of small streams and creeks and the deep well pumps installed by CLGIP.

Figure 17.1. Provinces covered by the Central Luzon Groundwater Irrigation Project, the Philippines.



The CLGIP pump schemes are about 100 m deep. The pumps installed have discharge capacities ranging from 1,000 to 1,600 gallons per minute (gpm) each of which is capable of irrigating an area of 40 to 60 ha. These pumps were fitted with electrically driven motors with sizes ranging from 40 to 100 horsepower (hp). The project provided funds for the costs of well exploration and development, pump units and accessories, electric motor, transmission lines, pump house, and the irrigation facilities and appurtenant structures. In each of the wells fitted with pumps, the farmer-beneficiaries were organized into irrigators' associations (locally known as *Damayang Patubigan*) for their eventual takeover of O&M of the schemes after completion of construction.

The Guimba-Cuyapo Pump Network

Within the towns of Guimba and Cuyapo there are a total 33 deep wells, seven of which were drilled under a former United Nations Development Programme (UNDP) assistance and were rehabilitated by the CLGIP, and an additional 26 installed under CLGIP. Twenty seven of these wells are located in Guimba and the rest (6) are in Cuyapo. Of the 33 deep tubewells formerly complete with pumps and accessories, only 27 covering an aggregate total area of about 1,243 ha are currently existing. The operation of two pumps has been temporarily shut down pending agreements with the farmers on the recent policies and requirements of the NIA on pump operation and management.

During project implementation, CLGIP attempted in 1978 to operate the completed pump systems to irrigate the farmlands of the prospective farmer-beneficiaries. The policy then was that each farmer benefitted by the system will pay to the project an irrigation fee of 3 *cavans*⁶⁰ per hectare (150 kg of rough rice) during the wet season and 5 *cavans* per hectare during the dry season. The cost of electric power then was Peso (₱) 0.22 per kilowatt-hour (kw-hr) (US\$1.00 = ₱ 27.5 in 1991). After the first wet season of operation an analysis of the CLGIP's pump operation showed that the average O&M cost was about 6.38 *cavans* (about 320 kg) per hectare which was a little more than double the irrigation fee of 3 *cavans*. In the following dry season (November 1978 to May 1979), O&M cost of the pump was determined to be the equivalent cost of 10 *cavans* (500 kg) per hectare.

The high cost of operating and maintaining the pumps, particularly the cost of electric power, prompted the project management to propose an increase in the irrigation fee rates from the former 3 and 5 *cavans* per hectare for the wet and dry seasons, respectively, to 8 and 12 *cavans* per hectare. This proposal, however, was rejected outright by the majority of the pump beneficiaries. In view of the subsidy the project has been providing for the operation of the pumping systems and to ensure the sustainability of irrigation facilities after the folding up of the project, the NIA authorized to implement the proposal prepared by the project for a management turnover. Under this set-up the irrigators' associations or *Damayang Patubigan* were held responsible for O&M of pumps.

Earlier Pump Turnover Schemes

As mentioned above, the high cost of operating the pumps led the CLGIP to devise alternatives and procedures for the turnover of the pump systems to the farmer-beneficiaries through their

⁶⁰ A *cavan* is a volume measure of rice and/or paddy in the Philippines, which has a weight of about 50kg. Paddy (unmilled rice/rough rice) is locally called *palay*.

irrigators' associations (Damayang Patubigan). The turnover schemes were formulated with the following considerations:

- i) To operate the pumps with minimal cost on the part of the NIA.
- ii) To make the farmers totally involved in the management and O&M of their pump systems through their duly organized irrigators' associations/ Damayang Patubigan.
- iii) To give the farmers a set of alternatives from which they can select a scheme which they think would best suit their situation.

The earlier turnover schemes proposed and implemented by the project were as follows:

- i) *The P 364,000 Amortization Scheme.* Under this scheme, the Damayang Patubigan will amortize to NIA a portion of the cost of constructing the pump system within a maximum period of 35 years without interest. Before the system was finally turned over to the association, a preparatory phase of one year had been adopted. During this transition phase, the project operated and maintained the pump system for two cropping seasons at its own expense while the association collected from the farmer-beneficiaries 3 and 5 cavans per hectare respectively for the wet and dry cropping seasons. Over and above the total irrigation fee of 8 cavans per hectare per annum which the association remitted to the project, the association was also advised to collect from the water users an amount needed to build its capital once it fully takes over the management of the pump system.
- ii) *The P 60,000 Amortization Scheme.* This second scheme was resorted to by the project after giving due consideration to the following: (i) that the 35 years amortization period was considered too long and beyond the economic life of the pumps; and (ii) quick recovery of its capital investment will be highly favorable to the NIA. The alternative proposal required, however, that the association pays to the NIA an advance payment of P 60,000 in the form of equity/counterpart cost to the construction of the pump system. After the takeover, the association shall be fully responsible for the management of the pump system including collection of the needed fees for payment of electric power and other O&M costs.
- iii) *The Equipment Rental Scheme.* Under this scheme the association was fully responsible for the operation and maintenance of the pump system. The association also had to bear all costs related to the O&M of the system. After each cropping season, the association was required to pay the NIA 2 cavans per hectare as rental for the use of the pump and the appurtenant irrigation facilities.

