CHAPTER 6

Studies on Rice-Based Irrigation Systems Management in Bangladesh

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INTRODUCTION

IRRIGATION SYSTEMS IN Bangladesh are primarily oriented to the production of rice. Rice is grown in three overlapping seasons: *aman*, or rainy-season rice for which supplemental irrigation is often useful; *boro*, or winter rice; and *aus*, grown during the hot spring and early summer. The types of irrigation systems used for rice are quite varied, and include tubewells, canal systems and low-lift pumps drawing water from surface sources. Recent growth in irrigation has been most noticeable in the tubewell sector, as Bangladesh has large groundwater resources which, in most places, are amply replenished during the monsoon season. Large numbers of wells and canal command areas, however, are underutilized, raising questions as to how they can be more productively and equitably managed. It was in this context that the Bangladesh portion of the IIMI/IRRI collaborative project on problems of irrigation management for rice-based farming systems was started.

The Bangladesh component of the IIMI/IRRI collaborative project has had a somewhat different emphasis from the components in Indonesia and the Philippines. In those countries the focus has been on irrigation management for diversified cropping, whereas in Bangladesh the emphasis has included the management of irrigation systems for rice whether or not other crops are grown. Nonrice crops do have an increasing significance in Bangladesh, but the country is not yet self-sufficient in rice and the general efficiency and equitability of its irrigation systems would appear, at this time, to be of the greatest importance.

IIMI's partnership with IRRI in Bangladesh had to await the arrival of the IIMI Resident Scientist in Dhaka in late 1988. Since 1982, IRRI has already been sponsoring some on-farm irrigation work in two projects through the Bangladesh Rice Research Institute (BRRI). Those two projects, plus one new site, were selected for the collaborative work. IIMI's part of this collaborative work was designed during 1989, but actual data collection started only with the dry season of 1989/1990, due to problems in arranging the deputation of a researcher to lead the work.

The BRRI team with which IIMI has worked on this program concentrated most of its efforts on issues that could be termed on-farm. These included water availability and utilization, fertilizer-water interactions and crop diversification demonstrations. They also examined main system possibilities of reusing drainage water for irrigation as well as of rescheduling the major lift pumping schedule within the Ganges-Kobadak canal project.

While the IIMI and BRRI teams worked closely together at all of the research sites, the emphasis of the IIMI group was more exclusively on systems management aspects of irrigation. The overall objective of the IIMI studies was to examine the constraints on better command area utilization and equity with a view towards identifying and, when possible, monitoring management changes that could relax those constraints. The specific studies undertaken included:

- The examination of an experiment in water rotation in the Ganges-Kobadak Irrigation System.
- The monitoring and assessment of a minimum irrigated acreage rule applied by the North Bengal Tubewell Project to increase command area utilization.
- A study of irrigation service fees and collection efficiency under various types of irrigation systems.
- A comparison of tubewell irrigation under a number of different management regimes.
- A look at farmer organizations in irrigation management in several types of systems.

The aim of this paper is to briefly present a selection of the findings from the studies undertaken primarily by the IIMI portion of the IIMI/IRRI collaborative program in Bangladesh. Of the above subjects, all but the last will be presented as separate sections. Issues of farmer participation and organizations permeate the discussions of the other topics. Studies conducted predominantly by the BRRI (IIRRI) portion of the collaborative IIMI/IRRI research team are reported elsewhere.[22]

STUDY LOCATIONS

Studies were conducted in three locations in Bangladesh. The Ganges-Kobadak Irrigation System operated by the Bangladesh Water Development Board (BWDB) is a major lift canal system pumping from the Ganges and having 145,000 ha of irrigable command area. Originally designed only for supplementary irrigation during the aman season, the system now pumps from February until November, covering both aus and aman. Sufficient water cannot be pumped to cover the whole of the command area, particularly during aus. BRRI has studied irrigated rice cultivation on nine tertiaries scattered among three secondaries of the project. In addition to working on information from these tertiaries, the IIMI team worked with a fourth secondary (S8K) on which an experiment in water rotation was being conducted.