During project implementation, most of the associations had been switching from one arrangement to another as the pumps started to suffer from depreciation and some needed part replacements and/or rehabilitation. Another major factor was the constant increases in the electric power rates. If the pumps were continually operated, particularly during the dry season, the cost of operation would have been beyond the economic paying capacity of the water users. While the NIA endeavored to negotiate with the National Power Corporation (NAPOCOR) for special subsidized rates for the pump systems nationwide, NAPOCOR did not consider the request favorably as it was allegedly no longer the sole monopoly holder of the power enterprise. Instead, Electric Cooperatives wielded authority for power distribution to consumers and determined the rates for electric power as well. Owing to the high cost of electric power, incessant increases in the cost of production and insistence of the pump users to plant wetland rice, most of the pump irrigation systems constructed by CLGIP ceased to operate within a few years after the completion of the project in 1983. Closure of most of the pump systems could also be attributed to the limited financial capability of the NIA to continue subsidies that were effective since 1980, compelling

the agency to survive from its own corporate income. The situation was further aggravated by the very low collection of pump amortization and pump rental payments by the associations.

Revitalization of Groundwater Pump Irrigation Systems

Three years after the completion of CLGIP, the supervision of the management of the pump irrigation systems in the Guimba-Cuyapo area was assigned to the Provincial Irrigation Office of Nueva Ecija (NEPIO). At the time of turnover in 1986, only one pump system was found to be satisfactorily operating. Although NEPIO lacked the needed manpower with the necessary skills and expertise in groundwater pump irrigation systems, initially it had to tackle a variety of situations and issues mostly arising out of the complaints from the farmer beneficiaries who were affected by the failure of the NIA to sustain the operation of their irrigation systems. Patiently but cautiously, the NEPIO looked into the similarities and peculiarities of each of the pump systems and the irrigators' associations before it indulged in the formulation of alternative strategies and approaches to revive the operation of the pumps. The office had based its proposals which were subsequently approved by the NIA management for adoption, on the following issues and problems identified by studies prior to the turnover of the systems to the NEPIO:

- i) *High Cost of Electric Power.* While some of the pump systems continue to receive their power supply directly from NAPOCOR, the cost of power had increased almost sevenfold, from P 0.22 per kw-hr in 1976 to the present rate of P 21.50 per kw-hr. On the other hand, the systems which are supplied with electricity from lines under the Electric Cooperatives had to pay P 1.60 per kw-hr initially while this figure now stands at P 3.40 per kw-hr. Under normal operating conditions, farmers who are supplied with electricity from NAPOCOR will have to pay from 6 to 8 cavans per hectare during the wet season and from 12 to 24 cavans per hectare during the dry season. For the pumps serviced by the Electric Cooperatives, the rates could range from 10 to 12 cavans per hectare in wet season and 28 to 34 cavans per hectare in dry season.
- ii) *Size of Landholding.* The amount of money needed by a farmer to support the basic needs of his family is practically the same regardless of the size of his farmholding. The average farm size associated with the pump systems is below 1.0 ha which could hardly produce enough to meet the farmer's basic needs, let alone the settlement of his obligations. One of the significant factors limiting farmer's production capacity is the exorbitant rates to be paid for electric power.
- iii) *Pump Performance.* The pump efficiency, its life span and the benefits that could be derived out of its operation are the major factors to which the beneficiaries pay attention before accepting a full turnover of pump systems from the NIA for O&M. Somehow, there are cases where farmers have accepted pumps due to lack of experience, without giving any consideration to the above factors. It should be noted that the pump sets including the transformers and other important accessories had already been procured even before CLGIP started. In the circumstance, the project was denied the opportunity to effect designing on the basis of actual field requirements, leading to undesirable economic consequences related to O&M of the pump systems.
- iv) *Social Environment and Farmers' Behavior.* Majority of the farmers within the pump systems were envious of the relatively low irrigation fee rates being paid by farmers served by gravity irrigation systems. They can hardly accept the imbalance in irrigation fee rates. They always alleged that besides being deprived of other government programs they were also being required to shoulder the high cost of production within

pump irrigation systems, of which, they alleged the government was to be the eventual beneficiary.

- v) *Functionality of Irrigators' Associations.* Majority of the Irrigators' Associations were found to be passive and with short-term visions. Only a few farmer-leaders were active. Collection of irrigation fees was therefore very low and, in most cases, the total amount collected was insufficient to defray their O&M expenses.
- vi) *Continued NIA Assistance to the IAs.* When the project folded up operations in 1983, only a skeletal force was left behind. Since the terms of these personnel were also co-terminus with the project plantilla, most of them sought transfers to other NIA projects or to other agencies for security of tenure. As a result, the IAs were temporarily denied continued guidance and assistance, particularly, in improving the operation of their respective irrigation systems. One important area of assistance could have been the improvement of the farmers' cropping pattern to include the cultivation of crops other than rice during the dry season to reduce the pumping cost, simultaneously providing incomes equal or even higher than the income derived from mono-cropped rice.
- vii) *Need for Irrigation.* The financially viable systems which continued to operate had active leaders with good foresight and their actions bestowed collective benefits on constituent farmers. Such leaders held the view that "it's better to have a costly water supply to irrigate farms and obtain a good produce than to leave the farms to be served by unpredictable rain water." They further alleged that the operation of pumps will continue without interruption as long as their co-members continue to settle their dues and the NIA or the government continues to provide the necessary guidance and assistance.

The NEPIO Strategies

Armed with sufficient background information from previous research studies and learning from the previous experiences of the former CLGIP, the NEPIO went on to revitalize the operation of the groundwater pump irrigation systems in the Guimba and Cuyapo Network. The office started dialogues with the office bearers and members of the Damayang Patubigan and established initial agreements and probed into the requirements of the associations. One of the important requirements was for the Damayang Patubigan to revitalize its organization; first, by increasing its membership; and second, by improving its rules and regulations relative to the operation of the pumps and the collection of fees.

In carrying out its various tasks, one strategy adopted by the NEPIO was to deputize its cadre of professional irrigation community organizers (ICOs) working in gravity communal irrigation systems, to assist the farmers and the leaders in the pump systems in programming and implementing activities for the strengthening of their respective associations. The major task performed by the ICOs was to work among the individual water users and to explain to them the importance and benefits of having a strong and active association for a sustainable operation of their pump systems. On-site seminars and planning workshops were organized for the farmers and their leaders to come out with their expectations. These forums gave them an opportunity to surface their problems as well as to express their opinions by way of suggestions and recommendations with a view to solving problems. The outcomes of these gatherings were useful to redefine the roles and responsibilities of both the IAs and the NIA toward reviving the operation of the pump systems of those associations willing to abide by the conditions and requirements for

re-operation of their systems. In most cases, these developments led to the revamp of the association's leadership by unanimous action of the farmer-members in re-electing their officers.

In addition to the above activities, the NEPIO provided training in basic leadership development, system management and financial management for the associations which showed a desire and an interest to re-operate their pump systems. The NIA shouldered all the costs for the initial training. But, subsequent training was undertaken by the NIA only at the request of the association and on condition that at least 25 percent of the cost of training will be borne by the latter. This policy of the NIA allows the association to be discreet in the selection of subject matters to be tackled in the training as well as to select participant-farmers at its discretion.

Other activities undertaken by the NEPIO included a joint review with individual associations of their respective cropping calendars (majority of which is the rice-rice pattern), with a view to improving cropping patterns on the following considerations.

- i) Wet season cropping should start in June which marks the onset of the rainy season, in order to maximize the use of rainfall and thereby avoid operating the pumps to supply the water requirements for land soaking and land preparation.
- ii) Land preparation for the dry season cropping should start immediately after the harvest of the wet season crop in order to make use of the residual soil moisture and thereby save on the pumping cost.
- iii) In scheduling/planning the dry season crop, critical well drawdowns (which in most cases start to occur as early as March) should be avoided.
- iv) Harvesting of the dry season crop should not fall within the rainy months in order to ensure good quality of produce, and therefore, better market prices.

One of the major strategies adopted by the farmers to shorten pumping duration in a cropping season is the designation of a contiguous area as their common seedbed/nursery. They supply pump water to this nursery area in advance and simultaneously prepare their seedbeds and sow their seeds. A week before transplanting, water is pumped to supply the requirements for land preparation of the entire pump service area programmed for irrigation for the cropping season.

Recent NIA Policies and Requirements in Reactivating Pump Operation

In the mid-1980s, the dearth of available funds and the mandate of the NIA to survive from its own income almost led the agency to abandon the operation of most of the groundwater pump irrigation systems. Realizing the serious implications this will have on the overall performance of the agency, new stringent policies and requirements were formulated for the reactivation of the operation of schemes. As a result, the pump schemes have been classified as communals and new turnover arrangements have been developed and adopted initially for the Guimba-Cuyapo Network. The two turnover schemes are briefly discussed below:

- i) *Full Turnover/Amortization Scheme.* The management of the pump will be fully turned over to the association after rehabilitation and/or restoration. The association will in turn amortize the total direct cost of rehabilitation of the pump, irrigation facilities and other accessories including the depreciated cost of the well and the pump within a maximum period of 30 years without interest.
- ii) *Amortization cum Rental.* The association will amortize the direct cost of rehabilitating the irrigation facilities. In addition, the association will pay NIA a rental fee of one cavan per hectare per season for the use of the pump.

In addition to the costs of amortization and rental, as the case may be, the farmers/association will likewise bear the cost of power and other O&M costs. An important agency policy which the association must observe is that at least 90 percent of its current account with the NIA is settled before it could be allowed to operate the pump for the succeeding planting season.

The model agreement between the NIA and the associations under the two turnover schemes are given in Annex 1. Besides the provisions of the agreement there are other requirements of the NEPIO which the association must comply with.

Request for Operation

Before the association could even finalize its plans for a particular season it should first secure a duly approved request for operation from the NEPIO. Approval of the request will be based on the following conditions:

- i) That 90 percent of the current account of the association making the request should have been settled with the NEPIO.
- ii) That the association should have coordinated with the power supplier to get an assurance that the transmission lines are fully maintained and are in proper order.
- iii) That the irrigation canals and the appurtenant structures are properly maintained and the necessary repairs have been undertaken.
- iv) That budget planning is done giving due consideration to the projected amount of fees to be collected from the water users.
- v) That an assurance is obtained from the water users through the association that the agreed cropping calendar will be followed and that the deadline dates for the major farming activities will be strictly observed.
- vi) That the individual farmers included in the season's program have duly accomplished and signed the Agreement on Using Pump Water (sample attached as Annex 2) and strictly abide by the policies, rules and regulations of the association. The duly approved agreements on pump water use should be attached to the Request for Operation.

Current Pump Management and Performance

Presently, there are 19 pump systems covering an aggregate area of 935 ha which have been revitalized. The management of these pumps is shared with the associations under the two turnover schemes discussed earlier. To provide continued supervision and assistance to the associations in the O&M of the pumps, the NEPIO deputed six staff members to work full time in the area, namely: 1 engineer; 2 irrigation technicians; and 1 each of bill collector, lineman and electrician. Depending on the desire of the associations, some of the pump operators who were formerly hired by the NIA became employees of the associations.

Primarily due to the high cost of electric power, some of the associations do not operate their pumps during the wet season when the abundant rainfall could be utilized to grow rice crops. In the wet season of 1990, 14 pumps were operated irrigating an area of 634 ha. During the same season in 1991, only 8 pumps operated irrigating an area of 412 ha. In the dry season of the same years, more pumps were operated; all of them (19) in 1990 and 17 in 1991.