[22] See Proceedings of the IIMI-IRRI Intercountry Workshop on Irrigation Management for Rice-Based Farming Systems, Colombo, Sri Lanka, 12-14 November, 1990.

The North Bangladesh Tubewell Project (NBTP), also run by BWDB, is located in the far northwest part of the country. It is composed of 381 deep tubewells installed during the 1960s. The system relies on an electrical grid that has often provided haphazard service. BRRI has intensively studied 12 pilot tubewells and 24 nearby "satellite" wells for several years. For the study of some issues, IIMI used information from these BRRI wells. To examine the implementation of a minimum irrigated acreage tubewell operation rule, the IIMI research team also randomly selected four clusters of tubewells, in each of which four wells were studied.

For further study of tubewells under various non-BWDB forms of management, the IIMI/BRRI research group chose a number of tubewells in the Rajshahi region, located north of the Ganges in the westernmost part of the nation. Six tubewells were chosen in the Barind Integrated Area Development Project (BIADP) of Bangladesh Agricultural Development Corporation (BADC). This project operates about 2,400 deep tubewells. Somewhat to the east of the BIADP area, six tubewells rented by BADC to farmer groups were chosen for study. For three of these six wells the farmer groups were provided with production loans (including irrigation costs) by the Rajshahi Krishi Unnayan Bank (RAKUB), the agricultural development bank. In the same area, three additional wells actually owned by farmer groups were also selected.

RESEARCH DESCRIPTIONS AND FINDINGS

The studies undertaken include two site-specific issues (rotation in the Ganges-Kobadak scheme and the minimum irrigated cropped acreage rule in the NBTB) and two cross-site studies (comparative tubewell management as well as irrigation fees), all of which include elements of farmer participation in irrigation management. It should be emphasized that there are a great number of types of irrigation management systems in Bangladesh and the studies (and sites) dealt with in this paper represent only a few of these types. There are, for example, additional irrigation management schemes run by various NGOs or by landless groups. There are also multipurpose schemes that incorporate flood control and drainage functions. Both time and resource limitations precluded the inclusion of all types of management regimes in this study. This study does, however, include management issues (and irrigation projects) that are of importance in Bangladesh.

An Experiment in Water Rotation in the Ganges-Kobadak (G-K) Irrigation System

As the G-K system is deficient in water relative to the total needs of the farmers within its command area, a nine-day rotation (with three days of flow followed by six days off) among secondaries was rather loosely followed for some years. In 1990, the rotation was changed to one of ten days-five days with water followed by five days without. The IIMI-IRRI-BRRI research group, in consultation and collaboration with the G-K project officials, undertook an experiment on one secondary to monitor the full implementation of the rotation and examine its results. The action research experiment attempted to resolve a number of problems encountered in the nine-day rotation system. These problems included the non-observance of rotation among tertiaries, the deteriorated condition of the canals and field channels, unauthorized cuts in the canals, the condition of hydraulic structures of some bridges and culverts, the absence of farmer organizations and participation by farmers, and a general lack of communication and interaction between the farmers and the project officials.

The secondary canal chosen for study (denoted as S8K) was one of the more problem-ridden parts of the G-K system. Project officials arranged for repairs to this canal and its control structures, and devised a system that ensured that the (5 + 5) ten-day rotation could be strictly observed in regard to water deliveries to the secondary. Project officials, along with research team members, made special efforts to keep the farmers along the secondary informed of developments and to encourage their participation. In addition to numerous field visits, these efforts included a field workshop held in a centrally located village along S8K. At this workshop farmers were able to voice their concerns and participate in decision-making regarding their (and the project's) responsibilities in the rotation scheme. A good deal of cooperation between farmers and officials, and among farmers of different tertiaries (notably absent in previous years, with head-end tertiaries taking all of the water), followed this workshop.