The cost of electric power in operating the pumps during the 1990 wet season amounted to an average of ₱ 177.50 per hectare or an equivalent of 0.71 cavan and about ₱ 674 per hectare (2.70 cavans) in 1991. Operation records for the dry season showed an average power cost of ₱ 2,030 per hectare (8.12 cavans) in 1990 and ₱ 4,055 per hectare (16.22 cavans) in 1991. In

addition to the cost of power, the associations also shouldered other O&M costs which included pump amortization/rental which is in the order of about ₱ 285 per hectare per season. Average irrigated rice yields were determined to be 4.17 tons per hectare with a range of 2.67 to 6.15 tons per hectare during the wet season and 4.78 tons per hectare with a range of 3.15 to 5.28 tons per hectare during the dry season. The lower yields obtained during the wet season were due to the occurrence of strong typhoons when the crops were about to be harvested. On the other hand, the low yields in the dry season were a result of the delayed start of farming activities in some of the command areas of the pumps wherein the well drawdowns could no longer supply the amount of water required by the rice crop. Likewise, the delayed start resulted in harvesting the crops within the early months of the rainy season when the rice fields were again full of water and, therefore, the farmers suffered a lot of grain losses due to shattering and rotting.

Although the current performance of the Guimba-Cuyapo farmer-managed groundwater pump irrigation systems may not yet be satisfactory in view of uplifting the socioeconomic plight of the farmer-beneficiaries to the expected standard, some valuable lessons could be learned for the NEPIO experience. These are as follows:

- i) Despite the marginal net incomes obtained by the water users, their will to produce a good crop is a key factor in assuring the continuation of the operation of pumps.
- ii) There is no substitute to a sincere and a dedicated staff whose primary concern is to provide continuous assistance services to the pump associations to improve operations and to sustain the organizational viability.
- iii) The sustainability of the O&M of irrigation systems, especially of the high cost pump schemes, is primarily anchored on the capability of the association leaders in formulating and implementing appropriate policies, rules and regulations, and in harnessing a binding cooperation and a commitment among their members. This is a major component of the NIA's Farmer Participatory Approach Program.
- iv) The farmers, through their associations, are made to become aware of the real financial difficulties experienced by the irrigation agency, the outcome of which could be the permanent closure of their pumps. Therefore, with the help of the association, the farmers will always find ways and means of exploring and making full use of the available resources so as to avert their pumps ceasing operation.
- v) Provided with initial guidance through seminars and workshops, the pump associations of the Guimba-Cuyapo Network have learned to coordinate and deal with other government and nongovernment agencies to obtain equally important support services such as production credit, low cost production inputs and marketing of their farm produce. Some associations even went to the extent of transforming/converting into cooperatives to avail themselves to agricultural support services.

The NEPIO has worked out continuing assistance programs in coordination with other agencies/institutions. The major objective of these programs is to develop the capability of the associations to manage pump water synchronously with their management of agricultural support services, thus improving the production and income of the water users. Therefore, in due course, these farmer-managed groundwater schemes could become financially viable and self-sustaining rural organizations within the towns of Guimba and Cuyapo in the province of Nueva Ecija.

Annex 1

SAMPLE MEMORANDUM OF AGREEMENT

KNOW ALL MEN BY THESE PRESENTS:

This Memorandum of Agreement executed and entered into this _____ day of _____, 19 _____ at _____ by and between:

The NATIONAL IRRIGATION ADMINISTRATION, a government-owned and controlled corporation created under Republic Act No. 3601 as amended by Presidential Decree No. 552 with principal office at Epifanio delos Santos Avenue, Diliman, Quezon City, Philippines, represented in this Agreement by _____ in his capacity as _____, hereinafter referred to as NIA;

and

The _____ IRRIGATORS' ASSOCIATION, Inc., an association organized and registered in accordance with the laws of the Philippines with principal office at _____, represented herein by its President, Mr. _____, hereinafter referred to as the ASSOCIATION;

WITNESSETH that:

WHEREAS, the Association has petitioned the NIA to rehabilitate/upgrade GP _____, an electrically-driven deep well pump presently serving agricultural lands for _____, situated in _____;

WHEREAS, the upgrading/rehabilitation of said groundwater irrigation system will reduce operating cost and improve its efficiency, thereby, redounding to the benefit of the Irrigators' Association;

WHEREAS, the upgrading or rehabilitation of said pump system is in line with the NIA's irrigation and institutional development programs;

NOW, THEREFORE, for and in consideration of the foregoing premises, the parties have mutually agreed as follows:

A. RIGHTS AND OBLIGATIONS OF THE NIA

1. The NIA shall provide the necessary funding for the upgrading and rehabilitation of subject pump system classified as communal irrigation system which shall be repaid by the ASSOCIATION for a period of thirty (30) years without interest. The total chargeable or direct cost includes any or a combination of the following:
 - 1.1 Depreciated cost of the groundwater well.
 - 1.2 Depreciated cost of the pump and prime mover.
 - 1.3 Modification of the pumps from two- to one-stage pump.
 - 1.4 Conversion from electric to diesel engine.
 - 1.5 Installation/repair/renovation of pump house, control and monitoring equipment, security fence and other facilities.
 - 1.6 Concrete lining of main farm ditch and installation/repair of turnouts.
2. The NIA shall afford the ASSOCIATION the full amortization scheme wherein the ASSOCIATION will amortize the total cost of rehabilitation of the pump and irrigation facilities, and the depreciated cost of the well and pump equipment.
3. The NIA shall have the right to enter private properties belonging to members of the ASSOCIATION in pursuing the upgrading and rehabilitation of the pump system and shall not be liable, whatsoever, for damages which the ASSOCIATION may sustain on account of said activities unless there is gross negligence or willful acts done by the NIA staff which cause such damages.
4. The NIA shall provide continuing development assistance services to the ASSOCIATION in terms of capability development trainings (leadership, financial management, operation and maintenance and repairs of pump system, crop production, etc.) as well as provision of agricultural support services through formalized tie-ups with government and private entities.
5. The NIA and the ASSOCIATION shall conduct periodic cost and equity reconciliations to determine the direct and or actual chargeable upgrading/rehabilitation cost.

B. RIGHTS AND OBLIGATIONS OF THE ASSOCIATION

1. The ASSOCIATION shall be responsible for securing and complying with all the legal requirements relating to the upgrading/rehabilitation of the pump system such as water permit, legal fees or charges and other similar requirements.
2. The ASSOCIATION shall undertake the negotiation for the acquisition, by whatever mode, of private properties affected by the upgrading/rehabilitation of the pump system.
3. The ASSOCIATION shall contribute as its counterpart in the upgrading/rehabilitation cost the total value of which shall be at least ____ % of the total chargeable cost.
4. The ASSOCIATION shall amortize annually/seasonally to NIA the amount of P_____ until fully paid in consideration of the expenditures incurred for the upgrading of the pump system.
5. The amount of amortization/installment shall be equivalent to the money value based on official government price of P _____ /kg multiplied by the total area benefitted,

provided that the resulting period of payment does not exceed thirty (30) years. If the computed repayment period exceeds thirty (30) years, the installment payments shall be correspondingly increased so that the same shall be within a period of 30 years from the completion of the pump project rehabilitation.

6. The ASSOCIATION's first installment on the payment to the NIA shall be due immediately after the cropping season following the upgrading/ rehabilitation; but the ASSOCIATION on written request may be granted by NIA a grace period of one season, provided that the entire amount shall be paid within 30 years from the completion of the upgrading/rehabilitation work.
7. Delayed amortization/installment payments shall be subject to an interest of 1/2 of 1% per month on the amount due. for this purpose, a delay of more than 15 days shall be considered as one month while delays of fifteen days or less shall be disregarded.
8. Upon the turnover of the upgraded/rehabilitated system the ASSOCIATION shall operate, maintain and administer the system in accordance with the By-Laws and rules and regulations which the ASSOCIATION shall promulgate with the concurrence of NIA.
9. The ASSOCIATION shall make available to the NIA for training all members and officers responsible for the operation, maintenance and management of the pump irrigation system.
10. The ASSOCIATION shall bear the cost of power bills, services of pump operators and cost of repair and other incidental expenses.
11. During the period of its operation, the ASSOCIATION will charge its members a reasonable rate of irrigation fee to cover all costs of pump operation, amortization payable to NIA, repair and other incidental expenses.

C. TERMINATION OF AGREEMENT

This agreement may be terminated at any time during its effectivity upon a three-month written notice served by the NIA to the ASSOCIATION on any of the following grounds:

- a. Refusal or failure of the ASSOCIATION to settle its scheduled payments;
- b. Failure of the ASSOCIATION to pay its power bills;
- c. Willful neglect of the pump system; and
- d. Violation of any of the provisions of this agreement.

D. SPECIAL CONDITIONS

1. All contracts not entered into by NIA or the ASSOCIATION in relation to this shall be considered as revoked and any payments made thereto shall be considered as rental for the season(s) for which the pump is put into operation.
2. The NIA reserves the right to supervise the activities and operation of the pump system until such time as the consideration of this agreement has been fully paid by the ASSOCIATION.

- 3. The ASSOCIATION shall submit itself to NIA supervisors as a safeguard that the provision of this agreement shall be faithfully observed and the interest of the members protected.
- 4. In the exercise of its supervisory functions, the NIA may audit the books of account and records of the ASSOCIATION and may issue necessary guidelines which will be understood to form part of this agreement.
- 5. In case of pump breakdown, the ASSOCIATION shall shoulder the cost of repair if the amount involved is P 10,000 and less. The NIA shall spend for the repair cost in excess of P 10,000 provided however that the amount shouldered by NIA shall be added to the chargeable cost to be amortized by the ASSOCIATION.

IN WITNESS WHEREOF, the parties to this agreement hereunto signed this instrument this _____ day of _____ 19__ .

NATIONAL IRRIGATION
ADMINISTRATION

_____ IRRIGATORS'
ASSOCIATION

by: _____

by: _____

Annex 2

AGREEMENT ON THE USE OF WATER FROM PUMP NO _____.

I, _____, member of _____ Damayang Patubigan of _____, Nueva Ecija, hereby agree to be included as one of the water users of the said pump system this _____ cropping season and abide by the rules and regulations promulgated by the Nueva Ecija Provincial Irrigation Office which are as follows:

1. That I agree that my farm lot containing an area of _____ hectares be included in the irrigation program of this cropping season;
2. That I agree to follow the Cropping calendar prepared by the NEPIO and the _____ Damayang Patubigan which will start on _____ and will end on _____
3. That I agree to plant early maturing rice varieties so that I could contribute in reducing the cost of electric power;
4. That I promise to pay through the Damayang Patubigan immediately after harvest whatever amount levied against my farm which may include the cost of electric power and pump amortization/rental regardless of whether the pump water has been used or not; and
5. That I authorized the Damayang Patubigan to collect from me the amount due at the time of harvest.

In witness hereof, I hereunto set my signature on this _____ day of _____, 19____.