The impact of the rotation experiment on S8K has been highly positive in terms of area irrigated and equity. Of course, the sustainability of this improvement in future seasons remains to be seen. The impacts are noted in Table 6.1.

Area Irrigated. The area irrigated under S8K in the 1990 aus season was 528 ha as compared with 54 ha in the 1989 aus — an increase of 877 percent. On this secondary, 82.8 percent of the 1990 Water Board target was achieved, as against 8.5 percent in 1989. This record of achievement at the macro level is supported by data collected from 77 sample farmers selected from head, middle, and tail locations of each of the four tertiaries of S8K. While the farmers included in the sample cultivated a total of only 1.6 ha of land in the aus season of 1989, they irrigated 20.8 ha of land in 1990 — an increase of 1,170 percent.

Equity. The distribution of water among different tertiaries and among farmers at the head, middle, and tail locations along the various field channels has also become much more equitable in 1990. In 1989, farmers of the tail tertiary (T4) irrigated an area which was only 2.5 percent of all land actually irrigated along S8K in that year. In 1990, their share of the total land irrigated increased to 18.4 percent; so, while this tail tertiary did not quite fulfill its own absolute target it did do well in relation to its upstream tertiary neighbors. The position of T3 farmers also improved dramatically, but not as much as that of the T4 farmers (an improvement from 5.8 percent of total S8K irrigated area in 1989 to 24.8 percent in 1990. The T3 1990 targeted share, however, was 27.3 percent). In addition, the position of tail-end farmers within each tertiary (not shown in Table 6.1) improved substantially in that their share of irrigated land also increased. In 1989, the sample tail-end farmers (on all four of the tertiaries) did not cultivate any land under irrigated crops during aus. In contrast, these same tail-end farmers irrigated 4.6 hectares of land in 1990 (22.2 percent of land irrigated by the full sample of farmers at the head, middle, and tail sections). In addition, all of the sample tail-end farmers reported that they received sufficient water during the aus season.

Table 6.1. Area irrigated in aus with (1990) and without (1989) rotation along tertiaries of secondary S8K in the Ganges-Kobadak Irrigation Project.

	T1	T2	T3	T4	Total
Target Area (ha) (system data)					
1989	132.4	236.8	178.1	90.3	637.6
1990	121.5	238.5	174.1	103.6	637.7
Actual Irrigation (ha) (system data)					
1989	21.6	28.0	3.1	1.3	54.0
1990	120.4	179.5	130.9	97.1	527.9
Actual Irrigation (ha) (sample farmers)					
1989	0.9	0.3	0.4	—	1.6
1990	4.5	4.8	5.5	6.0	20.8
% Target Irrigation (system data)					
1989	16.3	11.8	1.7	1.4	8.5
1990	99.1	75.3	75.2	93.7	82.8
% Total S8K Irrigation (system data)					
1989	39.9	51.8	5.8	2.5	100.0
1990	22.8	34.0	24.8	18.4	100.0

The success (at least for 1990) of the rotation experiment may be attributed to a number of factors:

- Effective communication and interaction between the farmers and project officials. The early field workshop (organized by the research team) brought farmers together from all parts of the secondary and gave them a forum for interaction and for direct contact with officials.
- Farmer participation. As farmers came to believe that the secondary would get water as scheduled, they were willing to work together on a rotation along S8K. In contrast to previous years, upstream farmers did not destroy the tertiary gates, remove the gauge meters or stop water from going to the downstream tertiaries. Farmers also participated in maintenance.

- Interest and attention of project officials. Both senior and field- level project officials paid attention to the needs of the rotation scheme on S8K and kept in touch with farmers as well as with the researchers.
- Change in the main canal control system. In contrast to previous years, a regulator in the main canal just downstream of S8K was used in such a way as to guarantee the delivery of water to the secondary on time during its five-day turn.
- Favorable rainfall. Rainfall during the 1990 aus season was well distributed over time and is, no doubt, partly responsible for the improved situation along S8K. On nearby (non-rotation-experiment) secondaries, however, the improvements during 1990 were on a much more modest scale, supporting the implication that a large part of the improvement on S8K was due to the rotation program.

These possible explanations do raise the question of sustainability and replicability. Can the G-K project guarantee scheduled water deliveries to a larger number of secondaries? Can project officials pay sufficient attention to localized problems and to farmer concerns in a greater number of secondaries? Will farmers continue to cooperate and participate during future years? To try to answer some of these questions there are plans to study an expanded rotation program in the Ganges-Kobadak system in the 1991 aus season.

The Implementation of a Minimum Irrigated Cropped Acreage Rule for Tubewell Operation in the North Bangladesh Tubewell Project (NBTP)

The results of the other experiment to increase irrigation coverage, a minimum irrigated cropped acreage (MICA) trial conducted in the North Bangladesh Tubewell Project (NBTP), are not as positive as those of rotation in the G-K system. However, as with rotation, this experiment also shows some of the potential for improving system performance through management changes and farmer involvement.

As is the case for a great number of deep tubewells (DTWs) throughout Bangladesh, the wells of the NBTP tend to irrigate much less than their technically practical command areas. Among the reasons for this tubewell underutilization are: a) disruptions in DTW operation due to faulty power supplies, inadequate maintenance, etc., and b) organizational problems with farmers creating severe inequities in access to reliable supplies of water.

To encourage farmers at these tubewells to work together, and to promote more interaction between farmer groups and agency officials, the research project made a policy suggestion that the Bangladesh Water Development Board (BWDB) adopt a minimum irrigated cropped acreage system. Under this system the farmer groups would indent for irrigation water before a given season but the agency would only operate the well if some predetermined minimum acreage was to be serviced. The rationale behind this policy was that it would put pressure on each farmer group to solve at least some of the organizational problems that may have constrained the spread of irrigation in the past. Those few farmers who, in the past, were normally using tubewell water would have to accommodate other farmers' demands if anyone at all was to receive water. The agency, at the same time, would have to make great efforts to improve the reliability of the operation of those tubewells where a minimum cropped acreage was enlisted for an irrigation season.

Serious implementation of the minimum irrigated cropped acreage (MICA) policy did not begin until the aus season of 1990, when the project officials and the research team made efforts to communicate the new system to the irrigators. Project officials and extension personnel spread the word about MICA, and agency officers and members of the research team also held a series of field workshops aimed at explaining the program and getting feedback from the farmers.

While participation did increase to some extent with the spread of MICA there were also problems, primarily caused by the design of the program. The water demand indent system was easily abused, as farmer groups only had to claim that they would be irrigating the minimum acreage for the water to be turned on for the season. No system was devised for stopping the operation of a well during the season if the number of irrigated acres claimed were not, in fact, irrigated. In addition, the Project's ability or will to enforce sanctions against noncomplying tubewell groups was in some doubt, though a formal test of that ability was avoided due to the manner in which the indent system operated. Table 6.2 shows some of the impacts of the minimum irrigated cropped acreage experiment.

Irrigated Area. Information on irrigated area, both during the 1990 experience with the MICA rule and during previous aus seasons, was available from 16 sample tubewells plus 58 other tubewells scattered around the North Bangladesh Tubewell Project (Table 6.2). Of these 74 wells, 30 met their minimum irrigated acreage targets. These wells had an average MICA target of 16.5 ha but actually attained 20.9 ha. In the 3 aus seasons preceding 1990 these same tubewells averaged 15.2 ha. The average improvement in irrigated coverage was 5.7 ha.[23] Of the 44 tubewells that did not meet their MICA targets (but which were operating because they had originally promised, through the indent system, to meet the MICA target) the average irrigated coverage increased from 6.3 ha in previous years to 7.5 ha in 1990.[24] It is quite possible that the increases in irrigated area can be explained by the MICA rule, or at least by the attention focused on the issue of command area utilization through the MICA experiment. The increases were moderate, however, indicating that the MICA rule by itself may not in its present form have the potential to solve the problem of tubewell underutilization. Another issue is also raised by these figures. It can be noted that the group that did not meet its MICA targets had an average irrigated area in pre-MICA years of only 41 percent of that of the group of wells that actually reached their minimum irrigated acreage targets. These two groups, then, are likely to have had quite different

[23] Statistically significant at the 1 percent level.