Signed:

ATTESTED BY: _____

Association President

CONCURRED BY:

VICENTE S. FLORES
Provincial Irrigation Officer

Development of Groundwater Resources and Farmer-Managed Irrigation Wells in Shandong Province, China

Sun Fu Wen⁶¹

ABSTRACT

THIS PAPER DISCUSSES the status of the development of the groundwater resources and the organizational structure of the farmer-managed irrigation wells in Shandong Province, China. In order to develop and utilize groundwater resources scientifically and effectively, an overall investigation should be made first, to understand the distribution of the aquifer and law of movement of groundwater so as to assess the availability of resources. On the basis of such an investigation, unified planning and a reasonable layout of wells can be effected. The following model is applied to control the groundwater table, pumping-recharging by diverting Yellow River pumping (drawdown-recharging-drawdown). With this model groundwater recharging capacity can be enlarged; the recharging ability can be raised so that more surface water goes to the aquifer and becomes resources that can be reclaimed. Thus a stable aquifer will be sustained.

With the widening of the agricultural reforms associated with the household, contract responsibility system changes have been noticed in the agricultural economy, production group, distribution method and the requirements of the irrigation projects at large. Simultaneously much attention has been paid to the development of the groundwater resources. Farmers hold the opinion that groundwater utilization through wells has many advantages such as less investment, short construction period, instant effect, less influence from outside, reliability as a water source, flexible application and convenient management. Farmers call it "self-responsible water" or "self-managed water." Management systems of irrigation wells are mainly as follows: (i) village committee management; (ii) production group management; (iii) special household management; and (iv) special selectee management. All these systems permit the direct participation of the farmers in the management system ensuring timely irrigation and the increase of crop yields.

INTRODUCTION

Shandong Province lies in the lower reaches of the Yellow River, covering an area of 153,300 square kilometers (km²). It has an agricultural population of 68,460,000 people and cultivated

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land of 6,852,000 hectares (ha). There are 4,700,000 ha suitable for well drilling, among which 3,370,000 ha with rich groundwater resources are suitable for shallow wells and 1,330,000 ha with more difficulties can be developed for medium and deep wells.

Since 1949, much progress has been achieved in the construction of irrigation wells. Earlier the wells were drilled by manpower and now power or semi-power machinery are utilized to drill wells to a depth of several hundred meters (m). Well drilling spreads from plain areas to hilly rock areas.

At present, there are 650 fully equipped irrigation wells with 766 sets of machinery. Two hundred and thirty thousand hectare have been developed under well irrigation accounting for 51.4 percent of the total effective irrigated area of Shandong. Wells have become the major mode of irrigation for agricultural production and 7,000 to 8,000 million cubic meters (m^3) of groundwater is used every year and each irrigates 4 ha of land on the average. Where there is a well, there is a piece of oasis and a scenery of a good harvest. For example, Shouguang County is a pure well irrigation area. There are 24,260 fully equipped wells through which 220 million m^3 of groundwater is exploited every year for the irrigation of 71,000 ha of grain land and some cash crops. The production yields of grain, cotton and vegetables are increasing year by year.

Development and utilization of groundwater resources demand a clear understanding of the distribution and recharge of groundwater as well as the necessary conditions for effective exploitation.

In 1973, a general survey of groundwater resources was carried out in 8,000 km^2 of Shandong. Drilling method was used in combination with surveys pertaining to exploitation, geophysical exploration, chemical analysis, pumping tests, etc. The movement law of groundwater was utilized to locate places suitable for well drilling. Maps of counties (1:50,000) and maps of prefectures and cities (1:100,000) were prepared to depict the following characteristics related to groundwater:

- i) Depth of the bottom surface of shallow fresh water.
- ii) Depth of the top surface of deep fresh water.
- iii) Thickness of the sand layer with shallow fresh water and the distribution of water quality.
- iv) Chemical varieties of shallow fresh water.
- v) Depth of groundwater table (dry period, wet period).
- vi) Characteristic value of groundwater table.
- vii) Hydrogeologic section.
- viii) Zoning of groundwater and exploitation conditions.

Information from the general survey and the production practice show that shallow groundwater has advantages such as large area coverage, quick permeability, convenient management, etc., while the deep groundwater does not have the above-mentioned plus factors and can be used only as a reserved source. Therefore, making full use of the shallow groundwater should be promoted in the development of groundwater resources.

UNIFIED PLANNING AND REASONABLE ZONING

Surface water and groundwater are transferable and needs integrated planning, reasonable zoning and comprehensive utilization, so as to gain maximum efficiency. The present situation of

Shandong is that places with sufficient groundwater are also rich in surface water. When both sources are equally rich there is a high level of irrigation guarantee. However, in places short of groundwater, some of the irrigation projects for surface water are not equipped to ensure constant supplies. Hence, the water resources cannot be fully utilized. Therefore, it is very necessary to study and work out the various zones which are technically feasible and economically viable.

Well Irrigation Zone

In the pre-mountain alluvial plains and the old river beds where there are rich water resources, wells provide the main source of irrigation and act as an anti-drought measure.

Well Irrigation Zone in Combination with Canals

In places relatively rich with water resources, the engineering structure of wells and canals is very significant. The wells play the major role with canals as an auxiliary measure so as to raise the regulation ability and ensure the water use of the farmlands.

Canal Irrigation Zone in Combination with Wells

In places short of groundwater, surface water should be fully utilized. Canal irrigation plays the major role and well irrigation is auxiliary.

The above zoning is based on the quantity of the local groundwater available. Nevertheless, in different zones surface water is used as a major or an auxiliary measure. However, Optimum benefit is made possible through combined and alternate use of water resources.