[24] A difference that was statistically significant at the 10 percent level.

characteristics or constraints. In fact, farmers who failed to meet their MICA targets identified poor channel conditions, sandy soils, weak farmer organizations, and the cultivation of wheat in parts of their command areas as reasons for their failure. It is unclear whether target-attaining wells faced these problems to the same degree. To be effective, policies to increase irrigation coverage may have to address these issues, and possible future research might address the better identification of these differences.

Table 6.2. Minimum irrigated cropped acreage (MICA) targets, actual irrigation attained and rice yields during the 1990 aus season in the North Bangladesh Tubewell Project.

	Average MICA target (ha)	1990 Average actual irrigated area under MICA (ha)	1987-89 Pre-MICCA average irrigated area (ha)	Pre/post MICA difference (ha)	Average rice yield (tons/ha)
Wells meeting MICA targets	16.5	20.9	15.2	5.7	5.54
Wells not meeting MICA targets	15.2	7.5	6.3	1.2	4.68

Note: Hectare figures are for 16 sample tubewells plus 58 other North Bangladesh Tubewell Project wells for which data were available. Yield figures are from crop cuts on sample wells only.

Yield. Among the 16 sample tubewells, average rice yield (for the Purbachi variety) was 14 percent higher for farms on tubewells that attained their MICA targets than for those on tubewells that did not. This range of difference was evident at head, middle, and tail locations.[25] Given the possible differences in characteristics of the two groups of tubewells, the yield difference may or may not be due to the implementation of MICA.

Equity. Among sample tubewells neither locational nor farm size equity in terms of irrigation coverage seems to have changed much during the 1990 MICA rule application.

[25] The yield differences between head- and tail-end farmers of both groups were statistically significant at the 1 percent level.

Irrigation Service Fee and Collection Efficiency

The collection of irrigation fees in order to at least cover the operation and maintenance costs of the system has often been put forward as a useful policy. With such fees, irrigation management is expected to improve for a number of reasons: a) The generation of funds can help in the timely provision of O&M functions. b) The sharing of costs by water users can improve the accountability of irrigation managers to water users. c) Water users can be expected to use irrigation facilities more carefully in order to avoid increases in O&M costs that might be translated into increased fees.

In Bangladesh, it is the stated government policy to recover the O&M costs of its irrigation projects. The experience in fee assessment and in collection efficiency varies widely, however, by agency and by type of system and management. The IIMI study team examined various aspects of irrigation fee collection and system management. As can be seen in Table 6.3, there is a great difference between Bangladesh Agricultural Development Corporation (BADC) and private tubewells in the Rajshahi area, on the one hand, and the BWDB canal and tubewell systems on the other. The irrigation fees paid by farmers in the BADC rental wells and in the Barind Integrated Area Development Project (BIADP) system approximate or exceed the level of O&M costs. For the few private tubewells under study the fees (at 208% of O&M costs) obviously make a substantial contribution to capital costs and/or the owners. Collection efficiency, as represented by the percentage of assessed fees collected, is also very high. This picture is in great contrast to the experience in the Ganges-Kobadak and North Bangladesh Tubewell Project. In these BWDB projects the assessed fees represent only a small fraction of the costs of operation and maintenance. Despite the low level of the BWDB fees, the collection efficiency is also very low. Only 1 percent of the fees is actually collected in the G-K project.

A number of factors might explain some of the differences between the fee experiences in the two BWDB projects and the various BADC and private wells under study. Sample farmers in each of these systems were asked a number of questions about their participation in, and understanding of, fee setting and collection. None of the G-K or NBTB (both BWDB systems) farmers had participated in fee-decisions, nor did they seem aware of the criteria used for the fixing of fees. Partly because of the tubewell-centered (as opposed to project-centered) nature of the management of the various types of tubewells under BADC or private ownership, farmers in these systems felt that they had participated in the setting of their fees and were well aware of the criteria used for fixing of fees. Farmers were also asked how fee collection could be improved. All of the NBTB respondents, but very few farmers from other projects, noted that improved irrigation service would be required. Respondents in the BADC and private wells, by contrast, concentrated on issues of improved farmer participation when answering the same question. These responses would indicate that greater farmer participation in fee-decisions (or other aspects of irrigation management), as well as adequate irrigation service delivery, may well lead to a greater willingness to pay for water received.

Table 6.3. O&M costs, irrigation fees, and collection efficiency (Taka figures are per season per hectare).

System	O&M costs	Irrigation fees (Taka)	Fees as % of O&M (Taka)	Collection as % fees
BADC rental DTW with bank loan	2,460	2,287	94	79
BADC rental DTW without loan	2,005	3,273	163	96
BADC, BIADP DTW	4,442	4,810	108	6
Private DTW	1,891	3,929	208	98
BWDB, NBTP DTW	4,426	289	7	24
BWDB, G-K Canals	2,097	329	16	1

Notes:

a) Figures are from sample tubewells in 1989-90 for all but the two BWDB systems where figures are from the project level for 1988-89.
b) Average per season per hectare irrigation fees are calculated by dividing gross yearly fees by gross annual irrigated area.
c) O&M costs include both direct and indirect costs.
d) Irrigation fees are defined as the sum of all payments made by the farmers for the irrigation services they receive. For BADC wells, the agency charges reflect only part of this fee.

In Bangladesh, there is an ongoing movement to privatize small-scale irrigation systems. It is likely that most of the NBTB tubewells will soon be privatized or taken over by the Grameen Bank. Farmers using these wells will then have to manage their own systems and will be forced to pay their own O&M costs — though perhaps not without a struggle, as irrigation charges have been the main item of friction in the wells already taken over by the Grameen Bank's irrigation management system. For canal systems such as G-K, however, improvements in fee collection may not be so easily solved. In some of its other surface projects, BWDB will soon be experimenting with ways of passing the responsibility for fee collection over to outlet committees. It will be useful to follow these experiments in farmer participation and assess their results.

Deep Tubewell Irrigation Under Different Management Regimes

The Rajshahi area was chosen for study because it provided an opportunity to examine tubewells under a variety of ownership/management situations. The cooperation of the Rajshahi Krishi Unnayan Bank (RAKUB) also provided the chance to examine a program for the provision of production and irrigation management credit as it might operate under the various management regimes under study. RAKUB was to extend its credit program to include a number of wells under the BIADP scheme, under BADC rental arrangements, and under private ownership. Within each management category, the IIMI/IRRI research group was to study several tubewells within, and several outside, the RAKUB credit program. Unfortunately, as the irrigation season got under way, RAKUB proved unable to extend its program beyond the BADC rental category, and the irrigation management credit part of the study lost much of its credibility. It was still possible, however, to compare aspects of irrigation performance for the various categories of tubewell management. These types of ownership/management included:

- *The BADC's Barind Integrated Area Development Project (BIADP).* In this project, informal farmer groups are provided with wells and are required to pay an irrigation charge based on estimated command area. The BADC provides repair and maintenance services up to a value of one third of the charge. The farmer groups collect a fee from the irrigators to bear the costs of the BIADP charge, any further repairs, all fuel and oil, and also to pay 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 of the wells to ensure that its irrigation charge is paid by the groups.