CONTROLLING THE GROUNDWATER TABLE TO IMPROVE THE STORAGE AND REGULATING ABILITY

In the irrigation district of the Yellow River Diversion, water quantity diverted from the Yellow River is bigger in volume than the groundwater exploited. In some parts of the district, the water table becomes high due to the irrigation recharge from the Yellow River waters, and regulation ability in such cases is low. For example, in Weishan Irrigation District, the water table before irrigation is about 2.5 to 3 m below surface. One spell of irrigation can raise the water table by 1.67 m on the average and by a maximum of 1.81 m. Observations show that there are 21,395 km² of area with a water table lying less than a 2 m depth (42 percent of the total area). However, in 6,765 km² this level lasts for 120 days and in 6,888 km² it lasts only for 60 days. The high water table is the main cause of surface salinization.

Saline soils also characterize the area from Jiazheng to Xueyan of Guanxian County where, for the past ten years, wells have been playing the major role in irrigation. In this area, the annual groundwater use is 120 to 150 thousand m³/km², the water table is kept at a depth between 3 - 6 m and 6,700 ha of saline lands are brought under control. According to the measurements of Jiazheng Rainfall Station, when daily maximum precipitation is 141 millimeters (mm) and three-day maximum precipitation is 154 mm, there is nearly no runoff. In the circumstance, most of the rainfall is converted into groundwater.

The conclusion can be drawn from the above two examples that when the water table is controlled at an optimum level, storage capacity is enlarged, more water is recharged to aquifers and the regulation ability is improved.

Controlling the groundwater table is a complicated issue directly related to technique, economy, management, policy and legislation. However, from the point of view of technique, long-term and steady development of groundwater can be ensured by taking the following measures: (i) adopting a suitable engineering structure for shallow wells and canals; (ii) combining drainage and irrigation with storage and recharge; (iii) unified dispatch of the "three water"; and (iv) applying the model of pumping irrigation by diverting Yellow River pumping (drawdown-irrigation recharge-drawdown).

The kind of water source used in applying this model depends on the groundwater situation. In general, well irrigation is used in spring to lower the water table for bigger storage. When the water table drops below 7 m, it is proposed to divert surface water for irrigation. When the water table stays between 5.5 to 7 m, 60 percent of the area is allowed to be irrigated with diverted water. When the water table stays between 4 to 4.5 m, only 30 percent of the area is allowed to be irrigated with diverted water. When the water table is less than 4.0 m, diversion is forbidden and only well irrigation is allowed. In this way, surface water plays the double function of irrigation and recharge, precipitation recharge is enlarged during the flood season and it can help reduce evaporation and gathering of surface salinity. Thus the multiple purposes of drought resistance, salinity treatment and increase of regulation ability are realized, providing for long-term, steady and balanced exploitation of groundwater resources.

ORGANIZATIONAL STRUCTURE OF FARMER-MANAGED IRRIGATION WELLS

The farmers think irrigation wells are less influenced by outsiders than other kinds of irrigation projects and that they need less investment. These wells can be constructed and operated by several households joining together. The well is drilled, equipped with completed pump sets and used throughout the year. The farmers call this type of irrigation "self-managed water" or "self-responsible water" through which increased production can be ensured during the whole year.

The following are the four types of farmer-managed irrigation wells:

Wells Managed by Village Committees with Contracts

All the facilities of the irrigation wells are owned by the village under the unified management of the Village Committee (the basic administrative unit in the rural areas of China). This type of management accounts for 27 percent of the total irrigation wells.

Under the village committee, an irrigation service team is set up. For example, in the rural areas of Yantai City, irrigation service teams are set up in most of the villages. These teams are responsible for irrigation construction and management of the whole village. It implements "four aspects of unified management," i.e., unified planning for well drilling, unified management of facilities, unified distribution of irrigation water and maintaining unified standards of water charges. Wells are contracted to the members of the service team. "Five fixes and one reward" responsibility system is implemented. This includes fixing (i) personnel, (ii) irrigation tasks, (iii) consumption of fuel and electricity, (iv) repair fee, and (v) salaries. At the end of the year, a reward is given according to the fulfilling of the targets. This type of management is further developed by the farmers of Haiyang County. First, an irrigation management organization is set up in the village consisting of a village cadre, an operator, an electrician and a cashier, whose tasks are to operate and manage the irrigation projects and collect water charges. Second, projects' accounting system is set up. Independent accounting is practiced to be self-responsible for the

benefits and losses. Third, reasonable water pricing based on costs is effected. Fourth, through a consultative process with the farmers, the depreciation fee and a part of the profit are taken out for the repair and rehabilitation of the projects.

Production Group-Managed Wells with the Contract and Reward System

The irrigation wells and the pumping facilities are owned by the farmers of the whole village. The production group is formed by farmers whose land is within the effectively controlled area of the well. The well is used and managed by the production group. Contracts of duties and rewards are made to the persons concerned. This type of management accounts for 48 percent of the total wells.

Detailed issues such as irrigation priority, water cost for one time of irrigation per mu (15 mu = 1 hectare), repair cost and payment of the contractor are discussed and determined by the farmers of the production group. Most of the production groups chose the average value of the past three years' expenditure to call for tenders. A contract is made between the production group and the contractor. The money saved belongs to the contractor and the money over-spent should be borne by him alone. If the work is well done, a sum of money is raised by the farmers at the end of the year to reward the contractor. If the work is not accomplished and if there is no special excuse the contractor should compensate for some of the losses incurred.

Specialized Household-Managed Wells

In this case, the village committee undertakes repairs and provides the well, pumping equipment, engine house, water tank, canals and commonly used instruments for the irrigation system to operate. Improvements to well discharge, pumping situation, soil quality, water price and irrigation area are effected through a tendering procedure open to all farmers. The households chosen sign the contracts with the village committee. Some of the households pay water charges according to the money earned by selling the products, some according to the irrigated area and still others according to the watering period. A certain proportion is given to the village committee as depreciation cost and the rest belongs to the contractor. This kind of management accounts for 22 percent of the total area.