- *The BADC rental program.* The BADC also owns a number of deep tubewells 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 attempted to sell the wells to the groups but this effort was largely unsuccessful, and the rental program continues. The farmer groups owe BADC an annual rent of Taka 5,000. The groups are responsible for the costs of operation and maintenance. The BADC retains some repair responsibilities but has little control of well management. While the tubewell managers collect fees to cover O&M as well as the rental charge, the rent seldom seems to reach BADC.

- *Private ownership and management.* Since 1979, the government has been selling deep tubewells (at subsidized rates) to farmer groups, which are then responsible for all aspects of operation and management. Most of these farmer groups exist in name only, with the wells effectively being owned and run by one individual or a few individuals. Capital loans were taken out to purchase the wells, but the level of loan repayment is very low — despite the fact that the fees paid by farmers are sufficient to pay the loan instalments as well as O&M costs.

A number of tubewell characteristics and performance indicators were examined by the study team. This paper concentrates primarily on irrigation coverage and, to some extent, on yield and equity.

Table 6.4. Deep tubewell irrigation coverage and rice yields in various systems in the Rajshahi area during aus of 1990.

Type of system	Area irrigated (ha)	Cusec discharge	Area per cusec (ha)	Operational hours	Water per irrigated ha (meters)	Yield per ha (tons)	Net return per ha (taka)
BIADP DTW	11.4	1.1	10.3	893	0.88	5.89	18,407
Private DTW	23.7	1.7	14.1	626	0.46	4.12	13,551
BADC rental with RAKUB	22.8	1.6	14.0	696	0.49	3.85	12,132
BADC rental w/o RAKUB	21.6	1.6	13.2	675	0.51	3.82	11,652

Irrigated area. The figures in Table 6.4 indicate that the BIADP tubewells irrigated roughly half as many hectares as the other types of wells during the aus season of 1990. When controlling for measured discharge (which is lowest for BIADP wells) it can be seen that the irrigated coverage per cusec capacity was about three quarters that of the others. The BIADP tubewells, however, were operated for a significantly larger number of hours during the season, resulting in 72 percent to 91 percent more water per irrigated hectare than in the other systems. Considering that the soil in the BIADP area was clay, with very low seepage percolation characteristics compared with the medium seepage percolation loam in other systems, the BIADP wells would seem to have very low relative irrigation coverage indeed.

Yield. Farmers using the private wells and those using the BADC rental tubewells mainly grew the *Purbachi* variety of rice, whereas the BIADP farmers chose IR-20 (a slightly higher yielding variety than Purbachi when grown under similar conditions). The BIADP farmers used more fertilizer and water per hectare (as noted above) than did the BADC rental and private tubewell irrigators. The result was that the BIADP farmers reported rice yields and net return per hectare that were 50 percent greater than those achieved by farmers on the other types of wells.

Equity. In none of the systems did distributional equity between actual irrigators (either by location or farm size) seem to be a major problem. In general, all categories of irrigators received adequate and timely supplies of water. However, larger farmers in all of the systems did dominate tubewell management positions, and further information is needed on those farmers who were unable to get irrigation water.

Differences in well capacity, soil, etc., would not seem to be sufficient to explain the very great differences in performance between the BIADP tubewells and those that were privately owned or rented from BADC. Further research is necessary on this subject, but a possible line of enquiry might concentrate, in part, on the enterprise focus of those who dominate the management of the various wells. In all of the wells under study, the locus of control of water distribution is at the tubewell (rather than project) level. Because of this local control, the irrigators seem well enough informed about various aspects of irrigation such as who will receive water, the setting of fees, etc. There is a difference between types of well, however, with respect to how much those who dominate the management of the wells (whether or not they are actual owners) can make from the operation of the tubewells.

Examining irrigation fees in relation to O&M costs reveals that the private wells, and many of the BADC rental wells, generate a large surplus in the way of fees. As the rental charges and capital loans are seldom actually paid to BADC or the banks this means that those people who dominate the management of their tubewells can generate some personal income from the wells. Their emphasis might be expected to be on running the tubewell as a business and attempting to maximize the tubewell enterprise profit. The enterprise focus of those who run the BIADP tubewells, however, would appear to be on their own farm businesses. As the BIADP system seems to have the power to enforce a high degree of payment of its tubewell charges (unlike the rental tubewells), it is possible that BADC has sufficient influence in the BIADP wells to control the level of fee collected by the local tubewell management groups.