Selected Operator-Managed Wells with a Land Payment System

The irrigation project belongs to the whole village and the costs of operation, repair and depreciation are paid by all farmers in the village. The village committee selects an operator with a high sense of responsibility and he is entrusted with the management. The operator has to take care of the wells, engine house, pump equipment, water tank, canal and he should also irrigate the land in time. A piece of land of 0.1 to 0.2 ha around the well is allocated to the operator as payment for his management functions. He gets irrigation water free of charge for the cultivation of this land. The income from the land is the salary he receives for the management. A farmer-user can make a demand to the operator for irrigation at any time and the costs of electricity and fuel should be paid by the user.

Through many years of experience, all types of farmer-managed irrigation wells have gained good results. First, the management person is active, responsible and highly efficient. Second, the management person has detailed and clear responsibilities. He can repair and maintain the equipment in time, put the instruments in order and keep the pumping equipment in good and safe condition, so as to start the engine at any time. Third, the core of the system of responsibility is that working is directly linked with payment. More work means more money and the savings belong to the management person himself. Therefore, the management person is thrifty and

hardworking, waste is reduced, energy is saved, cost is lowered, steady and high yield is ensured and the farmer income is increased year by year. Our experience shows that if the farmers are organized properly, there will be a bright future for the farmer-managed irrigation wells.

CONCLUSION

Both groundwater and surface water resources of the Shandong Province should be treated as an integrated whole in planning water resources development. Continued surface irrigation in places such as the Weishan District has led to a steady rise in the water table increasing the salinity of the soils. In areas with saline soils, extraction of groundwater exerts a salutary effect in controlling salinity. Further, groundwater development has not only assured drought-resistance to crops but has also provided a basis for a balanced development of water resources. Factors such as comparatively low investment, sense of ownership, low cost of operation and the ability to cater to water users' demands have made the farmer-managed irrigation systems more attractive to the farmers.

List of Workshop Participants

Country	Name of Participant	Institute
Bangladesh	M. Asaduzzaman	Bangladesh Agricultural Development Corporation (BADC)
	A. K. M. Moniruzzaman	Bangladesh Agricultural Research Council (BARC)
	M. D. Harun-ur-Rashid	Bangladesh Agricultural Research Institute (BARI)
	Anisur Rahman	Bangladesh Water Development Board (BWDC)
	M. A. Ghani	World Bank
	S. A. Rana	World Bank
	Snatosh Chandra Sarker	<i>Proshika Manobik Unnayan Kendra</i>
	M. N. Islam	Bangladesh Rice Research Institute (BRRI)
	Aung K. Hla	BADC
	M. A. Kalam	BADC
	W. M. H. Jaim	Rural Development Academy
	Abdus Sattar Mandal	Bangladesh Agricultural University
	T. H. Miah	Bangladesh Agricultural University
	Lutfor Rahman Khan	Bangladesh Agricultural University
M. A. Hakim	International Irrigation Management Institute-Bangladesh	
M. A. Sattar	International Rice Research Institute	
China	Han Chang Gang	Shandong Project
	Huang Qi Shu	Shandong Project
	Sun Fu Wen	Shandong Project
	Xue Jian Hua	Shandong Project
	Wang Yong Le	Water Resources Department of Anhui Province
	Tao Yue Zan	Water Resources Department of Anhui Province

India	S. T. Somashekhara Reddy	Indian Institute of Management
	M. Venkata Reddy	Institute for Social and Economic Change
	Marcus H. Moench	VIKSAT
	D. S. K. Rao	National Bank for Agriculture and Rural Change
	S. Janakarajan	Madras Institute of Development Studies
	T. Prasad	Patna University
Indonesia	Sigit Supadmo Arif	Gadjah Mada University
	Agus Pakpahan	Ministry of Agriculture
	Santo Purnomo	Ministry of Agriculture
	Subuh Nirwono	Ministry of Agriculture
	Daud Berahmana	Ministry of Agriculture
Nepal	Narayan Prasad	CEPA
	N. Ansari	Ministry of Water Resources
	Ujjwal Pradhan	IIMI-Nepal
	Ganesh Thama	Ministry of Agriculture
Pakistan	Irshad Ahmed	Irrigation and Power Department
	Mustaq Ahmad Gill	Water Management-Punjab
	Zia-U-Din	CTA/PATA Project
	Ijaz Rizvo	CTA/PATA Project
	Mees van Krimpen	CTA/PATA Project
Philippines	Charles Robert Blessley	IRRI
	Vicente S. Flores	National Irrigation Administration (NIA)
Sri Lanka	Marcus M. Karunanayake	University of Sri Jayawardenapura
	R. de Silva Ariyabandu	Agrarian Research and Training Institute (ARTI)
	M. D. C. Abhayaratna	University of Sri Jayawardenapura
Thailand	J. P. Grindey	Sukhothai Groundwater Project

UK	Linden Vincent	Overseas Development Institute (ODI)
	Richard W. Palmer-Jones	University of East Anglia
Others	R. Sakthivadivel	IIMI-Sri Lanka
	Nanda Abeywickrema	IIMI Headquarters
	Donald Parker	IIMI-Bangladesh
	Khalid Mohtadullah	IIMI Headquarters
	John Ambler	Ford Foundation-India
	Douglas Vermillion	IIMI Headquarters

Organizing Committee

Shaul Manor (Chairman)

Donald Parker

R. Sakthivadivel

Sattar Mandal