If this is the case, then the local tubewell management of BIADP wells would have little scope for appropriating much in the way of profits. They would do better to try to maximize returns from their own farms, perhaps by concentrating water deliveries on a much smaller command area (including their own land) than would be the case if the tubewell enterprise was their focus. This they seem to have done. The enterprise focus (tubewell versus farm) of tubewell managers may explain part of the difference in irrigation coverage (and yield) between types of systems.

CONCLUSIONS

This paper has summarized some of the findings of several different studies. Three of these have focused on command area utilization, yield, and equity under various irrigation systems or management changes. Another study has concentrated on irrigation fees in all of the systems. Common to all of these studies is the role of farmers and farmer managers (or "owners") in making decisions, in cooperating (or not), or in just reacting to the opportunities created by the actions of others. Inclusion of farmers in the operation of the G-K rotation scheme seems to have been associated with the success of that program. Increased farmer cooperation was to have been a driving force in the NBTP minimum irrigated cropped acreage program but as the MICA rule could be easily circumvented with false water demand indents, that cooperation was never elicited. In the Rajshahi area most wells are dominated not by the irrigation agency but by one farmer or a few of them who are de facto owners. It is these farmer managers, in reacting to the opportunities before them, who determine the irrigation performance of their tubewells. In the case of fee collection it again seems to have been farmer involvement in fee setting and collecting that has helped determine success or failure.

More research is needed in all of these areas, as noted in the individual subject discussions presented earlier in this paper. As Bangladesh moves further into the privatization of its small-scale irrigation systems, the participation and behavior of farmers and farmer/manager/"owners" will become more and more important to performance, particularly to the nature of command area and utilization, a priority in the nation's irrigation program.

References

HAKIM, M.A., M.A. Ghani and D.E. Parker. 1990. An approach to increase irrigation coverage in the North Bangladesh Tubewell System (Draft). Paper prepared for the Workshop on Applied Research for Increasing Irrigation Effectiveness and Crop Production, a Collaborative Project of BRRI, BWDB, IIMI and IRRI.

HAKIM, M.A., and D.E. Parker. 1990. Irrigation service fee and collection efficiency (Draft). Paper prepared for the Workshop on Applied Research for Increasing Irrigation Effectiveness and Crop Production, a Collaborative Project of BRRI, BWDW, IIMI and IRRI.

HAKIM, M.A., and D.E. Parker. 1990. Role of farmer organizations in irrigation management (Draft). Paper prepared for the Workshop on Applied Research for Increasing Irrigation Effectiveness and Crop Production, a Collaborative Project of BRRI, BWDB, IIMI and IRRI.

HAKIM, M.A., D.E. Parker and M.A. Ghani. 1990. Deep tubewell irrigation under alternate management (Draft). Paper prepared for the Workshop on Applied Research for Increasing Irrigation Effectiveness and Crop Production, a collaborative project of BRRI, BWDB, IIMI and IRRI.

HAKIM, M.A., D.E. Parker and M.A. Ghani. 1990. Socio-economic and institutional issues in irrigation management for rice-based farming systems in Bangladesh. Paper presented at the IIMI-IRRI Intercountry Workshop on Irrigation Management for Rice-Based Farming Systems, Colombo, Sri Lanka, 12-14 November, 1990.

HAKIM, M.A., D.E. Parker and M.A. Ghani 1990. An experiment in water rotation in the Ganges-Kobadak Irrigation System (Draft). Paper prepared for the Workshop on Applied Research for Increasing Irrigation Effectiveness and Crop Production, a Collaborative Project of BRRI, BWDB, IIMI and IRRI.